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Fertility Table and Thermal Requirements for the Development of *Callosobruchus maculatus* (F) Reared on Different Legume Seeds

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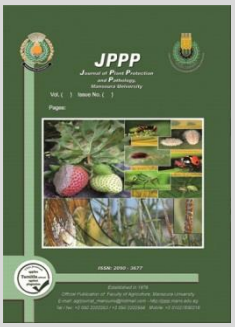

ABSTRACT

This research aimed to evaluate the effect of different constant temperatures and host grain species (cowpea, chickpea, and horse bean) on fertility table parameters, the developmental stages duration, and accumulated thermal units required for development of *Callosobruchus maculatus*. Data arranged in fertility tables indicated that the intrinsic rate of increase (r_m) of *C. maculatus* reared on cowpea was higher (0.062, 0.109 and 0.126) than those reared on chickpea (0.061, 0.046, and 0.112) or horse bean (0.062, 0.076 and 0.084 females/female/day) at 25, 30 and 35ºC, respectively. There was an inverse relationship between the generation time and temperature degrees, *C. maculatus* reared on cowpea exhibited the shortest duration of generation in comparison with those reared on chickpea or horse bean at 25, 30 and 35ºC, respectively. The eggs produced from *C. maculatus* females raised on cowpea significantly hatched early compared to females raised on chickpea or horse bean and chickpea. With respect to larval and pupal stages, as well as pre-oviposition period, the cowpea followed by chickpea was suitable for the development of larval and pupal stages in comparison with horse bean at all temperature degrees. The average accumulated thermal units required for development of eggs deposited by females raised on cowpea, chickpea, and horse bean was 82.87, 104.10 and 101.45 degree-days, respectively. While, thermal units required for larval-pupal, pre-oviposition period, and completion one generation raised on cowpea, chickpea, and horse bean was (304.88, 436.65, and 452.58DDs), (4.34, 5.64, and 8.15 DDS) and (385.91, 524.68, and555.82DDS), respectively.

Keywords: Fertility table, thermal requirements, *Callosobruchus maculatus*.

INTRODUCTION

Legume grains are considered the most important grains used as human food and animal feed in Egypt. The importance of legume grains as food is well known. Such importance is due to their high protein content, which reaches 20.25% in most dry legumes. This is characterized as a complete protein compared with those of other grains. The legume crops include several species, including cowpea (*Vigna unguiculata* L.), navy bean (*Phaseolus vulgaris*. L), soybean (*Glycine max* L.), horse bean (*Vicia faba* L.), and chickpeas (*Cicer arietinum*. L) that are a source of protein and food for many people (Singh et al., 2013, and El-Ghamery et al., 2021). According to (FAO 2012) approximately 870 million human beings withinside the globe is undernourished because of insufficient consumption of proteins, vitamins, and minerals in their diets. Stored grain infestation with insects causes economic damage and deteriorates the quality of food grains and food products (Trivedi et al., 2018). *Callosobruchus maculatus* is considered the most important pest attacking several legumes stored grains (Magagula and Maina, 2012; Uddin and Adesiyun, 2012 and Osman et al., 2015). *C. maculatus* can cause a potential loss in legumes ranging from 12 to 30% (FAO, 1994), The chrysomelid beetles, *C. maculatus*, females showed different degrees of egg-laying preference on the legume grains (Swella & Mushobozy, 2009 and Abd E-l Kareim et al., 2023). For the success of integrated pest management control, the intrinsic rate of natural increase (r_m) is an important parameter in inductive strategic and management for insect pest populations (Abd E-l Kareim et al., 2010 and 2018). Thermal conditions are the key environmental element that has profound and complex consequences on ecological and biological processes of *C. maculatus* (Ouedraogo et al., 1996; Huey& Berrigan, 2001; and Anandamay,2012). In recent years, a lot of interest has been received in heat treatments as a means of disinfecting storage products, and this method is expected to continue to reduce insecticide usage (Mahroof et al., 2003; Roesli et al., 2003). Information concerning fertility table parameter and thermal units required for development of insects could be useful to predict how fast the population could develop and give an idea of its population size on the different host plant (Abd El-l Kareim et al., 2010). Therefore, the present work aims to focus on some biological information for *C. maculatus* reared on some legume seeds at different temperature degrees by constructing life and fertility tables, and to estimate its thermal units in degree-days (DDs) required for the development to be used through forecasting system to establish an IPM program.

