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Effect of temperature on egg development and life table of *Chrotogonus homalodemus* (Blanchard, 1836) (Orthoptera: Pyrgomorphidae)

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ABSTRACT
Construction of a life table is a simple method for keeping track of births, deaths and reproduction for insect life tables, parameters are basically calculated by recording death and births within a population on a daily basis from the time that the first egg of an insect is born to the time that all of the insects regardless of their development die. *Chrotogonus homalodemus* is a grasshopper pest of seedlings in north and east Africa and in south Asia. This study indicated that the effect of constant temperature on the egg hatchability of *C. homalodemus* resulted in threshold temperature 15^0C. Life table of *C. homalodemus* was conducted and analyzed in outdoor conditions. The data also revealed that adult males metamorphosed from the sixth instar while some of adult females metamorphosed from seventh instar. Second and fourth developmental instars of *C. homalodemus* of the 1st generation and first, second and fourth instars of the 2nd generation may be the best target for the application of control measures.
Key words: Egg development, Life table, Pyrgomorphidae, Temperature.

INTRODUCTION

Chrotogonus homalodemus = *Chrotogonus lugubris* (Orthoptera: Pyrgomorphidae) is one of the common grasshoppers in Egypt. It is widely distributed in north and east Africa and in south Asia (Mestre and Chiffaud, 2006). Both nymphs and adults are considered as pests occurring throughout the year causing significant damage to seedling plants that are very important in Egypt as clover, cotton, wheat and bean (Abdel Rahman, 2001).

Although chemical pesticides have brought spectacular revolution of grasshopper control, however, concern about their negative impact on the environment caused them to be prohibited in most countries (Meena and Singh, 2014).

Insect survival and reproduction are dependent on biotic and abiotic environmental factors. Weather, food quality and quantity, soil type, predation and diseases are acknowledged as factors that may regulate grasshopper population dynamics (Schell, 1994).

Temperature is the most important abiotic factor affecting insects as it influences many physiological processes such as metabolism, digestion and also behaviour and development (Heinrich, 1993). Changes in temperature may have impacts on insects at both individual and population level (Nardoni and Belvosky, 2010). Also, it affects insect developmental processes including incubation period. Understanding the relationship between temperature and life history of the insect from egg to adult is needed for the development of reliable pest population prediction system and management strategies.

The present work aims to give information about the egg threshold temperature as well as the life table of *C. homalodemus* under outdoor conditions that may facilitate the control of this economically important insect species.

MATERIALS AND METHODS

Insect rearing

Adults and nymphs of *C. homalodemus* were hand collected from El-Mansouria and Abou-Rawash areas in Giza Governorate, Egypt. They were reared in Entomology Department, Faculty of Science, Cairo University in outdoor breeding cages (40x40x50 cm) with their sides made of wire screen. Cages were provided daily with suitable ovipositional containers (10 cm deep) filled with sieved and sterilized sand which were always kept moist. The stock culture was maintained on clover (*Trifolium alexandrinum*) from November to June and then on garden purslain (*Portulaca oleracea*) (Abdel Rahman, 2001).

Detection of the threshold temperature, mean incubation period, percentage hatchability and daily percentage rate of development of *C. Homalodemus* eggs

To detect the effect of different temperatures on the incubation period of *C. Homalodemus* eggs, a total of 150 freshly deposited eggs from different egg pods, were incubated at various constant temperatures: 25, 27, 30, 32, 35 , 37 and 42^0C all the time till hatching (3 replicates each of 50 eggs). The mean incubation period, percentage hatchability, the daily percentage rate of development and threshold temperature were recorded and analyzed by using Graphpad instat program.

Detection of the effect of outdoor temperature on the life table of *C. homalodemus*

To detect the effect of temperature on the survivorship of two successive generations of *C. homalodemus* under outdoor conditions, a total of 900 freshly deposited eggs from 55 egg pods (3 replicates each of 300 eggs) were taken randomly for sample survey. Daily maximum and

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minimum temperature and the duration of egg stage and each instar were recorded till adult emergence and mortality of the adult. In each cage, dead nymphs were counted and the nymphal mortality rate of respective instars was calculated.

