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Temperature effects on the development, survival and reproductive potential of the Greenburg aphid, *Schizaphis graminum* (Rondani) (Homoptera: Aphididae)

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Abstract
Development, survival and reproductive potential of the greenbug aphid, *S. graminum* were studied at constant temperatures of 18°, 22° and 26 °C. At a given temperature, the developmental time decreased significantly with the increase in temperature. The longest period was recorded at 18 ºC and the shortest was at 26 ºC. The developmental threshold (t_0) estimated as 10.37 ºC and the aphids required 103.72 day-degrees (DD) to complete the development of the whole nymphal stage. Generation time (GT), reproductive potential (R_0), population doubling time (DT), intrinsic (r_m) and finite rate of increase (λ) of the pest were also computed and discussed. Based on the obtained data, temperatures ranged from 22° to 26° were the most suitable for the development and multiplication of the greenbug aphid.

Keywords: Greenbug, Development, Survival, Reproductive potential, Temperature

1. Introduction
The greenbug, *Schizaphis graminum* (Rondani), is one of the most important cereal aphid species that infest wheat plants in Egypt [1, 2, 3]. It causes severe damages to wheat plants in all growth stages. This species is able to cause direct and indirect damage [4]. Their direct damage is caused by sucking phloem sap result in curling, chlorosis, distortion of leaves and hence stunted growth [5]. The aphids inject toxic salivary enzymes into the plants, interferes with the grain formation and resulting in less yield and lower economic return [6, 7]. Also, transmit several important viruses, including barley yellow dwarf [8], sugarcane mosaic [9] and maize dwarf mosaic [10]. The effect of temperature on the life history of pest is important and can be used to predict an insect's period of occurrence and also to determine the optimal timing of control [11]. Therefore, the effect of constant temperatures on the development, survival, longevity and fecundity of the apterous form of *S. graminum* were studied.

2. Materials and Methods
Constant temperatures of 18º, 22º and 26 °C were used to study the development as well as the adult fecundity and longevity of *S. graminum*.

2.1. Rearing technique
The experimental colonies (apterous form) of *S.* graminum 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 experiments.

2.2. Effect of constant temperatures on the Nymphal stage
First instar nymphs (<10 hrs. old) were placed in a separate petri-dishes lined with damp tissue papers and supplied with leaves of wheat plants (Sids 1). Leaves were replaced whenever necessary (about two days). Sixty nymphs were placed individually and exposed to each of the above-mentioned constant temperatures. Nymphs in each temperature regime were observed daily. Moult, development and survival until the appearance of the aptera were observed and recorded.

2.3. Effect of constant temperature on the adult stage

To study the effect of temperature on the adult stage, nymphs were allowed to grow to reach maturity. Newly emerged apterous females (<24 hrs.) were individually exposed to temperatures of 18º, 22º and 26 ºC until began to produce progeny. Females were daily observed to record the number of progeny per adult.

2.4. Statistical analysis

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 (t_o) were calculated according to the method of [12] and the thermal units (TU) needed for the developments of each stage were calculated according to [13].

K (TU) = T (t-t_0), where,

K (TU) = Thermal units (day-degree), (T) = Duration (in days), (t) = Exposure temperature (°C), (t_0) = temperature threshold (°C).

Indices of Efficiency (IE) for development of the different stages of *S. graminum* were calculated according to the formula of [14]:

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

S, is the percentage of 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 parameters according to [15]. All calculations were executed using a QBASIC program according to [16]. Net reproductive rate (R0), Generation time (GT), Population doubling time (DT), Intrinsic rate of natural increase (r_m), and Finite rate of increase (λ)

3. Results

The greenbug, *S. graminum* produces as a rule by parthenogenetic reproduction all over the year. It passes through four nymphal instars in developing from birth to adult. The present results show the effect of temperatures on the developmental periods and survival of different nymphal instars as well as reproductive potential of the adult stage.

