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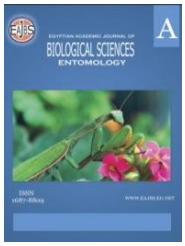

The Impact of Temperature on life-history traits of the bird cherry-oat aphid, *Rhopalosiphum padi* (Hemiptera: Aphididae) reared on wheat seedlings

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ABSTRACT

The impact of temperature and some life table parameters of *Rhopalosiphum padi* (Linnaeus, 1758), were investigated at 18, 20, 22 and 24°C constant temperatures. The development durations decreased as the temperature increased, recorded 8.36, 7.65, 6.8 and 5.19 days at 18, 20, 22 and 24°C, respectively. The temperature threshold for the development of first, second, third and fourth instars and overall nymphal stage were 4.53, 7.96, 10.02, 9.67 and 8.25°C, respectively. The thermal units required for each nymphal instar; first, second, third and fourth and overall nymphal stages were 27.78, 21.28, 16.39, 22.22 and 83.33 day-degrees, respectively. The average adult fecundity was as high as 91.74 and 73.25 offspring at 20 and 22°C, but dropped to 47.66 and 63.45 offspring at 18 and 24°C. However, the average (m_x) values per female/day were 2.24, 2.12, 1.93 and 1.01 offspring at 20, 24, 22 and 18°C, respectively. The highest net reproduction rates (R_0) were 61.46 and 54.42 at 20 and 22°C, and mean generation time (T) and population doubling time (DT) diminished as temperature increased. The intrinsic rate of increase (r_m= 0.3 and 0.25) and the finite rate of increase (λ= 1.36 and 1.29 nymphs/female/day) were greatest at 24 and 22°C, respectively. The results indicated clearly that temperatures from 20 to 24°C were in the favourable range for survival and reproduction of this serious pest.

INTRODUCTION

Aphids are a serious insect pest problem in many cereal-growing regions of the world (Blackman and Eastop, 2000). Among the numerous aphid species found in cereals, the bird cherry-oat aphid, *Rhopalosiphum padi* (Linnaeus, 1758), is considered to be one of the major pests causes severe damage (Hansen, 2000; Hill, 2008; Descamps and Chopa, 2011; Tabikha, 2016). Temperature is probably the most important physical environmental variable influencing the rate of aphids' development and reproduction (Salman, 2006). Furthermore, variations in life-history traits reflecting adaptations to local climatic conditions or different host plants may occur among different insect populations (Tang *et al.*, 1999; Kuo *et al.*, 2006).

Therefore, the present work was carried out to study the effect of different constant temperatures on the biological aspects and heat requirements for *R. padi* on wheat plants in the laboratory of plant protection research at Assiut Governorate, to better understand the variations in life-history traits among different geographically separated populations.

MATERIALS AND METHODS

Biological Aspects of *R. padi* on Wheat:

Adults of the bird cherry-oat aphid, *Rhopalosiphum padi* were collected from a wheat field. The aphids were multiplied in the laboratory on wheat seedlings kept in a controlled environment at 24±1°C, RH of 60-65 % and under a photoperiod of 16:8 (L: D) hours. Nymphs up to 12-h age were collected from the laboratory colony using a small camel's-hair brush (# 000), and caged individually on wheat seedling in plastic pots (7.5 cm in diameter and 12 cm in height).

The aphids were reared at temperatures of 18, 20, 22 and 24±1°C, RH of 60-65 % and photoperiod of 16:8 (L: D) hours. Each treatment contained 50 nymphs in a fully randomized setup. The following parameters were evaluated: number of instars; duration of each instar and nymphal period; survival of the different instars; daily and total capacity to produce nymphs; and longevity of the nymphal and adult phases.

Data Analysis:

The data were submitted to variance analysis 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 nymphal stage were submitted to regression analysis and the lower threshold temperatures (t_0) and the thermal units (TU) required for the development of the nymphal stage were estimated according to Mangat (1977).

The selected life table parameters; net reproductive rate (R_0), time interval between generation (T), population doubling time (DT), intrinsic (r_m) and finite (λ) rates of increase were calculated according to Birch (1948) as follows: $R_0 = \sum (l_x m_x)$; $T = \sum (l_x m_x . x) / \sum (l_x m_x)$; $r_m = \log_e R_0 / T = \ln R_0 / T$; $\lambda = e^{rm}$ and $DT = \ln (2) / r_m$.