Also the daily number of dead adults was recorded. Since all the nymphs in a cage were in the same age, it was expected that molting should occur on the same day, but in practice it was found that there was 1-3 days of deviation in molting from the 1^{st} instar to the 2^{nd} and from 2^{nd} to the 3^{rd} and so on up to the 7^{th} instar. To avoid error, newly emerged 2^{nd} instar (0 day old, 2^{nd} instar) were collected and transferred to be reared in a separate cage and the same procedure took place for the latter instars.

The same procedure was repeated for the 2^{nd} generation of *C. homalodemus*.

Variables were used according to Dash (1993) for detecting of *C. Homalodemus* life table:

- Age by instars (**x**)
- Number of individuals out of the cohort, who are expected to complete exactly X days of life (**I_x**)
- Number of individuals out of Ix who die before completing age x +1(**d_x**)
- Survival rate (proportion of individuals of age X surviving to age x) +1(**s_x**)
- Mortality rate (proportion of individuals of age X surviving to age x +1) (**m_x**)
- Number of individuals alive between ages x and x+1 (**L_x**)
- Total number of days lived by the cohort after age x days. In fact, this is the total future life time of the Ix individuals (until all of them die off) (**T_x**)
- Mortality rate for an age interval (**q_x**)
- Expectation of further life of individuals of age x (**e_x**)
- $\log_e$sx, the exponential mortality rate between age x and x+1 (**k_x**).

RESULTS

Threshold temperature, incubation period, percentage hatchability and daily percentage rate of development of *C. Homalodemus* eggs

From table (1) it is evident that the incubation period of *C. homalodemus* decreased significantly ($p<0.05$) with increasing temperature from 25 to 42^{0}C (35.46 to 11.61 days). The hatching percent of *C. homalodemus* eggs gradually increased by increasing the temperature from 25 to 35 ^{0}C reaching a maximum of 71.33% at 32 ^{0}C. By further increase of the temperature to 42 ^{0}C, it decreased again reaching 39.00% (table 1). Percentage development per day of egg *C. homalodemus* increased significantly by increasing temperature to reach its maximum (8.61) at 42^{0}C.

By plotting daily percentage rate of egg development against their respective temperature resulted in a representation at which the intersection of the straight part with the X- axis showed the hybothetical threshold temperature of *C. homalodemus* eggs development which is 15 ^{0}C (Fig. 1).

Table (1): Threshold temperature, incubation period, percentage hatchability and daily percentage rate of development of *C. homalodemus* eggs.

Temperature (^{0}C)	Incubation period (days)±SD (range)	% Hatchability	development per day
25	**35.46±0.15 a (33-39)**	**51.30**	**2.82**
27	**29.15±0.15 b (27-33)**	**55.32**	**3.43**
30	**22.23±0.13 c (20-25)**	**69.33**	**4.49**
32	**20.30±0.13 d (18-23)**	**71.33**	**4.92**
35	**17.22±0.12 e (15-20)**	**70.00**	**5.80**
40	**16.01±0.12 f (14-18)**	**39.3**	**6.84**
42	**14.61±0.10 g (12-16)**	**39.00**	**8.61**

Means followed by the same letter in the same column are not significantly different (P> 0.05).

