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SOME BIOLOGICAL ASPECTS AND LIFE TABLE OF THE OAT BIRD-CHERRY APHID, RHOPALOSIPHUM PADI L. (HOMOPTERA: APHIDIDAE) AS FUNCTION OF TEMPERATURE

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ABSTRACT

Some biological aspects and life table of the oat bird-cherry aphid, Rhopalosiphum padi L. feed on wheat (Sids 1) were studied at constant temperatures of 18º±2, 22º±2 and 26±2ºC. At a given temperatures, the time needed for the development of nymphal instars decreased significantly with the increase in temperatures. The longest period was recorded at 18±2ºC while the shortest one was found at 26±2ºC. The calculated developmental threshold (t0) of the whole nymphal stage was estimated as 12.66ºC. The thermal units needed for the development of the whole nymphal stage of the oat aphid were 67.95 day-degrees. Generation time (GT), reproductive potential (R0), population-doubling time (DT), intrinsic (rm) and finite rate (λ) of increase of the pest were also computed and discussed. Based on the obtained data, temperatures of 22°±2 and 26±2°C were the most suitable temperatures for the development and multiplication of the oat aphid.

Key words*: *R. padi, Some biological aspects, Life table, 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).

The life history parameters, such as development, longevity, survival and fecundity are essential for effective aphid management. Also, temperature is the main factor influencing the development, survival and reproduction capacity of the pests.

In this paper, we report the effects of three different constant temperature regimes (18º±2, 22º±2 and 26±2ºC) on the development, survival, longevity and fecundity of the apterous form of R. padi on wheat in the laboratory.

MATERIALS AND METHODS

The following experiments were carried out to study the effect of different constant temperatures of 18º±2, 22º±2 and 26±2°C on the

development of the immature stages of the oat bird-cherry aphid, R. padi as well as on the adult fecundity and longevity.

REARING TECHNIQUE

The experimental colonies (apterous form) of R. padi were collected from severely infested wheat plants grown at the experimental farm of Assiut University. Culture was maintained under laboratory conditions on wheat plants (Sids 1) for 6 months before using in the biological experiments.

Duration (in days) of successive nymphal instars, and adult longevity and number of offspring / adult (fecundity) were studied.

1- Nymphal stage

First instar nymphs (<10 hrs. old) were placed in a separate petri-dish supplied with a leaf of wheat plants (Sids 1) lined with damp tissue paper. Leaves were replaced whenever it necessary. Sixty nymphs were placed individually at each of the above-mentioned constant temperatures (18º±2, 22 º±2 and 26±2ºC). Nymphs in each temperature regime were observed daily to observe moult, development and survival until the appearance of the aptera.

2- Adult stage

To study the effect of the above-mentioned temperature regimes on the adult stage, nymphs were allowed to grow on the previously mentioned temperatures to reach maturity. Newly emerged apterous females (<24 hrs.) were individually exposed to the temperatures of 18º±2, 22º±2 and 26±2ºC until reached maturity and began to produce progeny. Apterous females were daily inspected throughout its life span to record the number of born nymphs per adult.

The time required for the development and survival of each stage was recorded. Data were subjected to statistical analysis using F-test and means were compared according to Duncan's multiple range test of significances at 0.05 level of probability.

Developmental thresholds (to) are calculated according to the method of Weinberg and Lange (1980) and the thermal units (TU) needed for the developments of each stage were calculated according to Madubunyi and Koehler (1974).

K (TU) = T (t-t0), where,

K (TU) = Thermal units (day-degree), (T) = Duration (in days), (t) = Exposure temperature (°C), (t0) = temperature threshold (°C).

Indices of Efficiency (IE) for development of the different stages of R. padi were calculated according to the formula of Khattat and Stewart (1977):

$$\text{Indices of Efficiency (IE)} = \frac{St}{Tt}, \text{ where:}$$

S is the percentage survival, T is the time required for development in days and t is the temperature in ºC.

The obtained data were also used to calculate the following fecundity table aspects according to Birch (1948).

All calculations were executed using a QBASIC program according to Jervis and Copland (1996).

Net reproductive rate (R_0), Generation time (GT), Population doubling time (DT), Intrinsic rate of natural increase (^{r}m), and Finite rate of increase (λ)= anti loge rm.

RESULTS

The present results show the effect of constant temperatures of 18º±2, 22º±2 and 26±2°C on the developmental periods and survival of different nymphal instars of the oat aphid as well as the reproductive potential of the adult stage.