RESULTS AND DISCUSSION

Nymphal Development:

Data showed in Table (1) depicts the duration of the different nymphal instars of the bird cherry-oat aphid, *R. padi* at 18, 20, 22 and 24°C, the nymphal passed through four instars to reach maturity. The total development period of the nymphal stage lasted for 8.36, 7.65, 6.8 and 5.19 at 18, 20, 22 and 24°C, respectively. The duration of nymphal instars decreased gradually as temperature increased from 18 to 24°C (Fig. 1). These results indicate that the nymphal development period was faster at the higher tested temperatures. Statistical analysis of data indicated significant differences between the nymphal instars and total nymphal periods at all tested temperatures. These results were in general agreement with the finding of Auad *et al* (2009) who found that periods of development from first instar nymph

to adult were 17.3, 12.93, 8.37 and 7.13 days at 12, 16, 20 and 24°C, respectively. El-Fatih *et al* (2015) reported that the four nymphal instars were lasted 2.55, 1.62, 1.76 and 2.43 days at 20°C, respectively. Asin and Pons (2001) found the time required for complete development at 18 and 22°C were 8.8 and 6.2 days, respectively. While, Tahri *et al* (2010), indicating that the developmental time of nymphal stages of *R. padi* reared on six wheat cultivars ranging from 4.37 to 5.53 days at 24°C. In this respect, Kuo *et al* (2006); El-Gantiry *et al* (2016) and Salman (2006) mentioned also that the development of aphid species, *Rhopalosiphum maidis*, *Aphis illinoisensis,* and *brevicoryne brassicae* is faster at the relatively higher tested temperatures.

Table 1: The effect of temperature on the developmental period of *Rhopalosiphum padi* (L).

Temp (°C)	Duration (indays)				
	Nymphal instars				Nymphal stage
	1st Mean ± SD	2nd Mean ± SD	3rd Mean ± SD	4th Mean ± SD	
18	1.89±0.49 ab	2.0±0.48 a	1.93±58 a	2.54±0.84 a	8.36±0.79 a
20	1.9±0.48 a	1.85±0.58 a	1.8±0.78 a	2.1±0.88 b	7.65±1.1 b
22	1.66±0.55 b	1.56±0.56 b	1.45±0.53 b	2.1±0.43 b	6.8±0.63 c
24	1.34±0.45 c	1.28±0.4 c	1.14±0.24 c	1.44±0.52 c	5.19±0.72 d
F	10.19	17.95	21.39	27.66	89.89
P	0.0001	0.0001	0.0001	0.0001	0.0001
LSD	0.2235	0.2104	0.2203	0.2443	0.4053