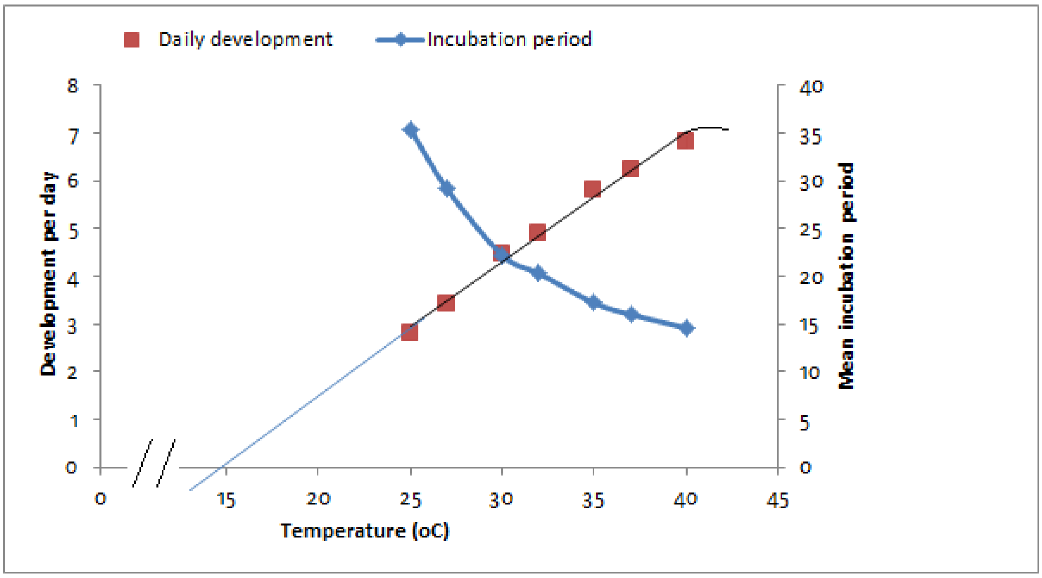

Figure (1): Rate of development and mean incubation period under constant temperature of *C. Homalodemus*e ggs.

Mortality rate of the egg and nymphal stages

From tables 2 and 3 it is clear that the observed mortality rate of the egg and nymphal stages of *C. homalodemus* was of the same trend during the two successive generations and a highest mortality occurred during the egg stage as well as during the 2nd and 4thnymphal instars in case of the 1st generation and during the 1st, 2nd and 4th instarsin case of the 2nd generation. Starting with 300 eggs in each generation, 142 adults (75 males and 67 females) and 101 adults (59 males and 42 females) are produced. 16% and 12% of the females passed through an extra instar (7th one) for -the 1st and 2nd generations respectively in which the 7th instar takes nearly the same time of 6th instar (i.e the total nymphal duration that produced both males and females nearly the same). No mortality was observed during the 6th and 7thnymphal instars.

The data also revealed that, second and fourth instars of the 1st generation have high mortality percents (10.57, 15.11%), while first, second and fourth instars of the 2nd generation have high mortality percents (17.11, 19.35 and 11.96%) respectively. So, it is clear that first, second and fourth instars may be critical for the application of control measures (Tables 2 and 3).

Table (2): Representation of mortality rate in different instars of *C. Homalodemus* under outdoor conditions (Generation 1).

Stage	I_x	d_x	d_x as % of I_x
Egg	300	74	24.66
1st instar	226	18	7.96
2nd instar	208	22	10.57
3rd instar	186	14	7.52
4th instar	172	26	15.11
5th instar	146	4	2.73
6th instar	142	0	0.00
7th instar	12	0	0.00

Table (3): Representation of mortality rate in different instarsof*C.homalodemus* under outdoor conditions (Generation 2)**.**

Stage	I_x	d_x	d_x as % of I_x
Egg	300	113	37.66
1st instar	187	32	17.11
2nd instar	155	30	19.35
3rd instar	125	8	6.40
4th instar	117	14	11.96
5th instar	103	2	1.94
6th instar	101	0	0.00
7th instar	9	0	0.00

Life table:

The number of adult males and females of *C. homalodemus* that are capable of reaching an age of more than 10 days and their life expectation (e_x) at different ages during the two successive generations at different ages are shown in tables 4, 5, 6 and 7. From these tables, it is clear that newly emerged individuals could be expected to survive 9.26 and 6.48 days (for males) and 7.80 and 5.92 (for females) for generations 1 and 2 respecively.

Table (4): Life table of adult males of *C. homalodemus* under outdoor conditions (Generation 1)

X(days)	I_x	d_x	s_x	m_x	L_x	T_x	$67q_x$	e_x	kx
0	67	0	1.00	0.00	67	620.5	0.00	9.26	0.000
10	67	0	1.00	0.00	67	553.5	0.00	8.26	0.000
20	67	1	0.98	0.02	66.5	486.5	1.34	7.31	0.008
30	66	0	1.00	0.00	66	420	0.00	6.36	0.000
40	66	2	0.96	0.04	65	354	2.68	5.44	0.017
50	64	3	0.95	0.05	62.5	289	3.35	4.62	0.022
60	61	5	0.91	0.09	58.5	226.5	6.03	3.87	0.040
70	56	7	0.87	0.13	52.5	168	8.71	3.20	0.060
80	49	8	0.83	0.17	45	115.5	11.39	2.56	0.080
90	41	11	0.73	0.27	35.5	70.5	18.09	1.98	0.136
100	30	13	0.56	0.44	23.5	35	29.48	1.48	0.251
110	17	14	0.17	0.83	10	11.5	55.61	1.15	0.769
120	3	3	0.00	1.00	1.5	1.5	67	1.00	-

Table (5): Life table of adult females of *C. Homalodemus* under outdoor conditions (Generation 1).