MATERIALS AND METHODS

The present investigation was carried out in the laboratory of Economic Entomology Department, Faculty of Agriculture, Mansoura University, Mansoura, Egypt.

1.Insect and seed legume sources:

laboratory cultures of *Callosobruchus maculatus* (F.) (Coleoptera: chrysomelidae) were established from the naturally infected cowpea seeds and reared separately on cowpea, *Vigna unguiculata*; chickpea, *Cicer arietinum*; and horse been, *Vicia faba* for several generations (within 2021) in an incubator maintained at 30 ± 2 ºC to become a homogenous

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strain. The legume seeds of each species used in the bioassays were purchased from grocery stores in Mansoura, Egypt.

2. Estimate the effect of different temperatures and legume seed species on fertility table parameters of *C. maculatus*.

To study the fecundity table of cowpea beetle on the legume seeds (cowpea, chickpea, and horse bean) under constant temperatures (25± 2, 30± 2, and 35± 2 ºC), an initial population of *C. maculatus* was started as 100 eggs/ grain species for each temperature degree. Eggs were placed in glass vials (10 eggs/vial) by using a lens with 10X magnification. The daily numbers of dead eggs were recorded, and the incubation periods were calculated. Then, the resulting larvae inside the seeds were investigated daily until adult emergence and the number of emerged adults was recorded. To construct age–specific fertility table of cowpea beetle, a sample of thirty pairs (male and female) of the newly emerged adults were used for each host seed (ten pair/ temperature degree). Each pair was confined with four seeds of the host in a glass test tube for oviposition. The daily number of eggs that were laid for each female was recorded with the change of the seeds and soon until the death of the adults.

Age-specific fertility table constructed with the following:

x: Actual female age (time from egg stage).

m_x: The number of females born per female at each age (sex ratio 1:1).

L_x: Represents the fraction surviving of females of an initial population of one.

The parameters, net reproductive rate (Ro), mean generation time (T) and the intrinsic rate of increase (r_m) were calculated according to Southwood (1978) as follow:

$R_o = \sum L_x m_x$, $T = \sum x (Lx\ mx) / Ro$ and $r_m = In\ (Ro)/T$.

3. Estimate the thermal units required for development of *C. maculatus*:

Mated females (2-day old) that emerged from a fresh culture were used for egg-laying on different legume seeds. Eggs laid on cowpea, horse bean, and chickpea on the same day were placed in glass vials, and ten replicates of (10 eggs/vial) were used for each tested temperature degree (25, 30, and 35 ºC). Observations were made daily to record the time of hatchability. All the *C. maculatus* stages were kept under three constant temperatures to determine the rate of development. The tubes were checked daily until adult emergence. According to (Campbell *et al*., 1974), the relationship between temperatures and the average rate of development for each stage and generation under the tested temperature was determined using linear regression. The minimum growth threshold (T_0) was determined. The thermal units (degree- days) required to complete the development of each stage were calculated according to (Campbell *et al*., 1974) from the following equation.

$$DD = d\ (T - t_0),$$

Where:

DD: thermal units (day-degree).

T = Temperature in degree centigrade.

t_0 = Temperature threshold of development, in degrees, centigrade.

d = Developmental duration of a given developmental stage.

Statistical analysis was fulfilled by using one-way ANOVA.

RESULTS AND DISCUSSION

1.Life and fertility table parameters for *C. maculatus* on cowpea, chickpea, and horse bean at certain temperature degrees.

