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INFLUENCE OF TEMPERATURE ON THE DEVELOPMENTAL RATE AND REPRODUCTION OF THE ENGLISH GRAIN APHID, *SITOBION avenae* (FABRICIUS) (HOMOPTERA: APHIDIDAE).

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ABSTRACT

A laboratory investigation was conducted to study the effect of constant temperature on some biological aspects of english grain aphid, *Sitobion avenae* (Fabricius). The present work was carried out in electrical incubators provided with photoperiod of 16 : 8 (L : D) and 55 – 60% R.H. Data revealed that the english grain aphid passed through four instars to reach maturity. The duration period of the nymphal stage was 19.0, 13.98, 11.96, 8.51 and 7.5 days at 12, 15, 18, 21, 24 °C, respectively. Developmental threshold of this stage is found to be 4.2 °C. The thermal units required for complete one generation was 148 day – degrees. Life table parameters were as following : The reproduction rate (R_o) were 18.75, 30.72, 36.53, 44.21 and 32.42; mean generation time (GT) were 26.16, 21.23, 17.39, 11.92 and 9.86 days; population doubling time (DT) of the english aphid were 6.19, 4.29, 3.35, 2.18 and 1.96; intrinsic rate of increase (r_m) were 0.1121, 0.1613, 0.2069, 0.3178 and 0.3528 and finite rate of increase (λ) were 1.119, 1.175, 1.229, 1.374 and 1.423 at 12, 15, 18, 21 and 24 °C, respectively. The results indicated clearly that the favourable range temperature for development and multiplication the english grain aphid between 18 and 24°C.

Keywords: *Sitobion avenae*; Temperatures, Duration, Development threshold (T_o), Repreoduction rate (R_o), Mean generation time (GT), Intrinsic rate of increase (r_m), Finite rate of increase (λ), Population doubling time (DT), wheat, Agronomy

INTRODUCTION

The english grain aphid *sitobion avenae* (Fabricius) is one of the most common and destructive aphid attacking the foliage and heads of wheat, barley and other small grains. Colonies of this aphid feed upon the leaves until the grain begins to head; then they aggregate on the heads among the ripening kernels. When sufficiently large populations develop, their feeding shrivels the growing ker-

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nels. Extensive early spring feeding can kill grain plants. This aphid species is also a known vector of the barley yellow dwarf virus disease of small grains, barley stripe mosaic virus and brome mosaic virus and providing a medium for fungal development (**Vickerman and Wratten, 1979 and Carter *et al* 1980**).

Although, the effect of temperature on the biology of english grain aphid, *Sitobion avenae* F. extensively studied by **Kieckhefer *et al* (1989)**. But the life history parameters of *Sitobion avenae* were not well documented, and these biological characteristics and parameters are essential for effective aphid management. Therfore, the present work aims to investigate the effects of five different constant temperature regimes on development, survivorship, longevity, fecundity and to determine the threshold of development (t_o), the thermal requirements (day – degrees) for the immature stage as well as to study life table parameters of the english grain aphid, *Sitobion avenae* F. on wheat in the laboratory.

MATERIAL AND METHODS

Host plant

Seeds of common wheat variety (Consolt) were seeded in a plastic pots (20 cm in diameter, 25 cm high) with five seeds per pot in a greenhouse at Scottish Agricultural College, University of Edinburgh, UK during post doctor for six months. Some of these seedling were maintained in the greenhouse, and others were maintained in an insectary for feeding the aphid colony.

Aphid source

The aphid colony has been maintained on wheat variety (Consolt) in a greenhouse. Both alate and apterous adult aphids collected from the greenhouse colony, and were transferred on to potted wheat in an controlled incubator at 20 ± 2 °C and 55 – 60 % relative humidity (RH) under photoperiod of 16 : 8 (L : D) houres, clean potted wheat plants were added when required for maintaining the high aphid density.

Development, Survivorship, Longevity and Fecundity

Seeds of common wheat variety (Consolt) were planted in a plastic pots (5.0 cm in diameter 7 cm high) and after emergence thinned to one seedling / pot. Seedlings were artificially infested with nymphs (> 24 hrs old 1st instars) were collected from the laboratory colony using a small camel's – hair brush (# 000) and covered with glass cages then covered with muselin fixed to the rime with rubberbands then placed in incubators provided with photo period of 16:8 (L : D) and 55 – 60% R. H. at constant temperatures of 12, 15, 18, 21 and 24 °C. Forty nymphs were individually placed in four replicates (ten nymphs for each) in each of the previously mentioned temperatures.

Nymphs in each temperature regime were observed twice day to determine the moulting, duration and survival. After nymphs moulted to adults, daily fecundity each female was determeined, and offspring were removed from the seedlings daily.