NYMPHAL STAGE

The duration of each nymphal instars of the pest at various constant temperatures is presented in Table 1. Data indicate that the durations of nymphal instars decreased significantly with the increase in temperatures. Apparently, there were significant differences in the duration periods at the tested temperatures. The longest period was recorded at 18±2ºC but the shortest one was found at 26±2ºC. At a given temperature, (18º±2, 22º±2 and 26±2ºC) the durations of the four instars (first, second, third, and fourth) were, 3.45±0.53, 1.58±0.49, and 1.44±0.50; 3.73±0.71, 1.63±0.48, and 1.40±0.49; 3.82±0.75, 1.35±0.55, and 1.25±0.44; and 3.65±0.62, 1.52±0.54; and 1.24±0.43 days, respectively. Duration of the whole nymphal stage lasted 14.35±0.86, 6.11±0.65, and 5.26±0.77 days at 18º±2, 22º±2 and 26±2°C, respectively. On the other side, increase of temperature by 4°C decreased developmental time by about 1.3 folds (table 1). It seems that, within the range of the tested temperatures the developmental time generally decreased with the increase in temperature.

Data presented in Table 2 indicate that within the range of 18±2º – 26±2°C constant temperatures, survival (%) of the nymphal instars and whole nymphal stage increase with the increase in temperature. The highest percentage of survival was observed at 22°±2 (86.67%) followed by 26±2°C (78.33%), whereas, the lowest percentage of survival was noticed at 18±2°C (66.67%). Using an Index of Efficiency (IE) for development of nymphal instars (Table 2), data indicate that the highest index values were obtained at 22°±2 and 26±2°C.

Data given in Table 1 were used to calculate regression equations, which were used in the estimation of threshold of development (t0). The equations (Y = a + bx) for the relationships between the rate of development (Y) and the constant temperatures (x) are shown in Table 3. It is clear that these regression equations fit the observed values rather well as indicated by the high values of the coefficient of determination (R). The calculated developmental thresholds of 1st, 2nd, 3rd, and 4th nymphal instars were shown to be about 11.34°, 12.46°, 13.06°, and 13.29°C, respectively (table 4). The calculated developmental threshold of the whole nymphal stage was estimated as 12.66ºC. By using these values as a base temperature, an average of 20.31, 16.72, 15.70, and 15.39 day-degrees were required, for the development of first, second, third and fourth nymphal instars, respectively. The thermal units needed for the development of the whole nymphal stage of the oat aphid were 67.95 day-degrees (table 4).

ADULT STAGE

Data presented in Table 5 Show the average length of the adult stage of R. padi at the tested temperatures. Adult longevity at each temperature was divided into pre-reproductive, reproductive and post-reproductive periods. The results indicate that reproductive periods decrease with increase in temperature. Pre-

reproductive period (the period between the adult moult and the onset of reproduction) ranged between 1.59±0.61 days at 18 ±2ºC to 0.52±0.55 day at 26±2ºC. The mean reproductive period ranged between 9.61±2.49 days at 18±2ºC to 6.07±2.64 days at 26±2ºC. The post-reproductive period ranged from 0.55 days at 18±2ºC to 0.02±0.01 day at 26±2ºC. Regardless of temperature the pre- and post- reproductive periods extended to the shortest time from the whole longevity of the adult stage while the reproductive period needed the longest time. It is clear that adults reared at 18±2ºC survived about one and half as long as adult reared at 26±2ºC. On the other hand, there were no significant differences between the longevity of adults reared at 22±2°C (7.85±2.25 days) and those reared at 26±2°C (6.82±2.52 days).

The number of progeny per aptera reached 15.18±3.22, 35.76±14.94 and 25.32±12.49 nymphs / female at 18±2, 22±2 and 26±2ºC, respectively (table 5). It is clear that the mean number of nymphs per aptera increased as temperature increased up to 22±2ºC, where the maximum number of nymphs / female (35.76±14.94 nymphs) was produced. There are significantly differences between the numbers of offspring for females reared at the tested temperatures.

The calculated life table parameters which have been taken into consideration of the oat aphid were: Generation time (GT), (Population doubling time (DT), Net reproductive rate (R0) and the intrinsic (rm) and finite rates (λ) of increase (λ), (Table 6).

