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EFFECT OF TEMPERATURE ON SOME BIOLOGICAL ASPECTS AND THE THERMAL REQUIREMENTS OF *Diaeretiella rapae* (M'INTOSH) (HYMENOPTERA:BRACONIDAE) REARED ON *Rhopalosiphum padi* L. (HOMOPTERA: APHIDIDAE)

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ABSTRACT

Developmental periods, adult longevity and thermal requirements of *Diaeretiella rapae* (M'Intosh) were investigated at 18, 20, 22 and 24°C constant temperature. The development durations decreased as the temperature increased. At 24°C and 18°C the periods for egg-mummy period was 8.85 days and 12.79 days; the mummy-adult period was 5.29 days and 7.31 days; the egg-adult period was 14.14 days and 20.10 days; and for the adult longevity was 3.22 days and 4.69 days. The rate of development of all stages increased as the temperature increased from 18 to 24°C. The developmental threshold of D. rapae estimated using linear regression was 4.5, 2.33, 3.75 and 4.87, while the mean thermal units were 166.8, 117.03, 282.53 and 64.51 for egg-mummy period, mummy-adult period, egg-adult period and adult longevity, respectively. Results revealed that the optimal temperature for growth population of D. rapae ranged from 18 to 20°C.

Key words: *Diaeretiella rapae, Rhopalosiphum padi,* biological aspects, Temperatures

INTRODUCTION

The oat bird-cherry aphid, Rhopalosiphum padi L. (Homoptera: Aphididae), is considered as one of the major cereal aphids of cereal crops (Baily, 2007 and Hill, 2008). It causes serious problems on wheat, corn, barley, sorghum, rye, and brome (Modarres Awal, 2002; Jimenez-Martinez et al., 2004; Fabre et al., 2006; Borer et al., 2009 and Wang et al., 2015).

***Diaeretiella rapae* (M'Intosh) (Hymenoptera: Braconidae) is considered a common parasitoid of brassica aphids (Sheehan and Shelton 1989b). *D. rapae* has been observed regularly parasitizing *B. brassicae, L. pseudobrassicae,* and *M. persicae* in canola (French et al., 2001; Elliott et al., 2014; Jessie 2017b). There is conflicting information regarding the potential importance of *D. rapae* as a parasitoid of *R. padi* and *S. graminum* in winter wheat (French et al., 2001; Elliott et al., 2014).**

Temperature may partially affect the effectiveness of a parasitoid as a biological control agent in a particular region. Thus, in addition to factors such as searching ability, host preference, and host suitability, knowledge of developmental responses to temperature should be considered when deciding which one of the parasitoids could be release for biological control (Bernal and Gonzalez, 1993).

The first objective of this study was to determine the influence of temperature

on developmental periods during immature stages of *D. rapae*, adult longevity, number of adult/female and sex ratio. The second objective was to determine developmental thresholds and temperature requirements for development. Knowledge about these parameters may serve as a benchmark to assess *D. rapae* as a potential parasitoid of the oat bird-cherry aphid, *Rhopalosiphum padi.*

MATERIALS AND METHODS

A population of *Rhopalosiphum padi* (Linnaeus, 1758) was originally collected from a wheat field in Faculty of Agriculture Experimental Farm, Assiut Univ., Egypt in October 2019. The aphids were multiplied on wheat seedlings in a growth chamber at 24±1°C, 60±5% relative humidity and a photoperiod 16: 8 h (Light: Dark) for several generations. A colony of *D. rapae* was established from mummies of *R. padi* from infested wheat field. Mummified aphids were separated out and kept singly in small glass vials until the emergence of adult parasitoids which were fed on sugar solution.

In order to determine the durations of different parasitoid stages *D. rapae*, on the nymphs of R. padi at four temperatures (18, 20, 22 and 24°C), Twenty nymphs of parasitized for each temperature were daily dissected to observe the development of parasitoid stages of *D. rapae*, (egg – mummy, Mummy –adult and egg –adult, % of emergence and sex ratio). At each temperature, twelve aphid colonies each one containing about 150 individuals reared on fresh wheat seedling, into a plastic cage (30 cm long, 25 cm high, 10 cm wide). Aphids were exposed to five mated female parasitoids for a 24 h stinging period. Afterwards, parasitoids females were removed and then the 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 parasitoids emergence. Adults were transferred to plastic vials (25 × 10 cm diameter) and kept under the same temperature treatment. Each adult was fed with 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.