Data analysis

Data obtained were statistically analyzed using analysis of variance and the means were separated 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 used to calculate the following parameters :

1. Duration of nymphal instars.
2. Threshold of development
   $t_o = t_1 - [T_2 (t_2 - t_1) / T_1 - T_2]$.
3. Age specific survival rate (L_x) : the number of individuals alive at age (x) as a proporation of one.
4. Age specific fecundity rate (m_x): the number of female offspring produced female in age interval (x).
5. Net reproduction rate (R_o): The number of female offspring that replace each female of previous generation
   $(R_o = \Sigma l_x . M_x)$.
6. Generation time (GT) : The mean time elapsing between birth of parents and the birth of offspring
   $(GT = \Sigma L_x m_x . X / \Sigma L_x m_x)$.
7. Population doubling time (DT).
   $DT = {}^{\log 2}/r_m$.
8. Intrinsic rate of increase (r_m) : the difference in birth rate and death rate in population with a stable age distribution
   $(r_m = \log e \; R_o/T)$.
9. Finite rate of increase (λ) : the number of individuals added to the population per female per day
   $(\lambda = e\ r^m)$.

The development threshold (t_o) and the thermal units (TU) required to complete development of the nymphal stage were calculated according to the method described by **Mangat (1977)**. Fecundity and life table parameters were calculated accourding to **Birch (1948)**.

RESULTS AND DISCUSSION

1. Nymphal stage

Data in **Table (1)** show that the english grain aphid, *Sitobion* avenae F. passed through four instars to reach maturity. The total nymphal period occupied the average of 19.0, 13.98, 11.96, 8.51 and 7.5 days, the first nymphal instar averaged 7.0, 4.48, 3.42, 3.0 and 2.5 days, the second ones 3.0, 3.0, 2.5, 1.2 and 1.41 days, the third 4.0, 2.5, 2.77, 1.57 and 1.59 days, the fourth 5.0, 4.0, 3.27, 2.74, and 2.0 days when reared at 12 °, 15°, 18°, 21° and 24 °C, respectively. It is evident that the duration of nymphal instars decreased gradually as temperature increase from 12° to 24°C. The longest nymphal stage was 19.0 days at 12 °C, while the shortest one was 7.5 days at 24 °C. Statistical analysis of the data showed significant differences between values of mean duration at the tested temperatures. Similar findings were recorded by **Ali *et al* (1991)** on green peach aphid, **Mohamed *et al* (2000)** on cotton aphid, **Ali *et al* (2002)** on Cowpea aphid and **Salman (2003)** on rose aphid.

Results in **Table (1)** were used to calculate the developmental threshold (t_o) and thermal units (TU) required for the development of the nymphal stage of the english grain aphid, *Sitobion avenae* according to **Mangat (1977)**. The hypotheritical temperature thresholds which were used in the estimation were below the rearing temperatures of 12 °C and 24 °C. The calculated data **Table (2)** were

Table 1. Duration of the nymphal instars of english grain aphid, *Sitobion avenae* at constant temperature of 12°, 15°, 18°, 21° and 24°C

Temp. (°C)	Duration (in days) ± SD									
	1st		2nd		3rd		4th		Nymphal Stage	
12	7.0 ± 0.19	a	3.0±0.15	a	4.0±0.15	a	5.0 ± 0.15	a	19.00±0.85	a
15	4.48±0.09	b	3.0±0.11	a	2.5±0.11	c	4.0 ± 0.18	b	13.98±0.45	b
18	3.42±0.09	c	2.5±0.09	c	2.77±0.11	b	3.27±0.08	c	11.96±0.21	c
21	3.0 ± 0.04	d	1.2±0.08	d	1.57±0.15	d	2.74±0.07	d	8.51 ±0.44	d
24	2.5 ± 0.11	e	1.41±0.09	d	1.59±0.09	e	2.0 ± 0.18	e	7.5 ±0.24	d
*F. value	18.25		11.25		21.29		8.32		5.40	
LSD at(0.05)	0.319		0.197		0.166		0.306		1.52	

Table 2. Day-degrees (DD) needed for the development from nymph to adult stage of *Sitabion avenae* using hypotheoritical temperatures thresholds