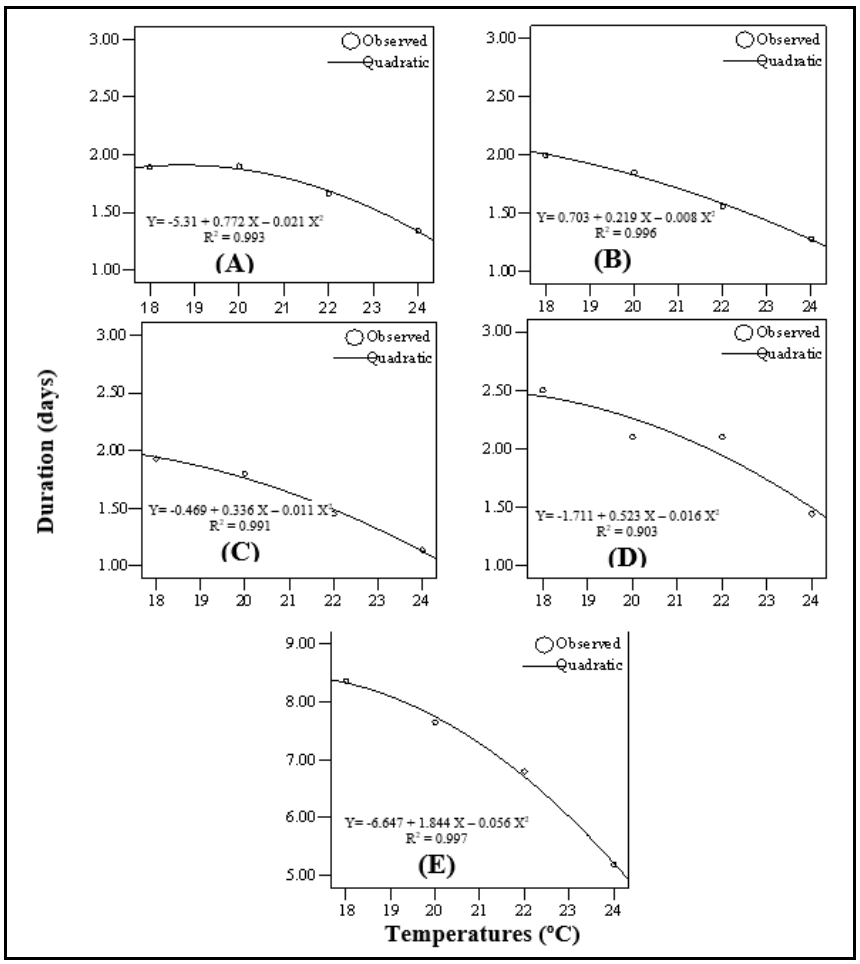

Fig. 1: Fitted regression curves for the duration of the first (A), second (B), third (C), fourth (D) instars, and nymphal (E) phases of *Rhopalosiphum padi*, as a function of temperature.

Determination of the Lower Developmental Threshold (t_0) and the Thermal Requirement (TU) for *R. padi*:

Data in Table (2) would be used to estimate the developmental threshold (t_0) and thermal units (TU) required for the development of the nymphal stage of *R. padi* according to Mangat (1977). Hypothetical temperature thresholds that were used in the calculation of (t_0) and (TU) were chosen below the rearing temperatures of 18 and 24°C (Table 2). Data indicated that the threshold temperature for the development of nymphal stage, as shown in (Fig. 2), was 8.25°C and the thermal units necessary for the development of one generation were 83.33 day-degrees.

Table 2: Day- degrees (DD) required for the development of nymph to adult stage of *Rhopalosiphum padi*, using hypothetical temperature thresholds below rearing temperatures of 18 and 24°C.

Temp. threshold (t_0)	Thermal units (DD) = T (t-t_0)	
	18°C (T=8.36)	24°C (=5.19)
1	142.12	119.37
2	133.76	114.18
3	125.4	108.99
4	117.04	103.8
5	108.68	98.61
6	100.32	93.42
7	91.96	88.23
8	83.6	83.04
9	75.24	77.85
10	66.88	72.66
11	58.52	67.47
12	50.16	62.28
13	41.8	57.09
14	33.44	51.9
15	25.08	46.71
16	16.72	41.52
17	8.36	36.33