Life and fertility table analysis were conducted for *C. maculatus* reared on cowpea, horse bean and chickpea seeds based on an initial cohort of 100 egg per each host at three constant temperatures (25, 30, and 35°C). The calculated fertility table parameters for *C. maculatus* reared under previously mentioned laboratory conditions are net reproductive rate (R_o), generation (G.T), and intrinsic rate of increase (r_m). Based on data in tables (1, 2, and 3) and illustrated in figure (1), this shows that:

Fertility table parameters on cowpea:

Data arranged in tables (1, 2, and 3) and figure (1) indicated that the net reproductive rate (R_o) of *C. maculatus* reared on cowpea was 9.075, 15.28 and 12.42 female's offspring / female parent at 25, 30 and 35ºC, respectively. It appears from the previous results that the highest (R_o) was 15.28 female / female at 30 ºC and the lowest was 9.075 females/ female at 25ºC. It is evident that the cowpea beetle preferred the zone of temperature ranged between 30 and 35ºC. The duration of one generation of *C. maculatus* lasted about 35.43, 24.82, and 19.92 days at 25, 30 and 35ºC, respectively. The generation time at 25 °C is approximately twice that at 35 °C. The values of intrinsic rate of increase (r_m) were 0.062, 0.109 and 0.126 females/female/day, respectively. The highest r_m value (0.126) at 35ºC was approximately twice higher than pest individuals reared on 25ºC.

Fertility table parameters on chickpea:

As seen in tables (1,2 and 3) and figure (1) the net reproductive rate (R_o) was 10.50, 7.99, and 12.75 female's offspring / female parent at 25, 30 and 35ºC, respectively. It appears from the previous results that the highest (R_o) was 12.75 female / female at 35ºC and the lowest was 7.99 females/ female at 30ºC.

Table 1. Fertility table parameters of *C. maculatus* reared on cowpea, chickpea, and horse bean at 25°C.

Cowpea				Chickpea				Horse bean			
X	**Lx**	**mx**	**Lx mx**	**X**	**Lx**	**mx**	**Lx mx**	**X**	**Lx**	**mx**	**Lx mx**
0	Immature stages										
32	0.22	0	0	0	Immature stages			0	Immature stages		
33	0.22	10.47	2.30								
34	0.22	7.68	1.69	36	0.38	0	0				
35	0.22	6.69	1.47	37	0.38	7.69	2.92	38	0.66	0	0
36	0.22	5.11	1.12	38	0.38	6.48	2.46	39	0.66	7.99	5.273
37	0.22	4.01	0.88	39	0.38	5.31	2.018	40	0.66	4.51	2.977
38	0.198	2.45	0.49	40	0.342	3.198	1.094	41	0.462	2.07	.956
39	0.198	2.84	0.56	41	0.304	2.63	.799	42	0.462	3.78	1.75
40	0.154	1.66	0.26	42	0.266	2.45	.652	43	0.264	1.29	.341
41	0.132	.193	0.025	43	0.152	3.32	.505	44	0.132	2.34	.309
42	0.11	1.17	0.13	44	.038	1.1	.042	45	0.132	0	0
43	0.088	1.74	0.15	45	.038	0	0	45	0	0	0

Table 2. Fertility table parameters of *C. maculatus* reared on cowpea, chickpea, and horse bean at 30°C.

Cowpea				Chickpea				Horse bean			
X	Lx	mx	Lx mx	X	Lx	mx	Lx mx	X	Lx	mx	Lx mx
0	Immature stages			0	Immature stages			0	Immature stages		
23	0.60	0.0	0.0								
24	0.60	12.6	7.56								
25	0.60	6.65	3.99	25	0.42	0.0	0.0				
26	0.54	5.0	2.7	26	0.42	9.2	3.86				
27	0.42	2.35	0.99	27	0.42	4.4	1.85	29	0.40	0.0	0.0
28	0.02	1.0	0.02	28	0.42	2.4	1.008	30	0.40	4.82	1.928
29	0.01	1.25	0.013	29	0.378	.92	.348	31	0.36	4.01	1.444
30	0.005	1.5	0.008	30	0.168	1.92	.323	32	0.32	2.09	.669
31	0.005	0	0	31	0.084	7.1	.596	33	0.24	.58	.139
32	0	0	0	32	0.01	0.0	0.0	34	0.12	0.0	0.0

Table 3. Fertility table parameters of *C. maculatus* reared on cowpea, chickpea, and horse bean at 35°C.