Temperature Thresholds (°C)	12°C (19 days) DD	24°C (7.5 days) DD
3	171.0	157.5
4	152.0	150.0
5	133.0	142.5
6	114.0	135.0
7	95.0	127.5
8	76.0	120.0
9	57.0	112.5
10	38.0	105.0

graphically illustrated in **Figure (1)**. The threshold temperature for development nymphal stage was 4.2°C and the thermal unit necessary for the development of one generation were 148 day – degrees. Similar findings were recorded by **Kieckhefer *et al* (1989)** in South Dakota found that the development thresholds of *Sitobion avenae* was 4.0°C. Meanwhile **Jansson and Smilowitz (1985) in USA and El-Din (1976)** in UK they found that the developmental thresholds of *Myzus persicae* were 6.4, 4.0 and 5.9°C, respectively. The present results disagree with those obtained by many investigators : *Aphis craccivora* (10.0°C) (**Ali *et al* 2002**); *Rhopalosiphum nymphaeae* (8.5°C) (**Nasser and Mohamed, 1992**), *Aphis gossypii* (7.34°C) and (6.84°C) (**Liu and Perng, 1987 and Mohamed *et al* 2000**, respectively); *Rhopalosiphum maidis* (6.36°C) (**Ahmed, 1996**).

The inconsistency in the results may be attributed to differences in the aphid ecotypes or to weather factors prevailing in these countries which appear to be a cause of low threshold of development of same aphid species and consequently the high thermal units required for completion of nymphal development. The thermal units needed for the development from nymph to adult was found to be 148 day – degrees. Similar results were found by **Kieckhefer *et al* (1989)** they found that the day – degrees (DD) requirements from birth to reproduction on set of english grain aphid, *Sitobion avenae* was 150.8 DD.

2. Adult Stage

2.1. Survival and fecundity

The age specific survival rate (L_x) and age specific fecundity rate (m_x) of english grain aphid, *Sitobion avenae* at five constant temperatures are shown in **Table (3)** and illustrated in **Figures 2, 3 and 4**. The results indicate that the average (m_x) value per female per day were 1.56, 2.71, 2.81, 5.0 and 4.56 individuals at 12, 15, 18, 21 and 24°C, respectively. The corresponding means of fecundity per female were 28.0, 38.0, 45.0, 60.0 and 41 individuals. The greatest number of offspring was produced at 21 °C. It seems that the fecundity of the pest decreased at temperature below 21°C or above this degree. Also the longest reproduction period (18 days) was achieved at 12 °C, the highest number of offsprings was 60.0 offsprings occurred at 21°C. It is evident that the exposure of the insect to relatively low temperature (12°C) seem to have adverse on adult fecundity. It appears also that the number of progeny per female depends on the female age. As shown in **Figures (2, 3 and 4)** the reproductive rate was declined with the progress of females age.

Non information is available on the survival and fecundity of english grain aphid, *Sitobion avenae*. But similar results of certain aphid species were recorded by many investigators: on *Myzus persicae* (80 youngs) (**Sylvester, 1954**); (68.2 individuals) (**MacGillivary and Anderson, 1958**); (61 individuals) (**Neitzal and Rauber, 1968**); (46.37 individuals) (**Culliney and Pimentel, 1985**) and (45.46 individuals) (**Ali *et al* 1991**). On the other hand on *Aphis craccivora* (65.48 offspring at 22°C) (**Ali *et al* 2002**), on *Macrosiphum rosae* (67.62) individuals at 25°C) (**Salman 2003**).

The longest longevity was 22 days at 12°C and the shortest one was 9 days at 24°C. Similar results obtained by **Ali *et al* (2002)** reported that the longest longevity