3.2. Nymphal stage

The durations of each nymphal instar at various constant temperatures are presented in (Table 1). The data exhibit that the time needed for the development of nymphal instars decreased significantly with the increase in temperatures. Statistical analysis showed that the longest time for development was recorded at the temperature of 18 ºC while the shortest period was noticed at 26 ºC. Regardless of temperatures, increase of temperature by 4 °C decreased developmental time by about 1.5 folds (Table 1). Data presented in (Table 2) indicate that the highest percentage of survival (%) and Index Efficiency values (IE) were obtained at 22º and 26 °C.

Data in (Table 1) were used to calculate regression equations, which were used in the estimation of threshold of development (t_0). The equations (Y = a + bx) for the relationship between the rate of development (Y) and temperature (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 (t_0) of 1st, 2nd, 3rd, and 4th nymphal instars were shown to be 9.21°, 9.52°, 7.08°, and 9.51 °C, respectively (Table 4). The calculated developmental threshold of the whole nymphal stage was estimated as 10.37 ºC. By using these values as a base temperature, an average of 32.89, 30.13, 31.36, and 24.81day-degrees were required, for the development of first, second, third and fourth nymphal instars, respectively. The thermal units (TU) needed for the development of the whole nymphal stage was 103.72 day-degrees (Table 4).

3.3. Adult stage

Data in (Table 5) show the effect of tested temperature on the longevity of the adult stage of *S. graminum*. Adult longevity was divided into pre-reproductive, reproductive and post-reproductive periods. Pre-reproductive period (the period between the adult moult and the onset of reproduction) ranged between 0.30±0.59 day at 26 ºC to 2.07±0.92 days at 18 ºC. The mean reproductive period was 10.09±2.62, 11.83±2.80 days and 10.95±3.04 days at 18, 22 and 26ºC, respectively. The post-reproductive period ranged from 0.28±0.62 day at 26ºC to 1.51± 1.29 days at 22°C. 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. The longest longevity of adult was recorded at 18 ºC and 22 ºC as 12.45 ±3.62 and 13.51±3.27 days, respectively with no significant differences. This duration decreased to 10.95± 3.04 days at 26 ºC, respectively.

The number of progeny per aptera reached 15.19±5.98, 54.95±19.05 and 44.16±15.09 nymphs / female at 18, 22 and 26ºC, respectively (Table 5). It is clear that the mean number of nymphs per aptera increased as temperature increased up to 22ºC, where the maximum number of nymphs / female (54.95±19.09 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 greenbug were: Generation time (GT), Population doubling time (DT), Net reproductive rate (R_0) and the intrinsic (r_m) and finite rates of increase (λ) (Table 6).

The duration of one generation of *S. graminum* lasted for about 24, and 13 days at 18 and (22º and 26ºC), respectively. The population of this pest had the capacity to double every 7.17, 2.49 and 2.56 days at 18º, 22º and 26 ºC, respectively. Net reproductive rate (R_0) at various constant temperatures indicated that the pest increased by 10.96, 40.33 and 31.64 times within a single generation at 18º, 22º and 26 ºC, respectively. The values of intrinsic rate of increase (r_m), which express the relationships between fecundity, generation time and survival, increased by increasing in temperature up to 22 °C. The values of r_m at 22º and/or 26 ºC (0.2775 and 0.2706, respectively) were approximately about two times higher than those of the pest at 18 ºC (0.0966). If r_m 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 to 26 °C is the optimum temperature, as it had the maximum r_m values. On the other hand, when the values of r_m were converted to the finite rate of increase (λ), it was shown that the population of *S. graminum* had an ability to multiply about 1.1014, 1.3198 and 1.3107 times per aptera per day at 18°, 22° and 26 ºC, respectively. This means that a population of ten aptera of the greenbug could increase in a period of one week to become 77.09, 92.39, and 91.75 individuals at 18°, 22° and 26 ºC, respectively.