X(days)	I_x	d_x	s_x	m_x	L_x	T_x	$75q_x$	e_x	k_x
0	75	0	1.00	0.00	75	585.5	0.00	7.80	0.000
10	75	0	1.00	0.00	75	510.5	0.00	6.80	0.000
20	75	3	0.96	0.04	73.5	435.5	3	5.92	0.017
30	72	4	0.94	0.06	70	362	4.5	5.17	0.026
40	68	6	0.91	0.09	65	292	6.75	4.49	0.040
50	62	5	0.91	0.09	59.5	227	6.75	3.81	0.040
60	57	8	0.85	0.15	53	167.5	11.25	3.16	0.070
70	49	9	0.81	0.19	44.5	114.5	14.25	2.57	0.091
80	40	10	0.75	0.25	35	70	18.75	2.00	0.124
90	30	12	0.60	0.40	24	35	30	1.45	0.221
100	18	16	0.11	0.89	10	11	66.75	1.10	0.958
110	2	2	0	1.00	1	1	75	1.00	-

Table (6): Life table of adult males of *C. Homalodemus* under outdoor conditions (Generation 2).

X(days)	I_x	d_x	s_x	m_x	L_x	T_x	$59q_x$	e_x	k_x
0	59	0	1.00	0.00	59	382.5	0.00	6.48	0
10	59	0	1.00	0.00	59	323.5	0.00	5.48	0
20	59	0	1.00	0.00	59	264.5	0.00	4.48	0
30	59	6	0.89	0.11	56	205.5	6.49	3.66	0.050
40	53	6	0.88	0.12	50	149.5	7.08	2.99	0.055
50	47	7	0.85	0.15	43.5	99.5	8.85	2.28	0.070
60	40	9	0.77	0.23	35.5	56	13.57	1.57	0.113
70	31	26	0.16	0.84	18	20.5	49.56	1.13	0.795
80	5	5	0	1.00	2.5	2.5	59	0.5	-

Table (7): Life table of adult females of *C. homalodemus* under outdoor conditions (Generation 2).

X(days)	I_x	d_x	s_x	m_x	L_x	T_x	$42q_x$	e_x	k_x
0	42	0	1.00	0.00	42	249	0.00	5.92	0.000
10	42	1	0.97	0.03	41.5	207	1.26	4.98	0.013
20	41	1	0.97	0.03	40.5	165.5	1.26	4.08	0.013
30	40	4	0.90	0.10	38	125	4.2	3.28	0.045
40	36	6	0.83	0.17	33	87	7.14	2.63	0.080
50	30	6	0.80	0.20	27	54	8.40	2.00	0.096
60	24	9	0.62	0.38	19.5	27	15.96	1.38	0.207
70	15	15	0	1.00	7.5	7.5	42	1.00	-

From the above mentioned data concerning the life table of egg, nymphal and adult stages of *C. homalodemus* under outdoor condition, it can be concluded that:

Generation 1 (from February to Septemper)

The mortality rate of immature individuals hatching from 300 eggs increased from February to May where the average temperature were about 25^{0}C. The emerging adult (♂and♀) showed a gradual increase in mortality rate from June to September at average temperature of 32^{0}C.

It is important to note that 16% of the produced (♂ and ♀) passed through an extra instar (7th instar). It can be concluded that during generation 1, the egg stage lasted about 25 days, Nymphal stages about 100 days whereas the adults lived for about 110 days. i.e. The whole 1st generation took about 230 days till all adults died (Figures 3 and 4).

Generation 2 (from July to January):

The mortality rate of immature individuals hatched from 300 eggs increased from August to October where the average temperature was about 29^{0}C. The emerging adult (♂and♀) showed a gradual increase in mortality rate from October to January at average temperature of 17^{0}C. It is important to note that 12% of the produced (♂ and ♀) passed through an extra nymphal instar (7th instar). It can be concluded that during the 2nd generation, the egg stage lasted about 18 days, Nymphal stage about 75 days whereas the adults lived for about 85 days. i.e. The whole 2nd generation took about 180 days till all adults died (Figures 5 and 6).