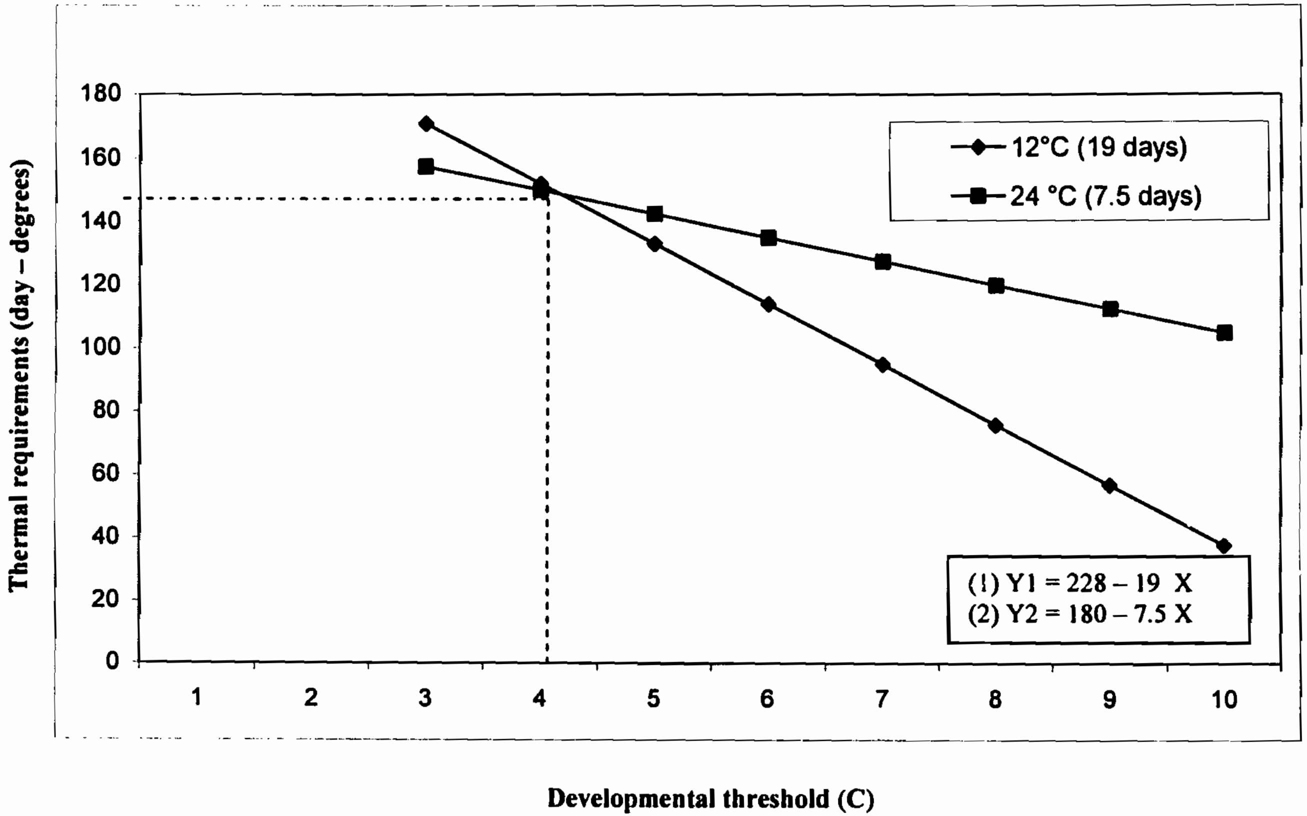


Fig. 1. Thermal unites needed for the development of the nymphal stage of *S. avenae*.

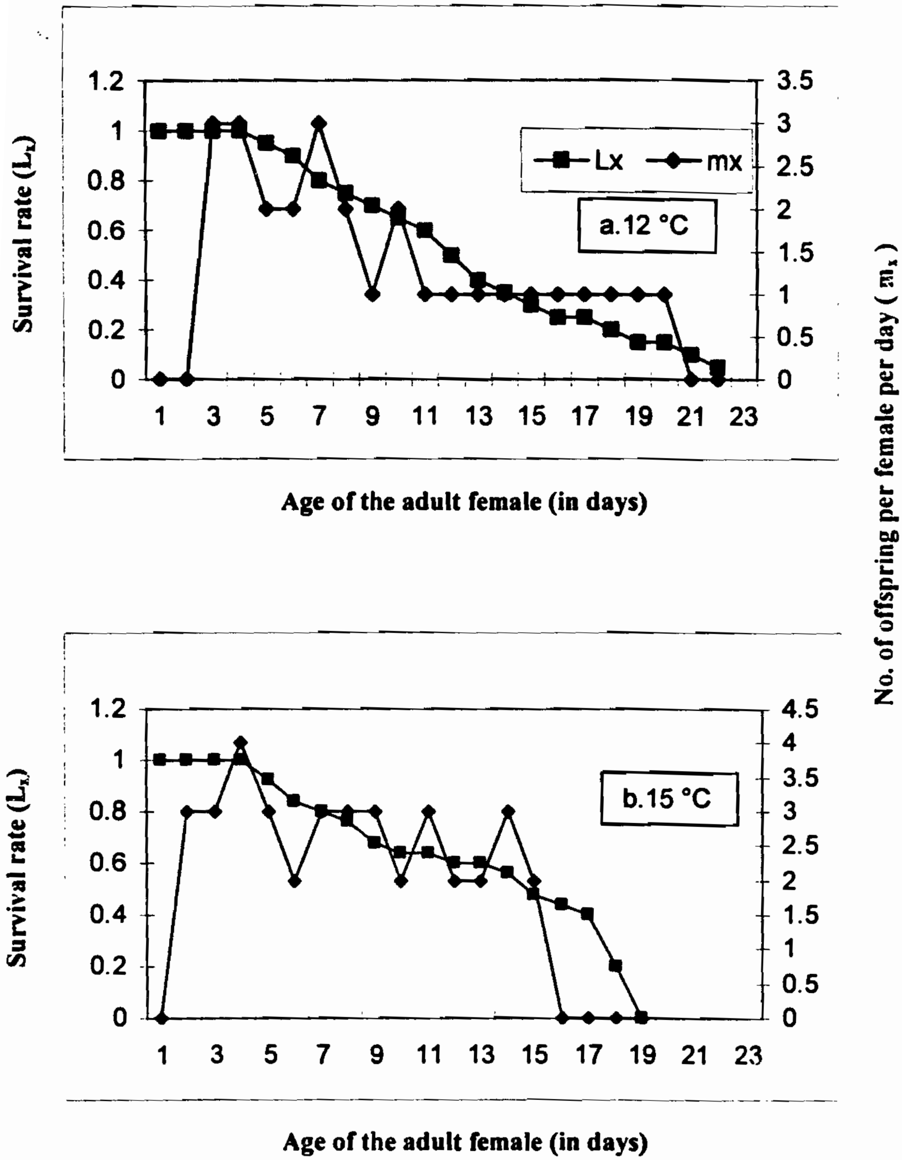
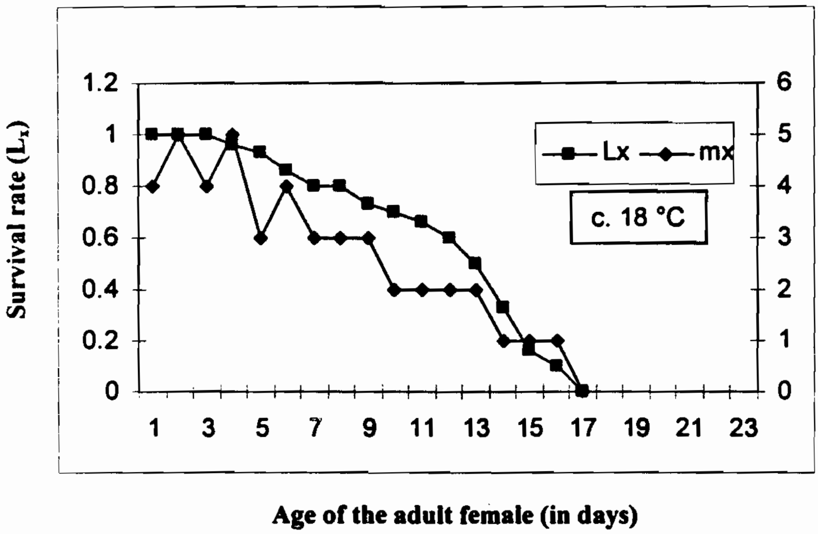