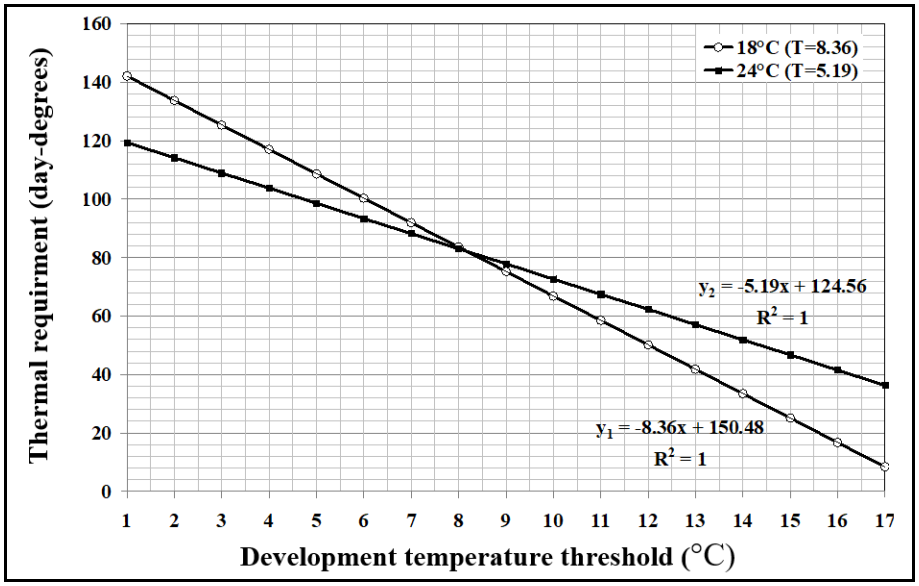

Fig. 2: Thermal units needed for the development of the nymphal stage of *Rhopalosiphum padi*.

The results of linear regression analysis for developmental rates and temperatures within the range of 18-24°C are shown in (Table 3). The evaluated lower developmental thresholds were 4.53, 7.96, 10.02, 9.67 and 8.25°C from the first through fourth instars and nymphal stage, respectively (Table 3). Regarding the developmental times in degree-days decreased from 27.78 DD for the first instars to 22.22 DD for the fourth instars. Total immature development required 83.33 DD above 8.25°C.

Table 3: Linear regression equations, determination coefficients (R^2), the lower threshold temperatures (t_0), and development time in day- degrees (DD) of immatures of *Rhopalosiphum padi* within the temperature range of 18–24°C.

Instar	Regression equation	R^2	*p* value	Developmental time in DD	Low developmental threshold (°C)
1	Y= -0.163 + 0.036 X	0.830	0.089	27.78	4.53
2	Y= -0.374 + 0.047 X	0.947	0.027	21.28	7.96
3	Y= -0.611 + 0.061 X	0.929	0.036	16.39	10.02
4	Y= -0.435 + 0.045 X	0.816	0.097	22.22	9.67
Nymphal stage	Y= -0.099 + 0.012 X	0.891	0.056	83.33	8.25

These results are consistent with those of Abdel-Rahman *et al.* (2002) reported that the temperature threshold (t_0) of *R. padi* was 8.89°C and the thermal units necessary for the development were 92.32 day-degrees. Auad *et al.* (2009) mentioned lower values of developmental threshold and higher values for developmental time for the different instars and nymphal phase for *R. padi* kept at temperatures from 12 to 32°C. Meanwhile, El-Fatih *et al* (2015) reared *R. padi* on wheat under temperatures of 15, 20 and 25°C recorded lower temperature threshold (4.4°C) and higher thermal units (142.57 day-degrees). El-Gantiry *et al* (2016) also estimated the developmental threshold and thermal requirement of grapevine aphid, *Aphis illinoisensis* reared on Superior variety by 12.7°C and 80.73 DD, respectively. Hence, a lower threshold (t_0) of *R. padi* reared on wheat, were estimated at 4.4°C for the nympal stage (Abdalla, 2002). In this respect, Kuo *et al* (2006) and El-Sheikh *et al.* (2009) estimated (t_0) of (4.44 and 6.84°C) and thermal units as (119.05 and 87.31 day-degrees) for *Rhopalosiphum maidis* recorded on leaves corn and barley, respectively. With 4.5 as the lower temperature limit for the development of the nymphal phase, 137.0 degree-days are required for *Brevicoryne brassicae* to reach the adult phase (Salman, 2006).

These results show that the temperature influenced the duration of the instars and the nymphal cycle of *R. padi*, with an increased rate of development as temperature increased. The similarity or difference of results concerning the development periods of a nymphal cycle at the same temperatures suggests that the type of host plant offered as well as the geographic origin of the aphid can affect its development, even when kept under similar heat conditions. This is in line with the observations of (Smith, 1922; Lamb, 1992; Tang *et al.* 1999 and Auad *et al* (2009).