Survivorship Curves

The convex survivorship curve of adults males and females of generation 1 and 2 indicates a low mortality rate of these adults until near the end of their life span (Figure 2).

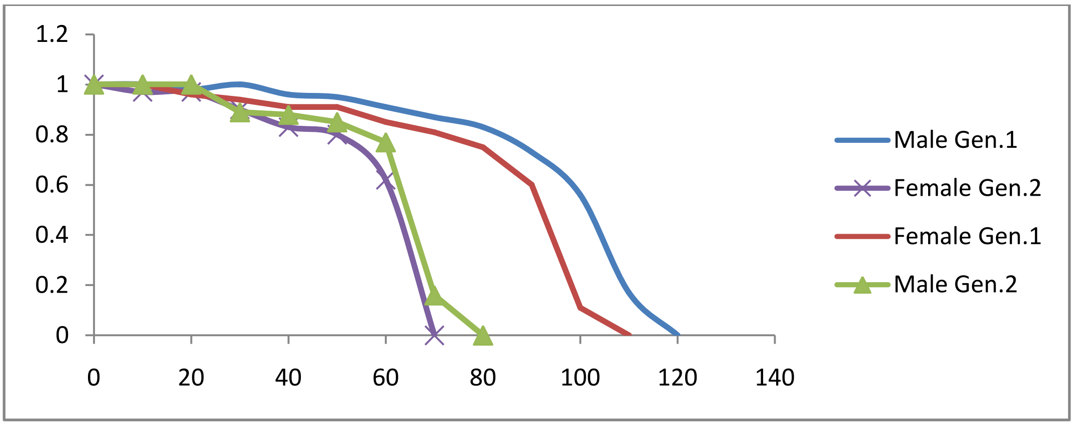

Figure (2): Survivorship curves of males and females of the first and second generations of *C. homalodemus*:

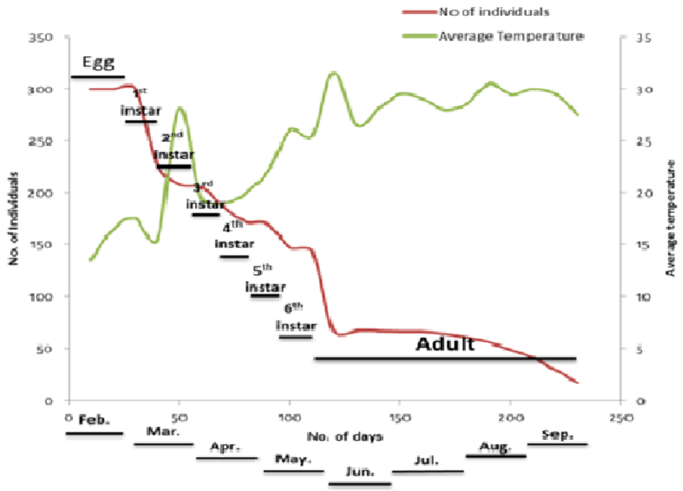

Figure (3): Life table and temperature curves of male C. Homalodemus (Generation 1).

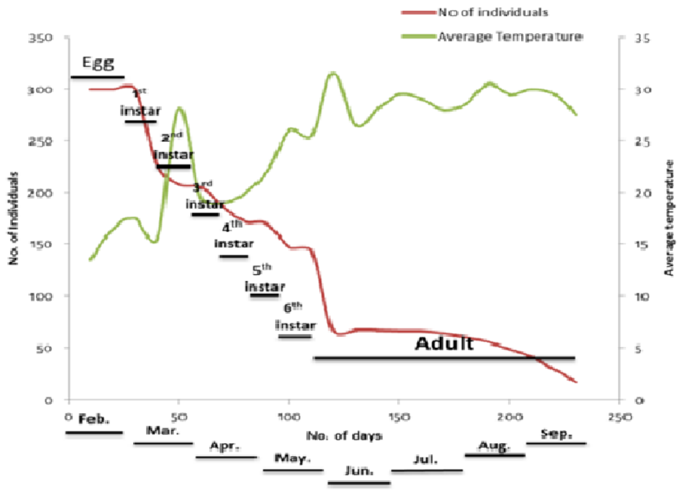

Figure (4): Life table and temperature turves of female *C. homalodemus*(Generation 1).