The duration of one generation of R. padi lasted for about 20, and 11 days at 18 and (22±2º and 26±°C), respectively. The population of this pest had the capacity to double every 6.66, 2.24 and 2.48 days at 18±2ºC 22º±2 and 26±2ºC, respectively. Net reproductive rate (R0) at various constant temperatures indicated that the pest increased by 8.35, 28.02 and 16.88 times within a single generation at 18º±2, 22º±2 and 26±2ºC, respectively. The values of intrinsic rate of increase (rm), which express the relationships between fecundity, generation time and survival, increased by increasing in temperature up to 22°C. The values of rm at 22º±2 and/or 26±2ºC (0.3092 and 0.2792, respectively) were approximately about three times higher than those of the pest at 18±2ºC (0.1041). If rm is a measure of the suitability of the environment, then the maximum ^{r}m values are the most appropriate reproductive potential under these conditions. Examination of the data indicates that a constant temperatures ranged from 22º±2 to 26±2°C is the optimum temperature, as it had the maximum ^{r}m values. On the other hand, when the values of rm were converted to the finite rate of increase (λ), it was shown that the population of R. padi had an ability to multiply about 1.1097, 1.3624 and 1.3221 times per aptera per day at 18°±2, 22°±2 and 26±2ºC, respectively. This means that a population of ten aptera of the oat aphid could increase in a period of one week to become 61, 57, and 15 individuals at 18°±2, 22°±2 and 26±2ºC, respectively.

DISCUSSION

Several studies have shown that the temperature dependent development of aphids including R. padi may be strongly influenced by the geographical origin of the aphid (Campbell et al., 1974; Foottit and Mackauer, 1990 and

Mokhtar et al., 1993), while other authors emphasized the effect of host plants on morphological variations and aphid development (Wool and Hales, 1996; 1997; Kersting et al., 1998; Van Lerberghe-Masutti and Chavigny, 1998; Satar et al., 1999 and Satar, et al, 2005). Thus, developmental and fecundity data for R. padi on one host plant and from one region should be used with caution if applied to different host plants and regions.

The present study was designed to provide data on the developmental rate and fecundity of an Egyptian population of R. padi at different constant temperatures that might be used for developing integrated pest management strategies, in particular monitoring and sampling plant of the oat aphid infesting wheat plants in Egypt. Temperature has the major effect on the biology and life cycle of aphids. Controlled laboratory studies can provide detailed information about the population dynamics of aphids. Our results clearly show the effects of temperature on the developmental time, nymphal mortality rate, longevity and fecundity of R. padi on excised leaf disks. Optimum temperature for the development of the oat aphid was 22±2°C and 26±2ºC. Similar to the result obtained by DeLoach (1974) and Satar, et al (2005), they reported the shortest development period at 24±2°C. The theoretical lower development threshold of 12.66°C, computed from the linear segment of the growth curve, was similar to (Campbell et al., (1974) and Salman, (2006) for a population of R. padi. In contrast, a considerably lower developmental threshold (1.7°C) for the cabbage aphid was obtained from Finland by Markkula (1953). These results are in agreement with those of Campbell et al. (1974), who stated that the developmental threshold of aphids originating from warm summer or mild spring climates should be higher than those from cooler climates. The Upper Egypt (Assiut area), with its typical climate with warm summers and semi cool winters, resulted in a slightly higher developmental thresholds for the oat aphid than those obtained in the slightly warmer climate. The intrinsic rate of natural increase (^{r}m) is a good indicator of the temperature at which the growth of a population is most favorable, because it reflects the overall effects of temperature on development, reproduction and survival characteristics of a population. R. padi reared at 22º±2 and 26±2°C had the highest ^{r}m-value among all temperatures (rm = 0.3092 and 0.2792), because of the faster development and higher survivorship of immature stages as well as the high daily rate of progeny. However, the growth rate at 18±2°C was statistically different from 22º±2 and 26±2°C. The growth rate of the R. padi used in our studies was considerably higher for all temperatures tested than those reported by DeLoach (1974). These differences were due to a much longer generation time and considerably lower reproduction rates. Closer to our own results, Hoseini et al. (2003) reported an ^{r}m-value of 0.25 aphids per aptera/day at 25°C, whereas Satar et al., (2005) reported 0.2009 aptera/aphid per day at 20°C. According to our results, R. padi populations in Assiut (Upper Egypt) are well adapted to temperatures between 20 and 25°C, showing a high growth rate within this temperature range. Temperatures below or above this range result in drastically reduced population growth, and temperatures over 28°C

are lethal to nymphs of the oat aphid. With this information it should be now possible to establish monitoring and sampling plans for this important wheat pest as a first step in developing IPM programs.

Table (1): Duration (days ± SE) of R. padi reared at different constant temperatures.

Temp. (±2°C)	Duration (days) ± SE				
	1st	2nd	3rd	4th	Total
18	3.45±0.53a	3.73±0.71a	3.82±0.75a	3.65±0.62a	14.35±0.86a
22	1.58±0.49b	1.63±0.48b	1.35±0.55b	1.52±0.54b	6.11±0.65b
26	1.44±0.50b	1.40±0.49b	1.25±0.44b	1.24±0.43b	5.26±0.77c

Means followed by the same letters vertically, are not significantly different at <0.05 level of probability.