DATA ANALYSIS

The data were submitted to analysis of variance (ANOVA) and the means were compared by using the least significant difference (LSD) test at p=0.05 upon a significant F-test (Duncan's 1955). Obtained results of the parasitoids stages were submitted to regression analysis and the lower threshold temperatures (t0) and the thermal units (TU) required for the development of the nymphal stage were estimated according to Mangat (1977).

RESULTS AND DISCUSSION

Parasitoid response to temperature:

The results of the effect of different temperatures 18, 20, 22 and 24°C on developmental periods, adult longevity, number of adult/female and sex ratio of Diaeretiella rapae parasitoid *Rhopalosiphum padi* on wheat plants are

shown in (Table 1). There was significant difference amongst development periods of egg-mummy (F=95.40, P<0.0001), mummy-adult (F=38.65, P<0.0001), egg-adult period (F=135.12, P<0.0001) and adult longevity (F=75.14, P<0.0001) at temperatures of 18, 20, 22 and 24°C. Data indicated significant difference in the number of adult/female of D. rapae (F=28.38, P<0.0001) at 18, 20, 22 and 24°C. In addition, the results demonstrated that the sex ratio of D. rapae were 2.17:1, 1.49:1, 1.37:1 and 2.34:1 at 18, 20, 22 and 24°C, respectively. D. rapae showed greater emergence percent at 20 and 22 °C than 18 and 24°C (F=9.810, P=0.220; Fig. 1). Nevertheless, the rise in temperature caused a linear decrease in the number of mummies/female with significant different (F=19.502, P=0.048; Fig. 2).

Rate of development and thermal threshold of *D. rapae*:

The rate of development, threshold (t0) and thermal units (DD's) of egg-mummy period of *D. rapae* at 18, 20, 22 and 24°C are depicted in (Table 2). The results cleared that the egg-mummy period of D. rapae decreased gradually as temperature increased from 18 to 24°C. Thus, the rate of development egg-mummy increased as well as temperature increase from 18 to 24°C, achieved 0.078, 0.099, 0.106 and 0.113% at 18, 20, 22 and 24°C, respectively. Also, the threshold of egg-mummy period was 4.5°C and thermal units were 172.67, 156.40, 165.55 and 172.58 DD's at 18, 20, 22 and 24°C, respectively with an average of 166.8 DD's.

Data in (Table 3) represent the rate of development, threshold (t0) and thermal units (DD's) of mummy and adult period of D. rapae at different temperature 18, 20, 22 and 24°C. As mention before, the variation of temperature has clear effect on the mummy-adult period of *D. rapae*. The rate of development was positively depended on temperature which recorded 0.137, 0.151, 0.161 and 0.189% at 18, 20, 22 and 24°C, respectively. Meanwhile, the estimated threshold developmental (t0) of mummy-adult period was 2.33°C and thermal units were 114.55, 116.80, 122.15 and 114.63 DD's at 18, 20, 22 and 24°C, respectively with an average of 117.03 DD's.

Depicted data in (Table 4) cleared the rate of development, threshold (t0) and thermal units (DD's) of egg-adult period of D. rapae at different temperature 18, 20, 22 and 24°C. The obtained data indicated that the period of egg-adult stage of D. rapae inversely affected with increasing temperature from 18 to 24°C while the rate of development ascending influenced as temperature increase which recorded 0.050, 0.060, 0.064 and 0.071% at 18, 20, 22 and 24°C, respectively. Also, the calculated threshold developmental (t0) of egg-adult period was 3.75°C, and thermal units were 286.43, 271.38, 285.98 and 286.34 DD's at 18, 20, 22 and 24°C, respectively with an average of 282.53 DD's.

The obtained data in (Table 5) indicated that the rate of development, threshold (t0) and thermal units (DD's) of adult longevity of *D. rapae* on four respected temperatures. Likewise of other developmental stages, the duration of adult stage decreased as temperature increase while the rate of development lagged at lower temperature which recorded 0.213, 0.234, 0.243 and 0.311 DD's at 18, 20, 22 and

24°C, respectively. The estimated threshold of adult development (t0) of *D. rapae* was 4.87°C. Moreover, the thermal units were 61.58, 64.61, 70.23 and 61.60 DD's at 18, 20, 22 and 24°C, respectively with an average of 64.51 DD's.