Life Table Parameters:

1- Fecundity (m_x) and Net Reproductive Rate (R_0):

Data in (Table 4) revealed that females reproduced most nymphs (91.74 nymphs/female) at 20°C and the lowest ones at (73.25, 63.45 and 47.66 nymphs/female) at 22, 24 and 18°C, respectively. Whereas, the average (m_x) values per female/day were 2.24, 2.12, 1.93 and 1.01 offspring at 20, 24, 22 and 18°C, respectively. The average number of nymphs added to the population per one female was 30.37, 61.46, 54.42 and 47.99 individuals at 18, 20, 22 and 24°C, respectively. The data indicated that at 20°C, the population of *R. padi* increased twice than in the course of one generation as compared to that reared at 18°C. It appears that exposure of the pest to relatively low temperature (18°C)

seems to have an adverse effect on fecundity. These results corroborate those of Auad *et al* (2009) reported (9.92 and 13.88) as a value of R_0 for *R. padi* at 16 and 28°C, respectively. Segonca *et al* (1994) indicating that the number of times *R. padi* increases in population from one generation to the next was nearly 5 times higher when kept at a range of temperatures from 12 to 28°C. On cabbage aphid, *brevicoryne brassicae*, Salman (2006) reported that the population at 21°C increased more than three times compared to that reared at 15°C. Whereas, Satar *et al* (2005) found the population increased more than the double (47.1) at 25°C compared to (20.3) at 15°C. Moreover, El-Gantiry *et al* (2016) mentioned that the net reproductive rate for *Aphis illinoisensis* was (2.04 and 6.30) at 17 and 24°C, respectively. Also, Kuo *et al* (2006) indicated that the net reproductive rates of *Rhopalosiphum maidis* increased as temperature increased, but they reached the highest values at respective optimal temperatures and then decreased as temperature increased.

2- Generation Time (T):

As shown in (Table 4), the time interval between each generation (T) diminished with increasing temperature. The interval of one generation was 17.85, 16.92, 15.77 and 12.70 days at 18, 20, 22 and 24°C, respectively. A significant reduction in this interval was also found by Auad *et al.* (2009) and Segonca *et al.* (1994) studying *R. padi* kept at 8 to 28°C.

Table 4: Adult fecundity and selected life table parameters of *Rhopalosiphum padi* reared at constant temperatures.

No.	Parameter	Formula	Value			
			18°C	20°C	22°C	24°C
1	Total number of offspring/females	$\sum \mathbf{m_x}$	47.66	91.74	73.25	63.45
2	Number of offspring/reproduction day	$\mathbf{m_x}$	1.01	2.24	1.93	2.12
3	Net reproduction rate (R_0)	$\sum \mathbf{l_x m_x}$	30.37	61.46	54.42	47.99
4	Approximate generation time (T), (days)	$\sum \mathbf{l_x m_x . X / \sum l_x m_x}$	17.85	16.92	15.77	12.7
5	Intrinsic rate of increase (r_m)	$\mathbf{\ln R_0 / T}$	0.19	0.24	0.25	0.3
6	Finate rate of increase (λ)	$\mathbf{e^r}$	1.21	1.28	1.29	1.36
7	Doubling time (DT), (days)	$\mathbf{\ln 2 / r}$	3.62	2.85	2.73	2.27

3- Intrinsic (r_m) and Finite (λ) Rates of Increase:

The Intrinsic rate of increase (r_m) was higher at 24°C (0.3), indicating at this temperature the population increases faster, while aphids kept at 18°C had a lower r_m (0.19). The value of (r_m) at 24°C was approximately 1.2, 1.25 ad 1.6 times higher than that of the pest at 22, 20 and 18°C, respectively (Table 4). These results agree with those of Auad *et al.* (2009) for *R. padi*, who found the highest rate (0.640) occurred at 28°C and mentioned that r_m was 4 times higher when the temperature increased from 16 to 28°C. Asin and Pons (2001) reported the highest rate occurred at 27°C and found that r_m of *R. padi* in the range of 18 to 27°C doubled at the highest temperature. Also, Segonca *et al.* (1994) observed a gradual increase in r_m from 8 to 20°C.

On the other hand, when the values of the intrinsic rate of increase (r_m) were used to estimate the finite rate of increase (λ) according to Birch, 1948; it was found that the population of *R. padi* had the capacity to multiply about 1.21, 1.28, 1.29 and 1.36 times per female per day at 18, 20, 22 and 24°C, respectively. This trend conforms basically with the findings of Auad *et al.* (2009) found that the finite rate of increase for *R. padi* was 1.09, 1.14, 1.22, 1.32 and 1.89 at 12, 16, 20, 24 and 28°C; respectively. Values of (λ) obtained by Salman (2006) for *B. brassicae* were 1.15, 1.26, 1.39 and 1.43 at 15, 18, 21 and 24°C, respectively. Also, the same trend of results has been found by El-Gantiry *et al.* (1999) on *Schizaphis graminum*.