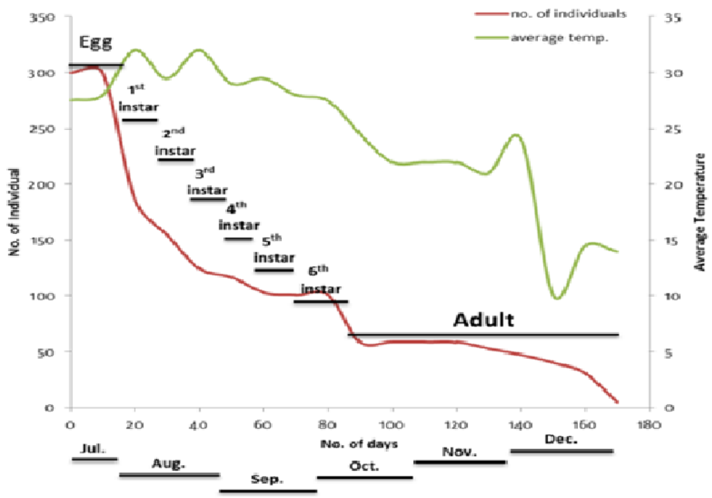

Figure (5): Life table and temperature curves of male *C. homalodemus* (Generation 2).

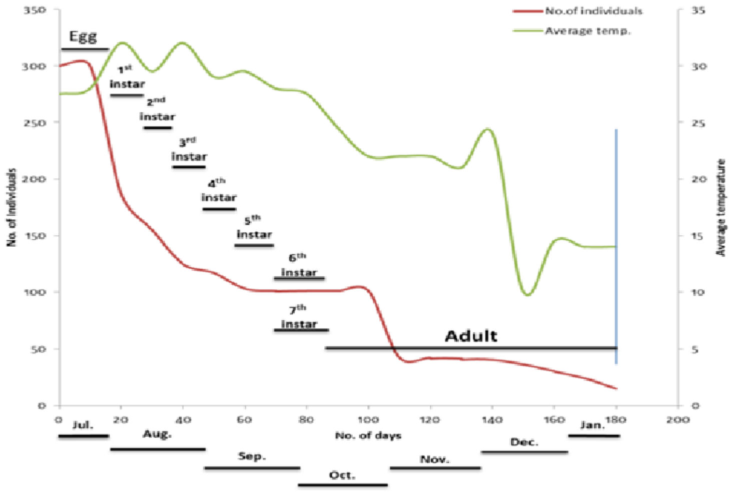

Figure (6): Life table and temperature curves of female *C. homalodemus* (Generation 2).

DISCUSSION

Temperature is one of the most important abiotic factor affecting insects rate of development per time and survivorship. All physiological processes require energy obtained from temperature dependent chemical reactions that are restricted by lower and upper threshold (Akman and Gulel, 2002). The egg incubation period of *C. homalodemus* varied from 11 to 35 days at different temperatures which was shortest at 37± 1^0C and 42± 1^0C. This might be due to enhanced metabolic activity with increasing temperature as in different grasshopper species. Similar results were found by Ibrahim (1972) and Abdel Rahman (1995) for *Chrotogonus lugubris*, Parihar and Pal (1978) for *Chrotogonus trachypterus trachypterus*, Grewal and Atwal (1968) for *Chrotogonus trachypterus*, Hamilton (1950), Elminiawi (1964) and Jones (1970) for *Schistocerca gregaria,* Hafez and Ibrahim (1958, 1962) for *Acrida pellucida* and *Aiolopus thalassinus*, Soliman (1968) for *Euprepocnemis plorans*, Wardhaugh (1970) for *Chortoicetes terminifera*, Bassal and Sallam (1986) for *Aiolopus thalassinus*, El- Shazly (1991) for *Heteracris littoralis*, Elder (1991) for *Nomadacris guttulosa* and *Locusta migratoria* and Das *et al*. (2012) for *Oxya hyla hyla*. In general, according to Das *et al.* (2012) a short egg incubation period might lead to early adult stage. Therefore, more life cycles might be completed in a year and more acridid biomass will be obtained. This may explain the presence of more than one generation/ year of *C. homalodemus*.

In the present work, the most favorable temperature of *C. Homalodemus* eggs was 32±1^0C as the percentage hatchability was maximum (71.33%) and the optimum temperature zone was (30 – 35^0C). According to Das *et al.* (2012), metabolic rate are directly influenced by temperature. Temperature increases up to 35±1^0C favoured the hatchability of *C. homalodemus* eggs that might be due to enhanced metabolic activity with temperature increase.