Fig. 2. Age – specific survival rates (L_x) and age specific fecundity rates (m_x) of *S. avenae* reared at constant temperatures of 12°C (a) and 15°C (b).



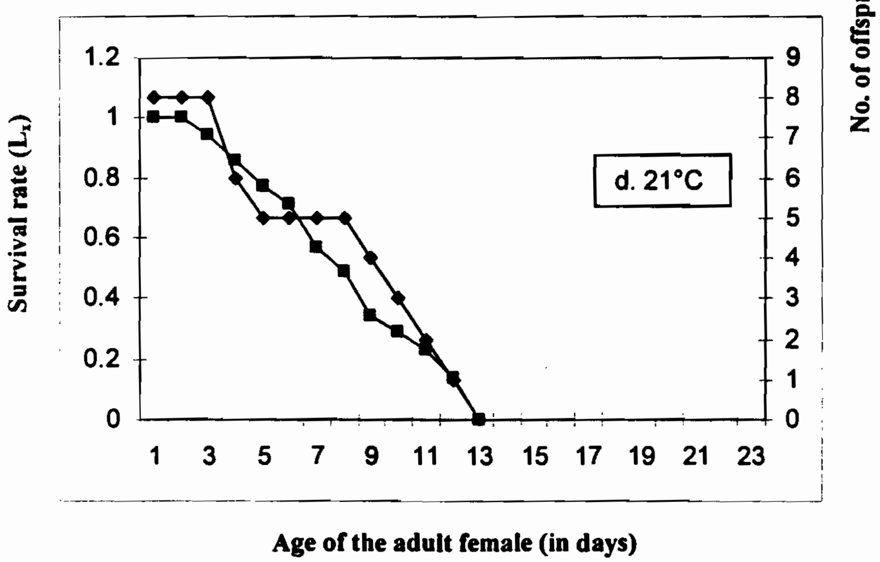
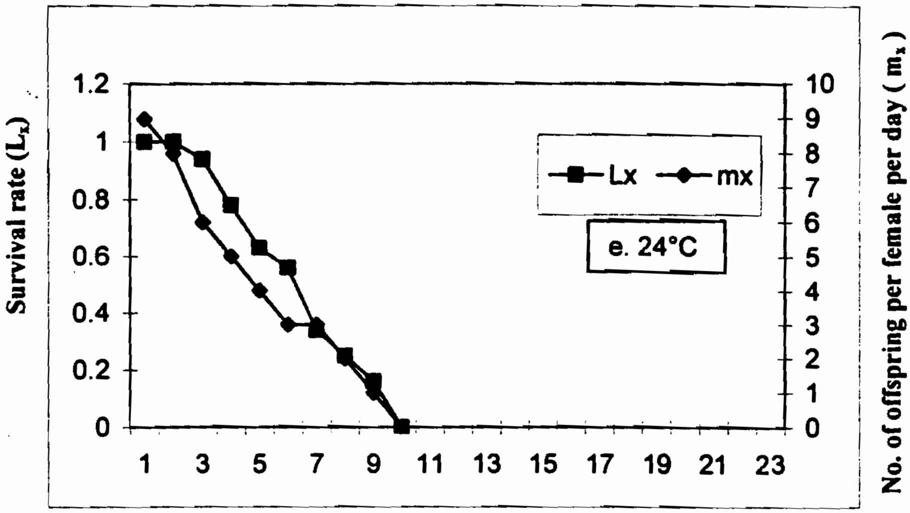