These results were in general agreement with the finding of Eliott et al. (1995), Saleh *et al*. (2009), Taha *et al*. (2014) and Basheer *et al.* (2015) who reported that the developmental periods of different stages of parasitoid *D. rapae* shortened as the temperature increased from 10°C to 30°C. It appears that exposure the parasitoid *D. rapae* to relatively low or high temperature (18°C or 24°C) led to lower emergence percent compared with higher emergence percent at temperature of 20°C and 22°C, in corroborate with Souza et al. (2017) reported decreasing in the emergence percent of *D. rapae* at temperature between 16°C and 19°C as well as above 25°C, but stabilized between 19°C and 25°C. The higher number of mummies/female was achieved as temperature decrease, in harmony with Zahra et al. (2012) mentioned the highest number of mummies of D. rapae at 10°C. Souza et al. (2017) indicated that the increase of temperature led to a linear decrease of the parasitoid's total viability. In respect of sex ratio, the results showed that the highest ratio of female obtained at 24°C in consistent with Basheer et al. (2015) who found the highest ration of female was recorded (3.642 female : 1 male) at 25°C. The results show that the temperature influenced the developmental threshold and thermal requirements consequently affect the duration of different stages of *D. rapae*. This is line with the observation of (Bernal and Gonzalez, 1995; Zahra *et al*., 2012 and Taha *et al*., 2014).

In conclusion, in the range of 18°C to 22°C, the calculated biological parameters (adult longevity, number of mummies/female, number of adult/female and percentage of emergence) seem to fall in the favorable range for development and multiplication of *D. rapae* parasitoid of *R. padi.*

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Table (1): Effect of different temperatures on some biological aspects of *D. rapae* parasitoid of *R. padi.*

Temperature	Biological aspects of *D. rapae* (days)				Number of adult/female	Sex ratio (F:M)
	Egg-mummy period	Mummy-adult period	Egg-adult period	Adult longevity		
18 °C	12.79±0.26 a	7.31±0.11 a	20.10±0.24 a	4.69±0.07 a	14.97±1.09 a	2.17 : 1
20 °C	10.09±0.14 b	6.61±0.21 b	16.70±0.29 b	4.27±0.08 b	9.81±0.55 b	1.49 : 1
22 °C	9.46±0.13 c	6.21±0.11 c	15.67±0.20 c	4.10±0.04 b	9.45±0.67 b	1.37 : 1
24 °C	8.85±0.14 d	5.29±0.07 d	14.14±0.11 d	3.22±0.09 c	5.62±0.39 c	2.34 : 1
$LSD_{0.05}$	0.51	0.39	0.62	0.20	2.05	
F value	95.40	38.65	135.12	75.14	28.38	
P	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	

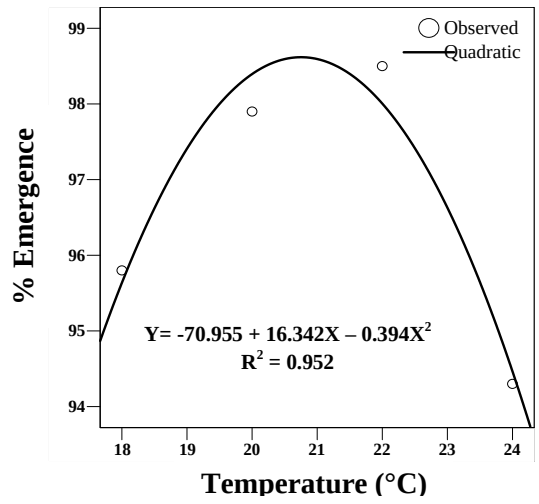

Fig. 1: Fitted regression curve for the emergence percent of *Diaeretiella rapae*, as a function of temperature.

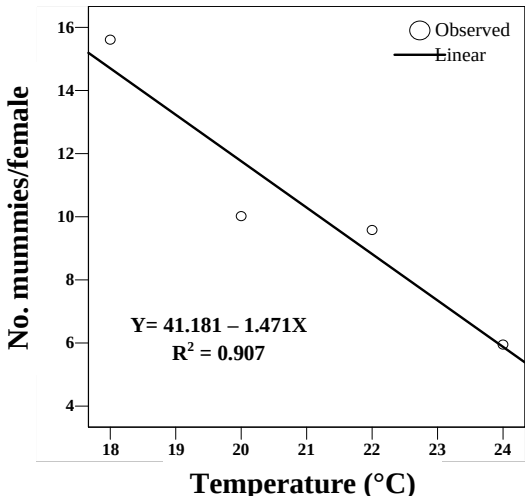

Fig. 2: Fitted linear regression for the number of mummies/female of *Diaeretiella rapae*, as a function of temperature.

Table (2): Rate of development, threshold (t0) and thermal units (DD's) of egg- mummy period of D. rapae parasitoid of R. padi.