4. Discussion

The results of this study indicated that temperature has a major effect on biology of *S. graminum*. The time needed for the development of nymphal stage decreased with increasing of temperature. This result is similar to that previously reported by [17] [18]. When the temperature was increased from 10 to 26 ºC, greenbug aphid development decreased significantly [19]. Also, [20] mentioned that the development of R. padi was faster with increased temperature. In general, optimum temperature for the development of greenbug ranges from 22 - 26 ºC within the tested range of temperature. This result similar to [21] who obtained that the best temperature for development of *S. graminum* reared on barely was at 26 ºC. Previous results in another aphid species were comparable to our results, [22] reported that the shortest developmental period of the cabbage aphid was at 24±2 ºC. While, [23] indicated that the most suitable temperature for development of R. padi was 28.5 ºC. The longevity of adult decreased by increasing temperature to 26º C, [19] revealed that Adult longevity decreased with increasing temperature from 10 to 26 ºC. The maximum number of nymphs / female was produced at 22ºC and 26 ºC. This result agree with [19] found that the mean total number of nymphs per female was highest at 26 ºC (66.14 ± 3.47) and lowest at 10 ºC (16.38 ± 0.60).

In our study, *S. graminum* has slightly higher developmental threshold (t_0) was about 10ºC and this in similar with [24]. In contrast, a considerably lower developmental threshold (1.7º C) for the cabbage aphid was obtained from Finland by [25]. These results are in agreement with those of [26] who stated that the developmental threshold of aphids originating from warm summer or mild spring climates should be higher than those from cooler climates. Aphids originate from Upper Egypt (Assiut area), with its typical climate of hot summer and warm winters, result in a slightly higher development thresholds than those obtained in the cooler climate. (t_0) values for R. maidis recorded as 6.84ºC according to [27]. The previously recorded (t_0) of R. padi were estimated as 4.4ºC on wheat, and 5ºC on barley, respectively [28]. [27], recorded the (t_0) values for R. padi as 5.78ºC. Previous and present results suggest that there is differences in t_0 values, may have been caused by the effect of host plant as well as aphid species and their geographical origin. The estimated (DDs) values in this study for whole nymphal stage was 103.72 day- degrees. These results go on line with those obtained by [29]. Also, our value was slightly higher than those obtained by [30]. [31] recorded that the thermal units needed for R. padi to complete its development were about 92.32 day-degrees using 8.89 ºC as base temperature (t_0). The lower developmental threshold for *S. graminum* reared on barley was as 5.73 ºC and required 133.33 day-degrees to complete immature life stages [21]. Developmental threshold and degree-day were reported 6.8 ºC and 109 degree-day by [32], which were lower and higher, respectively, than those obtained in this study. Within the tested range of temperature, it is clear that the mean number of nymphs per aptera increase as temperature increased up to 22 ºC. This result does not agree with [33] who found that the highest reproductive rate for *S. graminum* was at 17ºC. Also, [21] obtained that the mean total number of nymphs per female of *S. graminum* on barely was highest at 26 ºC.

The mean generation time and doubling time were significantly higher at the lowest temperature (18 ºC) and decreased by increasing the temperature from 18 to 26 ºC. This result comparable to [34] for Aphis gossypii on cucumber at 10 to 25 ºC and [19] for *S. graminum* on barley at 10 to 26 ºC. Highest net reproductive rate (R_0) as 40.33 was recorded at 22ºC then decreased to 10.96 and 31.64 at 18 and 26ºC, respectively. These results disagree with those recorded by [17] who reported that the highest R_0 value (35.09) for *S. graminum* at 24 ºC. On the contrary, this value was very low (0.19) for *S. graminum* on barley plants [18]. The highest R_0 value of R. padi was at 24 º and 28 ºC according to [20].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. *S. graminum* reared at 22 and 26ºC had the highest r_m-value, because of the faster development and higher survivorship of immature stages as well as the high daily rate of progeny. In contrast, the groups exposed to 18ºC had a prolonged developmental time, resulting in extremely smaller intrinsic rate of increase. [33], mentioned that the (r_m) per day and (λ) for *S. graminum* were greater as temperature increased. In all tested temperatures estimated intrinsic rate of increase was greater than for the same species reared on synthetic hexapolid wheat (0.01) [35]. [19] calculated that r_m values for *S. graminum* reared on barley were increased by increasing temperature and ranged from 0.06 at 10 ºC to 0.31 at 26 ºC, respectively and the highest λ values were observed at 26 ºC. (r_m) and (λ) values for R. padi were highest at 24°C and 28°C, respectively [20].