Fig. 3. Age – specific survival rates (L_x) and age specific fecundity rates (m_x) of *S. avenae* reared at constant temperatures of 18°C (c) and 21°C (d) .



Age of the adult female (in days)

Fig. 4. Age - specific survival rates (L_x) and age specific fecundity rates (m_x) of *S. avenae* reared at constant temperatures of 24 °C (e)

of *Aphis craccivora* was 13.37 days at 18°C and the shortest one was 5.91 days at 18°C.

In general it could be concluded that the contradiction in the results of the foregoing discussion may be due to differences in the characteristics of the aphid ecotype in addition to other factors e.g. differences in soil and plant quality between the above mentioned studies and present study.

2.2. Life table parameters

2.2.1. Net reproductive rate (R_0)

The results in **Table (3)** indicate that the english grain aphid can increase ca. 18.75, 30.72, 36.53, 44.21 and 32.42 times after a single generation at 12°, 15°, 18°, 21°, and 24 °C, respectively. The net reproduction rate for the population at 12°, 15°, 18°, and 21° was about 42.41%, 69.45%, 82.62% and 73.33%, respectively of that reared at 21°C. Nearly similar trend has been previously observed by **Ali *et al* (1991)** stated that the net reproduction rate for the green peach aphid reared at 18°C was about 30 % of that reared at 24°C.

2.2.2. Interinsic rate of increase (r_m) and finite rate of increase (λ)

Data in **Table (3)** show the intrinsic rate of increase (r_m) of the english grain aphid was 0.112, 0.161, 0.207, 0.318 and 0.353 at 12°, 15°, 18°, 21° and 24 °C, respectively. The values of r_m increased markedly with the rise of temperature. It appears that the values r_m at 24 °C was apporoximately 3, 2, 1.71 and 1.11 time higher than that of the pest at 12°, 15°, 18° and 21°C, respectively. The data indicates that a constant temperature of 24°C is nearly the optimal temperature among those tested, as it had the maximal r_m value. The intrinsic rates of increase has been used a comparative manner to estimate the degree of fitness of various genotypes to their environment **(Ayala, 1968)**. It appears that the intrinsic rate of increase of english grain aphid were much higher at favorable range of temperature (18° - 24°C). These values decreased with the increase or decrease of temperature. Higer value of r_m is mainly attributed to the greater rate of fecundity per female and shorter generation time at the favorable temperatures than those at unfavorable ones (higher or lower temperatures). Similar results obtained by **Ali *et al* (2002)** reported that the value of (r_m) of *Aphis craccivora* at 26°C was approximately 1.4 times higher than that the pest at 18°C 1.2 times of that at 22°C. Also **Culliney and Pimentel (1985)** reported 0.348 as value of (r_m) for *Myzus persicae* at 25°C. Moreover, when the values of intrinsic rate of increase (r_m) were converted into finite rate of increase (λ) according to **Birch (1948)** it was clear that the population of english grain aphid had the capacity to multiply by about 1.119, 1.175, 1.229, 1.374 and 1.423 times per female per day at 12°, 15°, 18°, 21° and 24°C, respectively. Similar results were obtained by **Ali *et al* (2002)** found that the population of *A. craccivora* had the capacity to multiply about 1.3258, 1.4372 and 1.5471 times per female per day at 18°, 22° and 26°, respectively. Also **Salman (2003)** revealed that the population of *M. rosae* had the capacity multiply about 1.152, 1.281, 1.379 and 1.446 times per female per day at 17°, 20°, 25° and 30°C, respectively.