Table (2): Survival (%) and indices of efficiency (IE) of R. padi reared at different constant temperatures.

Temp. (±2°C)	Indices of Efficiency (IE)				
	1st	2nd	3rd	4th	Total
18	26.57	23.39	24.54	24.35	4.64
22	60.13	59.19	70.03	65.79	14.18
26	64.81	67.60	73.96	77.35	14.89

Table (3): Regression equations expressing development of R. padi reared at different constant temperatures.

Instars	Regression equations	(r)	(R)
1st	Y= -57.33+5.05x	0.77	59.29
2nd	Y = -69.51+5.58x	0.95	90.25
3rd	Y = -87.92+6.73x	0.91	82.81
4th	Y = -88.49+6.65x	0.97	94.09
Total nymph	Y = -18.99+1.50x	0.95	90.25

Regression equation = (Y= a + b X)

(r) = Correlation coefficient. (R) = Coefficient of determination

Table (4): Developmental thresholds (t0) and thermal units (day-degrees) needed for the development of R. padi reared at different constant temperatures.

Instars	Temperature thresholds (t0)	Thermal units (TU)				
		Temperatures±2 (ºC)			Total	Mean
		18	22	26		
1st	11.34	22.98	16.84	21.11	60.93	20.31
2nd	12.46	20.66	15.55	13.95	55.17	16.72
3rd	13.06	18.87	12.07	16.17	47.11	15.70
4th	13.29	17.19	13.24	15.76	46.19	15.39
Nymphal stage	12.66	76.63	57.07	70.17	203.86	67.95

Table (5): Reproductive potential of R. padi reared at different constant temperatures.

Temp. (±2°C)	Longevity (days ± SE) and fecundity (No progeny / female)				
	Longevity				Fecundity (♀/♀)
	Pre.-	Reproductive	Post.-	Total	
18	1.59±0.61a	9.61±2.49a	0.55±0.75a	11.73±2.17a	15.18±3.22c
22	0.85±0.78b	6.94±2.33b	0.00±0.00b	7.85±2.25b	35.76±14.94a
26	0.52±0.55c	6.07±2.64b	0.02±0.01b	6.82±2.52b	25.32±12.49b

Means followed by the same letters vertically, are not significantly different at <0.05 level of probability.

Table (6): Some life table parameters of R. padi reared at different constant temperatures.

Temp. (±2°C)	(GT)	(DT)	(R0)	Rate of increase	
				Intrinsic (rm)	Finite (λ)
18	20.3936	6.6604	8.3507	0.1041	1.1097
22	10.7774	2.2414	28.0195	0.3092	1.3624
26	10.1224	2.4825	16.8826	0.2792	1.3221

(GT) = Mean generation time, (DT) = Doubling time, (R0) = net reproduction rate, (rm) = intrinsic rate of increase, (λ) = finite rate of increase.

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بعض المفاهيم البيولوجية وجداول الحياة لحشرة من الشوفان متأثرة بدرجات الحرارة الثابتة

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الملخص العربي:

تم دراسة بعض المفاهيم البيولوجية وجداول الحياة لحشرة من الشوفان التي تصيب نباتات القمح تحت تأثير درجات الحرارة الثابتة ١٨±٢°م ، ٢٢±٢°م ، ٢٦°±٢°م. أوضحت الدراسة أن طول فترة نمو هذه الآفة تتأثر بدرجات الحرارة عكسيا حيث مثلت اقصر فترة للنمو على أعلى درجة حرارة تم تربية الحشرة عليها في حين كانت أطول فترة للنمو على اقل درجة حرارة وهى ١٨±٢°م. تم حساب الحد الحرج للنمو لهذه الآفة ووجد انه ١٢.٦٦°م. أظهرت الدراسة أن الوحدات الحرارية اللازمة لتطور جيل كامل من هذه الآفة هو ٦٧.٩٥ وحدة حرارية يومية. تم حساب بعض مقاييس جداول الحياة لهذه الآفة تحت نفس الظروف من الحرارة الثابتة وهى فترة الجيل ، معدل التضاعف ، والزمن اللازم لتضاعف المجموع ومعدل الزيادة النهائي لهذه الآفة. ومن النتائج المتحصل عليها وجد أن درجات الحرارة ما بين ٢٢ ، ٢٦°م هي انسب درجات الحرارة لنمو وتطور حشرة من الشوفان التي تصيب نباتات القمح.