5. Conclusion

The present results showed that the nymphal stage of Scizaphis graminum (Rond.) passes through four instars to reach maturity. The lower developmental threshold (t_0) of its immature stages was found to be 10.37 ºC. The calculated thermal units needed for the development from birth to onset of reproduction were 103.72 day-degrees. This value could be used to estimate the number of theoretical of generations of the pest which could develop in a wheat growing season under Assiut conditions (Upper Egypt). Also, this information may be useful to establish monitoring and sampling plans in developing IPM programs.

Table 1: Duration (days ± SE) of *S. graminum* reared at different constant temperatures.

Temp. (°C)	**Duration (days) ± SE**				
	1st	2nd	3rd	4th	Total
18	4.28±0.67a	3.89±0.89a	3.40±0.78a	3.18±0.65a	14.53±1.61a
22	2.62±0.59b	2.09±0.70b	1.56±0.54b	1.74±0.48b	8.03±0.69b
26	1.64±0.52c	1.90±0.71b	1.78±0.54b	1.56±0.61b	6.84±0.81c

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 *S. graminum* reared at different constant temperatures.

Temp. (°C)	Survival (%) and Indices of Efficiency (IE)									
	1st		2nd		3rd		4th		Total	
	S	IE	S	IE	S	IE	S	IE	S	IE
18	95.00	22.19	98.92	23.90	94.34	27.74	90.00	28.30	75.00	5.16
22	98.33	37.53	93.22	44.60	96.36	61.77	96.23	55.30	85.00	10.58
26	95.00	57.93	98.24	51.70	92.86	52.17	96.15	61.63	83.33	12.18

Table 3: Linear regression equations expressing development of *S. graminum* reared at different constant temperatures.

Instars	Regression equations	(r)	(R)
1st	Y= -31.76+3.45x	0.99	0.98
2nd	Y = -31.99+3.36x	0.97	0.94
3rd	Y = -23.72+3.35x	0.98	0.96
4th	Y = -38.81+4.08x	0.97	0.94
Total nymph	Y = -9.96+0.96x	0.99	0.98

Regression equation = (Y= a + b X)
(r) = Correlation coefficient. (R) = Coefficient of determination

Table 4: Developmental thresholds (t_0) and thermal units (day-degrees) needed for the development of *S. graminum* eared at different constant temperatures.

Instars	Temperature thresholds (t_0)	Thermal units (TU)				
		Temperatures (ºC)			Total	Mean
		18º	22º	26º		
1st	9.21	37.62	33.51	27.54	98.67	32.89
2nd	9.52	32.99	26.08	31.31	90.38	30.13
3rd	7.08	37.13	23.27	33.68	94.08	31.36
4th	9.51	26.99	21.73	25.72	74.44	24.81
Nymphal stage	10.37	110.86	93.39	106.91	311.16	103.72

Table 5: Reproductive potential of *S. graminum* reared at different constant temperatures.

Temp. (°C)	Longevity (days ± SE) and fecundity (No progeny / female)				
	Longevity				Fecundity (♀/♀)
	Pre.-	Reproductive	Post.-	Total	
18	2.07±0.92a	10.09±2.62b	0.47±0.74b	12.45±3.62a	15.19±5.98c
22	0.31±0.63b	11.83±2.80a	1.51±1.29a	13.51±3.27a	54.95±19.05a
26	0.30±0.59b	10.95±3.04ab	0.28±0.62b	10.95±3.04b	44.16±15.09b

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

Table 6: Some life table parameters of *S. graminum* reared at different constant temperatures.

Temp. (°C)	(GT)	(DT)	(R_0)	Rate of increase	
				Intrinsic (r_m)	Finite (λ)
18	24.78	7.17	10.96	0.0966	1.1014
22	13.32	2.49	40.33	0.2775	1.3198
26	12.76	2.56	31.64	0.2706	1.3107

(GT) = Mean generation time, (DT) = Doubling time, (R_0) = net reproduction rate, (r_m) = intrinsic rate of increase, (λ) = finite rate of increase.