Temperature	Egg-mummy period	Rate of development (%)	Threshold development	Thermal units (DDs)
18 °C	12.79±0.26 a	0.078	4.5	172.67
20 °C	10.09±0.14 b	0.099		156.40
22 °C	9.46±0.13 c	0.106		165.55
24 °C	8.85±0.14 d	0.113		172.58
Average				166.8

Table (3): Rate of development, threshold (t0) and thermal units (DD's) of mummy- adult period of *D. rapae* parasitoid of *R. padi*.

Temperature	mummy-adult period	Rate of development (%)	Threshold development	Thermal units (DDs)
18 °C	7.31±0.11 a	0.137	2.33	114.55
20 °C	6.61±0.21 b	0.151		116.80
22 °C	6.21±0.11 c	0.161		122.15
24 °C	5.29±0.07 d	0.189		114.63
Average				117.03

Table (4): Rate of development, threshold (t0) and thermal units (DD's) of egg- adult period of *D. rapae* parasitoid of *R. padi*.

Temperature	Egg-adult period	Rate of development (%)	Threshold development	Thermal units (DDs)
18 °C	20.10±0.24 a	0.050	3.75	286.43
20 °C	16.70±0.29 b	0.060		271.38
22 °C	15.67±0.20 c	0.064		285.98
24 °C	14.14±0.11 d	0.071		286.34
Average				282.53

Table (5): Rate of development, threshold (t0) and thermal units (DD's) of adult longevity of *D. rapae* parasitoid of *R. padi.*

Temperature	adult longevity	Rate of development (%)	Threshold development	Thermal units (DDs)
18 °C	4.69±0.07 a	0.213	4.87	61.58
20 °C	4.27±0.08 b	0.234		64.61
22 °C	4.10±0.04 b	0.243		70.23
24 °C	3.22±0.09 c	0.311		61.60
Average				64.51

تأثير درجة الحرارة على بعض الخصائص الحيوية والاحتياجات الحرارية لطفيل *Diaeretiella rapae* (M'Intosh) (Hymenoptera:Braconidae) عند تربيته على منّ الشوفان *Rhopalosiphum padi* L. (Homoptera: Aphididae)

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الملخص العربي

اجريت دراسة عن تأثير درجات الحرارة (١٨، ٢٠، ٢٢، ٢٤°م) على فترات التطور ، طول فترة حياة الأفراد الكاملة ، الاحتياجات الحرارية للطفيل *Diaeretiella rapae* (M'Intosh) عند تطفله على منّ الشوفان *Rhopalosiphum padi*.

اظهرت النتائج ان فترات التطور تقل كلما زادت درجة الحرارة. فقد زادت فترة التطور لمرحلة (بيضة – مومياء) من ٨,٨٥ يوم عند درجة حرارة ٢٤°م إلى ١٢,٧٩ يوم عند درجة حرارة ١٨°م ، وبالنسبة لمرحلة (مومياء – حشرة كاملة) سجلت ٥,٢٩ يوم عند درجة حرارة ٢٤°م وزادت إلى ٧,٣١ يوم عند درجة حرارة ١٨°م ، كذلك سجلت مرحلة (بيضة – حشرة كاملة) ١٤,١٤ يوم عند درجة حرارة ٢٤°م وارتفعت إلى ٢٠,١٠ يوم عند درجة حرارة ١٨°م. بخصوص فترة حياة الحشرة الكاملة ، فقد اوضحت النتائج انه عند درجات الحرارة المنخفضة تزداد هذه الفترة بينما تقل عند زيادة درجة الحرارة حيث سجلت ٤,٦٩ يوم عند درجة حرارة ١٨°م ، ٣,٢٢ يوم عند درجة حرارة ٢٤°م.

معدل تطور المراحل المختلفة للطفيل اظهرت استجابة طردية مع زيادة درجة الحرارة من ١٨°م إلى ٢٤°م. عند استخدام الانحدار الخطي لتقدير صفر (عتبة) النمو وجد ان عتبة النمو هي ٤,٥ ، ٢,٣٣ ، ٣,٧٥ ، ٤,٨٧°م ، والوحدات الحرارية كانت ١٦٦,٨ ، ١١٧,٠٣ ، ٢٨٢,٥٣ ، ٦٤,٥١°م وحدة حرارة لكل من مرحلة (بيضة – مومياء) ، (مومياء – حشرة كاملة) ، (بيضة – حشرة كاملة) ، (مرحلة حياة الحشرة الكاملة) ، على التوالي. من خلال هذه النتائج يتضح ان درجة الحرارة المثلى لنمو وتضاعف اعداد طفيل *D. rapae* عند تطفله على منّ الشوفان *R. padi* تتراوح من ١٨°م إلى ٢٢°م.