2.2.3. Generation time (GT)

Duration of one generation lasted for 26.16 days at 12°C and 9.86 days at 24°C. These results are in agreement with those reported by **Mohamed *et al* (2000)** who found that the generation time of *A. gossypii* was shorter (8.53 days) at 30 °C as compared with other temperatures of 20 and 25 °C. Also **Ali *et al* (2002)** found that the decrease of temperature from 26 °C to 18 °C led to length the generation time of *A. craccivora* from 7.72 to 13.22 days.

2.2.4. Population doubling time (DT)

The population of *Sitobion avenae* had the capacity to double every 6.19, 4.29, 3.35, 2.18 and 1.96 days at 12°, 15°, 18°, 21° and 24°C, respectively **Table (3)**. This means that population doubling time markedly decreased as temperature increased with the shortest doubling time at 24 °C. Similar findings were recorded by **Ali *et al* (2002)** on *Aphis craccivora* and **Salman (2003)** on *M. rosae*.

In Summary, the calculated biological parameters (R_o, r_m, λ, GT and DT) indicate that temperatures (18 – 24 °C) seems to be a favourable temperatures for development and multiplication of english grain aphid, *Sitobion avenae* F. These results obtained from the present work are very important for predication purposes used in integrated control programme for managing this pest. The accumulation of heat units (day – degrees) become a useful tool for predicting the appearance of various insect species in the field.

Table 3. Effects of different constant temperatures on some biological parameters of english grain aphid, *Sitobion arenae* (fabricius)

Temp. (°C)	Fecundity Per female	Fecundity Per day (m_x)	Net reproduction rates (R_o)	Gene. Time days (GT)	Rate of increase Intrinsic (r_m)	Rate of increase Finite (λ)	Doubling time (DT)
12	28.0	1.56	18.75	26.16	0.1121	1.118	6.19
15	38.0	2.71	30.72	21.23	0.1613	1.1751	4.29
18	45.0	2.81	36.53	17.39	0.2069	1.2299	3.35
21	60.0	5.00	44.21	11.92	0.3178	1.3742	2.18
24	41.0	4.56	32.42	9.86	0.2528	1.4231	1.96

REFRENCES

Ahmed, M.A.A. (1996). Studies on Certain Insect Pest Infesting Sorghum with Reference to Their Natural Enemies in Upper Egypt. 170 pp. M.Sc. Thesis, Fac., Agric., Assiut Univ. Assiut, Egypt.

Ali, A.M.; S.A. Ahmed and A.M.A. Salman (1991). Temperature and reproductive potential of the green peach aphid., *Myzus persicae* (Sulzer) (Homoptera : Aphididae). ***Proc. 4th Nat. Con. of Pests, Dis. of Veg. Fruits in Egypt, Ismailia,*** **pp. 17-26.**

Ali, A.M.; G.H. Abou-Elhagag and A.M.A. Salman (2002). Some biological aspects of the cowpea aphid, *Aphis craccivora* koch (Homoptera : Aphididae) on faba bean. Assiut. ***J. Agric. Sci., 33(1): 201-213.***

Ayala, F.F. (1968). Genotype environment and population numbers. ***Science, 162: 1453–1459.***

Birch, L.C. (1948). The intrinsic rate of natural increase of an insect population. ***J. Anim. Ecol., 17: 15-26.***

Carter, N.; I.F.G. Mclean; A.D. Watt and A.F.G. Dixon (1980). Cereal aphids. a case study and review. ***Applied Biology, 5 : 271 – 348.***

Culliney, T.W. and D. Pimentel (1985). The intrinsic rate of natural increase of the green peach aphid, *Muzus persicae* (Sulzer) (Homoptera : Aphididae), on collards (*Brassica oleracea* L.). ***Can. Entomol. 117 : 1147-1149.***

Duncan, D.B. (1955). Multiple range and multiple F. test. ***Biometrics, 1: 1-42.***

El-Din, N.S. (1976). Effects of temperature on the aphids *Myzus persicae* (Sulz.), with special reference to critically low and high temperature. ***Z. Ang. Entomol., 80: 7 – 14.***

Jansson, R.K. and Z. Smilowitz (1985). Development and reproduction of the green peach aphid., *Mysus persicae* (Homoptera : Aphididae), on upper and lower leaves of three potato cultivars. ***Can. Entomol., 117 : 247 – 252.***

Kieckhefer, R.W.; N.C. Elliot and D.D. Walagenbach (1989). Effects of constant and fluctuating temperatures on development rates and demographic statistics of the english grain aphid (Homoptera : Aphididae). ***Ann. Entomol. Soc. Am. 82 : 701 – 706.***