6. References

1. Abdel-Rahman MAA, Nasser MAK, Ali AM. Incidence of hymenopterous parasitoids attacking cereal aphids in wheat fields in Upper Egypt. Ass. J. Agric Sci, 2000; 31(2):317-328.
2. Hamouda SHH. Bionomic of the dominant cereal aphid species and natural enemies inhabiting wheat fields in Minia district, middle Egypt. Minia J. of Agric. Res. 2007; 27(5):1041-105.
3. Hashem HF. Studies on cereal aphids infesting wheat plants and their natural enemies at Assiut. M. Sc. Thesis, Fac. Sci., Assiut Univ., Egypt. 2013, 214
4. Yang XL, Thannhauser TW, Burrows M, Cox-Foster D, Gildow FE, Gray SM. Coupling genetics and proteomics to identify aphid proteins associated with vector-specific transmission of polerovirus (Luteoviridae). Journal of Virology. 2008; 82:291–299.
5. Gildow FE, Shah DA, Sackett WM, Butzler T, Nault BA, Fleischer SJ. Transmission efficiency of Cucumber mosaic virus by aphids associated with virus epidemics in snap bean. Virology. 2008; 98:1233–1241.
6. Stone B S, Shufran RA, Wilde GE. Life history study of multiple clones of insecticide resistant and susceptible greenbug *Schizaphis graminum* (Homoptera: Aphididae). Journal of Economic Entomology. 2000; 93(3):971–974.
7. Royer TA, Giles KL, Kindler SD, Elliott NC. Cereal aphid expert system and Glance 'n Go sampling for greenbugs: Questions and answers. CR-7191. Oklahoma Cooperative Extension Service, Stillwater, OK. 2004.
8. Rezvani A. Key to the aphids (Homoptera: Aphididae) in Iran. 1st ed. Tehran: Ministry of Jihad Agriculture. Agricultural Research, Education and Extensions Organization. 2001.
9. Ingram J, Summers E. Transmission of sugarcane mosaic