4- Population Doubling Time (DT):

As shown in (Table 4), the population of the *R. padi* doubled every 3.62, 2.85, 2.73 and 2.27 days at 18, 20, 22 and 24°C, respectively. This means that the population doubling time decreased markedly as temperature increased with the shortest doubling time at 24°C. these results corroborated those of Auad *et al.* (2009) for *R. padi*, who reported that the doubling time was 8.06, 5.42, 3.43, 2.47 and 1.08 days at 12, 16, 20, 24 and 28°C; respectively. The same direction of results has been also found by Salman (2006) on *B. brassicae*.

In conclusion, in the range of 20 to 24°C, the calculated biological parameters (R_0, T, DT, r_m and λ) seem to fall in the favourable range for development and multiplication of *R. padi*. The obtained results can provide valuable information about the population growth of *Rhopalosiphum padi*, they could serve as a basis to develop control strategies and subsequent improvement of management programs.

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ARABIC SUMMARY

تأثير درجة الحرارة على بعض الخصائص الحياتية لمنّ الشوفان المربى على نباتات القمح

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تم دراسة تأثير درجة الحرارة وايضا بعض مقاييس جداول الحياة عند اربع درجات حرارة ثابتة هي ١٨، ٢٠، ٢٢، ٢٤ درجة مئوية على من الشوفان. اوضحت النتائج ان طور الحورية يتم اكتماله في حدود ٨,٣٦، ٧,٦٥، ٦,٨، ٥,١٩ يوم على درجات الحرارة ١٨، ٢٠، ٢٢، ٢٤ درجة مئوية على التوالي. وقد وجد ان صفر (عتبة) النمو لاعمار طور الحورية (اول، ثاني، ثالث، رابع) ولأكتمال دورة حياة هو ٤,٥٣، ٧,٩٦، ١٠,٠٢، ٩,٦٧، ٨,٢٥°م على التوالي. وان الوحدات الحرارية اللازمة لاعمار طور الحورية (اول، ثاني، ثالث، رابع) ولأكتمال دورة حياة هو ٢٧,٧٨، ٢١,٢٨، ١٦,٣٩، ٢٢,٢٢، ٨٣,٣٣ وحدة حرارية على التوالي. وجد ان اعلى عدد من الحوريات الموضوعة هو ٩١,٧٤، ٧٣,٢٥ لكل انثى عند درجتي حرارة ٢٠، ٢٢°م على التوالي، إلا ان عدد الحوريات الموضوعة لكل انثى انخفض الي ٤٧,٦٦، ٦٣,٤٥ عند درجتي حرارة ١٨، ٢٤°م على التوالي. بينما متوسط عدد الحوريات الموضوعة / انثى / يوم كان ٢,٢٤، ٢,١٢، ١,٩٣، ١,١ عند درجات حرارة ٢٠، ٢٤، ٢٢، ١٨°م على التوالي.
عند دراسة تأثير درجة الحرارة على بعض مقاييس جداول الحياة وجد ان اعلى معدل تضاعف خلال جيل واحد (R_0) يساوي ٦١,٤٦، ٥٤,٤٢ عند درجتي حرارة ٢٠، ٢٢ °م على التوالي، وان فترة الجيل (T) والزمن اللازم لتضاعف المجموع (DT) تقل كلما زادت درجة الحرارة. وجد ان اعلى معدل للزيادة الطبيعية (r_m) كان (٠,٣، ٠,٢٥) واعلى معدل للزيادة النهائية (λ) كان (١,٣٦، ١,٢٩) عند درجتي حرارة ٢٤، ٢٢°م على التوالي.
وقد اظهرت النتائج بوضوح ان درجات الحرارة من ٢٠ الى ٢٤ هي انسب درجات الحرارة لتطور وتكاثر هذه الآفة الخطيرة.