Liu, Y.C. and J.J. Perng (1987). Population growth and temperatures dependent effect of cotton aphid, *Aphis gossypii* Glover. ***Chinese-J. Entomol., 7(2): 95-111.***

MacGillivray, M.E. and G.B. Anderson (1958). Development of four species (Homoptera) on potate. ***Can. Entomol., 90 : 148 – 155.***

Mangat, B.S. (1977). Thermal threshold and temperature accumulation for the Cotton Bollworm. ***J. Tenn. Acad. Sci., 52: 15 – 16.***

Mohamed, S.H.; F.A. Abdel-Galil and S.M. Gameel (2000). Effect of temperature on the developmental rate and life table parameters of the Cotton *aphid, Aphis gossypii* Glover (Homoptera : Aphididae). ***Proc. Hoc. 2nd Sci., Conf. Agric. Sci., Assiut, Egypt.*** **PP. 583 – 590.**

Nasser, M.A. and S.H. Mohamed (1992). Some biological aspects of *Rhopalosiphum nymphaeae* (L.) (Homoptera : Aphididae) reared on waterhyacinth. ***Assiut J. Agric. Sci., 23 : 247 – 255.***

Neitzal, K. and A. Raeuber (1968). Ecological Studies of aphids : I. on the temperature tolerance of the virginoparae of *Myzus persicae* at constant temperature on weeds. ***Entomol. Exp. Appl. 11: 115 - 132.***

Salman, A.M.A. (2003). Effect of constant temperatures on certain biological aspect of the rose aphid, *Macrosiphum* rosae (Linnaeus) (Homoptera:Aphididae). ***Assiut J. Agric. Sci. 34(5): 173-185.***

Sylvester, E.S. (1954). Insectary life history and apterous morphology of *Myzus persicae* (Sulzer) (Homoptera : Aphididae). ***Ann. Entomol. Soc. Amer., 47: 397 – 406.***

Vickerman, G.P. and S.D. Wratten (1979). The biology and pest status of cereal aphids in Europe : a review. ***Bulletin of Entomological Research, 69: 1-32.***

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تأثير الحرارة على معدل تطور وتكاثر مَنْ الحبوب الإنجليزي

[٥٠]

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تم دراسة تأثير خمس درجات حرارة ثابتة على بعض الخصائص الحياتية لمَنْ الحبوب الإنجليزى ، وأوضحت النتائج أن تطور العمر الحورى يستغرق ١٩,٠ ، ١٣,٩٨ ، ١١,٩٦، ٨,٥١ ، ٧,٥ يوم على درجات الحرارة الثابتة ١٢ ، ١٥ ، ١٨ ، ٢١ ، ٢٤ درجة مئوية على التوالى . ووجد أن صفر (عتبة) النمو للطور الحورى يساوى ٤,٢ درجة مئوية وأن الوحدات الحرارية اللازمة لتطور العمر الحورى تساوى ١٤٨ وحدة حرارية. كما أمكن حساب معايير جداول الحياة لهذا النوع من المن وكانت كالتالى : وجد أن معدل التضاعف خلال جيل واحد (R_o) يساوى ١٨,٧٥ ، ٣٠,٧٢ ، ٣٦,٥٣ ، ٤٤,٢١ ، ٣٢,٤٢ وفترة الجيل ٢٦,١٦ ، ٢١,٢٣ ، ١٧,٣٩ ، ١١,٩٢ ، ٩,٨٦ يوم وبلغ الزمن اللازم لتضاعف المجموع الحشرى (DT) لمن الحبوب الإنجليزى ٦,١٩ ، ٤,٢٩ ، ٣,٣٥ ، ٢,١٨ ، ١,٩٦ يوم على درجات الحرارة ١٢ ، ١٥ ، ١٨ ، ٢١ ، ٢٤ درجة مئوية على التوالي . كما وجد أن معدل الزيادة الطبيعى (r_m) يساوي ٠,١١٢١ ، ٠,١٦١٣ ، ٠,٢٠٦٩ ، ٠,٣١٧٨ ، ٠,٣٥٢٨ . كما وجد أن معدل الزيادة النهائى (λ) يساوى ١,١١٩ ، ١,١٧٥ ، ١,٢٢٩ ، ١,٣٧٤، ١,٤٢٣ على درجات الحرارة ١٢ ، ١٥ ، ١٨ ، ٢١ ، ٢٤ درجة مئوية على التوالى . وقد دلت النتائج بوضوح أن درجات الحرارة بين ١٨ ، ٢٤ درجة مئوية تقع فى المدى الحرارى المفضل لنمو وتكاثر هذه الآفة .

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