by the green bug (*Toxoptera graminum* Rond.). J Agr Res. 1938; 56:537–540.
10. Nault LR, Bradley RHE. Acquisition of maize dwarf mosaic virus by the greenbug, *Schizaphis graminum*. Ann Entomol Soc Am. 1969; 62:403–406.
11. Wu JJ, Liang F, Liang GQ. Research on relationship between growth rate and temperature of Bactrocera dorsalis (Hendel). Inspection and Quarantine of Science, 2003; 13:17–18.
12. Weinberg HL, Lange WH. Development rate and lower temperature threshold of the tomato pinworm. Environmental. Entomology, 1980; 9(2):245-246.
13. Madubunyi LC, Koehler CS. Effect of photoperiod and temperature in Hypera brunneipennis. Environmental Entomology, 1974; 3:1017-1021.
14. Khattat AR, Stewart RK. Development and survival of Lygus lineolaris exposed to different laboratory rearing conditions. Annals of Entomological Society. Amer., 1977; 70(2):274-278.
15. Birch LC. The intrinsic rate of natural increase of an insect population. Journal of Animal Ecology. 1948; 17(1):15-26.
16. Jervis MA, Copland MJW. The life cycle. In insect natural enemies. Chapman & Hall, 2-6 Boundary, London SE18HG, UK. 1996, 63-160
17. Abd El-Rahman MAA. Biological and ecological studies on cereal aphids and their control in Upper Egypt. M. Sc. Thesis, Fac. of Agric., Assiut Univ., Egypt. 1997, 231
18. El-Heneidy AH, Sobhy HM, Abd- El-Wahed SMN, Mikhail WZA. Biological aspects and life table analysis of cereal aphid species and their parasitoid, Aphidius colemani Viereck (Hymenoptera: Aphidiidae). Egyptian Journal of Biological Pest Control, 2004; 14(1):43-51.
19. Tofangsazi N, Kheradmand K, Shahrokhi S, Talebi AA. Temperature-dependent life history of *Schizaphis graminum* on barley. Bulletin of Insectology. 2010; 63(1):79-84,
20. Auad AM, Alves SO, Carvalho CA, Silva DM, Resende TT, Verissimo BA. The Impact of Temperature on biological aspects and life table of Rhopalosiphum padi (Hemiptera: Aphididae) Fed with Signal Grass. Florida Entomologist. 2009; 92(4):569-577.
21. Tofangsazi N, Kheradmand K, Shahrokhi S, Talebi AA. Effect of different constant temperatures on biology of *Schizaphis graminum* (Rondani) (Hemiptera: aphididae) on barley, Hordeum vulgare L. (poaceae) in iran. Journal of plant protection research 2012; 52(3):320-223.
22. Satar S, Kerstng U, Ulusoy MR. Temperature dependent life history traits of Brevicoryne brassicae (L.) (Hom. Aphididae) on white cabbage. Turkish Journal of Agriculture and Forestry. 2005; 29(5):341-346.
23. Asin, L, Pons X. Effect of High Temperature on the Growth and Reproduction of Corn Aphids (Homoptera: Aphididae) and Implications for Their Population Dynamics on the Northeastern Iberian Peninsula. Environmental Entomology. 2001; 30(6):1127-1134.
24. Salman AMA. The relationship between temperature and rate of development of the cabbage aphid, Brevicoryne brassicae (Linnaeus) (Homoptera: Aphididae) Annals of Agricultural Science, Cairo Univ. 2006; 51(1):271-281.
25. Markkula M. Biologisch-.kologische Untersuchungen. ber die Kohlblattlaus, Brevicoryne brassicae (L.) (Hem. Aphididae). Siiomal el. in-ja kasvit. Seur. van. kasvit. Julk. 1953; 15:1-113.
26. Campbell A, Frazer BD, Gilbert N, Gutierrez AP, Mackauer M. Temperature requirements of some aphids and their parasitoids. Journal of Applied Entomology. 1974; 11(2):431-438.
27. El-Sheikh MAK, Elnagar S, El-Hariry MA, El-Fatih MM. Life Table parameters and heat units for the corn leaf aphid, Rhopalosiphum maidis (Fitch), reared on barely host plant.4 th Conference on Recent Technologies in Agriculture, 2009, 101-109
28. Abdalla DA. Biological and ecological studies on the parasitoid Aphidius matricariae Hal. (Hymenoptera: Aphidiidae). Parasitizing the cereal aphid. M. Sc. Thesis, Fac. of Agric., Cairo Univ., Egypt. 2002; 134
29. Elliot NC, Kieckhefer RW. Effects of constant and fluctuating temperatures on immature development and age-specific life tables of Rhopslaosiphum padi (L.) (Homoptera: Aphididae). Canadian Entomologist. 1989; 21(2):131-140.
30. Walgenbach DD, Elliott NC, Kieckhefer RW. Constant and fluctuating temperature effects on developmental rates and life table statistics of greenbug (Homoptera: Aphididae). Journal of Economic Entomology,1988; 81(2):501-507.
31. Abdel-Rahman MAA, Ali AM, Ali AG. Reproductive potential of the oat bird-cherry aphid, Rhopalosiphum padi L. (Homoptera: Aphididae) at constant temperature. 2nd International Conference, Plant Protection Research Insitiute, Cairo, Egypt, 2002; 21-24
32. Lee JH, Kim TH, Kim JS, Hwangn YC, Lee SG. Temperature-dependent development and its model of greenbug, *Schizaphis graminum* (Rondani) (Homoptera: Aphididae). Korean Journal of Applied Entomology, 2007; 46(2):213-219.
33. El-Gantiry AM, Abou-Setta MM, Moussa SFM. Certain biological studies on Aphis craccivora and *Schizaphis graminum* (Homoptera: Aphididae) under different constant temperatures. J. Egypt. Ger. Soc. Zool. 1999; 30:123-132.
34. Zamani AA, Talebi AA, Fathipour Y, Baniameri V. Effect of temperature on biology and population growth parameters of Aphis gossypii Glover (Hom., Aphididae) on greenhouse cucumber. Journal of Applied Entomology, 2006; 130(8):453-460.
35. Lage J, Skovmand B, Anderson SB. Characterization of Greenbug (Homoptera: Aphididae) Resistance in Synthetic Hexaploid Wheats. Journal of Economic Entomology, 2003; 96(6):1922-1928.