At the same time the observed decreased of egg hatchability at 37±1^0C and 40±1^0C may be due to hampered of normal metabolic activity. Hao and Kang (2004) found that maximum hatchability of *Omocestus haemorrhoidalis* was 91.17% at 23.7^0C and the optimum temperature range was (12.2 – 35.2^0C). For *Calliptamus abbreviates* was 75.67% at 29^0C and the optimum temperature range was (21.7 – 36.3^0C) and *Chorthippus fallax* was 94.07% at 31.3^0C and the optimum temperature range was (20.9 – 41.7^0C). Threshold temperature differs with different grasshopper species.

In the present work, threshold temperature of *C. Homalodemuse* ggs was 15^0C and that of *Chrotogonus lugubris* was 17.8^0C (AbdelRahman, 1995)*, Schistocerc agregaria* was 15.1^0C (Jones, 1964), 90^0C (Eylem et al, 2001), *Aulocara elliotti*was 16.30^0C (Kemp and Dennis, 1989)*, Melanoplus bivittatus* was 12^0C (Church and Salt, 1952), *Aiolopus thalassinus*was 19.2^0C (Bassal and sallam, 1986), *Nomadacris guttulosa* and *Locusta migratoria* were 19.8^0C (Elder, 1991),*Melanoplus sanguinipes* was 10^0C (Olfert and Erlandson, 1991) and Hao and Kang (2004) found that there was 9.9^0C of*O. haemorrhoidalis*, 10.9^0C of *C. abbreviates* and 10.5^0C of *Ch. fallax*.

Nymphal mortality of insects in general has an important role on population size, structure and dynamics. In case of *C. homalodemus* the obtained average nymphal developmental period of generation 1 was about 100 day which seems longer than that of generation 2 that takes about 75 days that is may be due to lower average temperature during the 1st generation than that during the 2nd generation. In generation 1, nymphal instars started in February reaching adult stage in May, while in case of generation 2, nymphal instars begin in July reaching adult stage in October. Average nymphal developmental time varies from species to species in grasshoppers, as in case of *S. Gregaria* it was 32 and 22 days at 25 and 30^0C respectively (Akman and Gulel, 2002), while Whitman (1986) stated that *Taeniopoda eques* requires 60 and 35 days at 25 and 30^0C respectively from the 1stnymphal instar to the Adult stage. *Aiolopus longicornis* also show varying number of instars that may result in generations with different population growth rates and migratory ability (Habtewold *et al.*, 1995).

In case of *C. homalodemus* adults, males and females reached adult stage after 6 nymphal instars while about 16% and 12% of females passed through an extra nymphal instars according to generation 1 and 2 respectively. Ibrahim (1972) stated that the nymphal stages of *Chrotogonus lugubris* are commonly six; an extra-moult occurs in about 25% of females. while in the desert locust, gregaria develops faster than solitaria partly because many solitary individuals pass through 6 instars instead of 5 (Cheke, 1978) also *A. Longicornis* may occur in phases as the locusts do (varied from 4 to 6 instars) (Habtewold *et al*., 1995). For each species, the frequency with which an additional instar was inserted during nymphal development increased with temperature (Willott and Hasal, 1998).

In many species of grasshoppers with notable sexual size dimorphism, the larger female has one instar more than male (Nath and Rai, 2010). Also it is obvious that from the present work of *C. homalodemus* that the adults of the 1^{st} generation takes about 110 days at nearly average temperature of 30^{0}C while those of the 2^{nd} generation takes about 85 days at nearly average temperature of 20^{0}C.

That is may be because a drop in average temperature during the 2^{nd} generation occurs due to drastic condition in December as the average temperature reaches 10^{0}C these results in high mortality in the population. Das *et al.* (2012) stated that, extreme high and may be extreme low temperature were not favourable for the survival of *Oxya hyla hyla* and the optimum temperature regime of its survival was from 25 ± 2^{0}C to 35 ± 2^{0}C. Giberson and Rosenberg (1992) found a similar trend of results for Ephemeropteran insects. Also, on the studied of *Locusta sp*. and *Schistocerca gregaria*, Uvarov (1966) reported similar observations.

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