Cowpea				Chickpea				Horse bean			
X	Lx	mx	Lx mx	X	Lx	mx	Lx mx	X	Lx	mx	Lx mx
0	Immature stages			0	Immature stages			0	Immature stages		
18	0.41	0.0	0.0	21	0.62	0	0	23	0.45	0.0	0.0
19	0.41	14.49	5.94	22	0.62	9.69	6.01	24	0.45	5.16	2.322
20	0.369	9.5	3.51	23	0.56	8.87	4.97	25	0.405	6.14	2.487
21	0.328	4.49	1.47	24	0.496	2.98	1.48	26	0.36	5.98	2.153
22	0.246	4.78	1.18	25	0.248	1.04	.258	27	0.36	3.14	1.130
23	0.205	.52	0.11	26	0.062	.524	.0325	28	0.135	2.79	0.377
24	0.082	2.6	0.21	27	0.062	0.0	0.0	29	0.045	0.465	0.0209
25	0.041	0.0	0.0	28	0	0	0	30	0.045	0	0
26	0.041	0.0	0.0	29	0	0	0	31	0	0	0

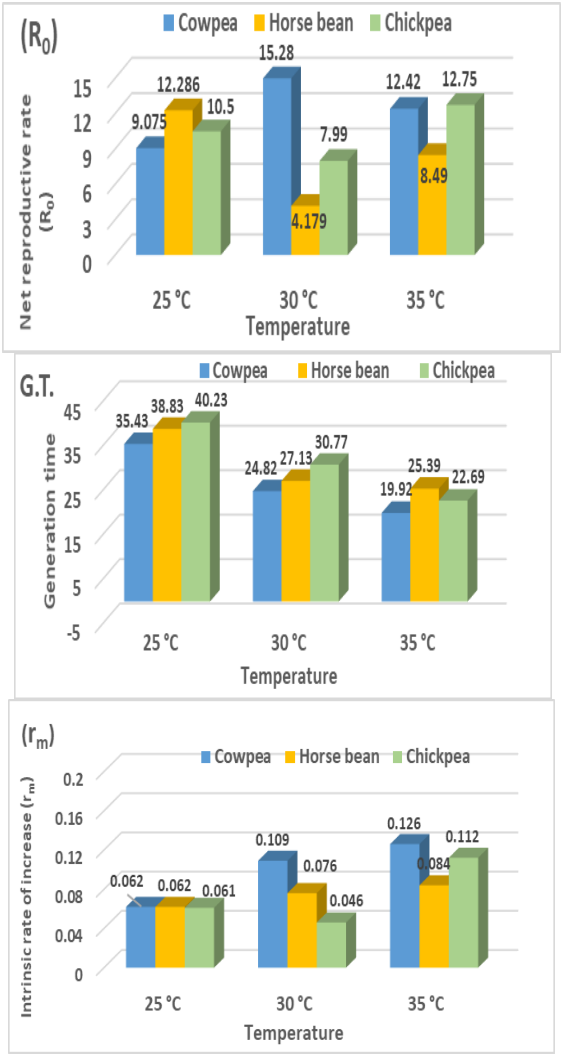

Figure 1. Certain fertility tables parameters (net reproductive rate (R0), intrinsic rate of increase (rm) and the generation time) of cowpea beetle reared on cowpea, horse bean and chickpea at different. constant temperature (25, 30, and 35oC.

It is evident that the cowpea beetle preferred the zone of temperature ranged between 25 and 35ºC. The duration of one generation of *C. maculatus* as shown in figure (1) lasted about 40.23, 30.77 and 22.69 days at 25, 30 and 35ºC, respectively. The generation time at 25 °C is approximately twice that at 35 °C. The intrinsic rate of increase (r_m) was 0.061, 0.046, and 0.112 females/female/day at 25, 30 and 35ºC, respectively. As shown in Figure (1) the highest value (0.112) at 35°C was approximately twice as high than pest individuals reared on 30°C.

Fertility table parameters on horse bean:

With respect to *C. maculatus* reared on horse bean, the net reproductive rate (R_o) was 12.286. 4.179 and 8.49 female's offspring / female parent at 25, 30 and 35ºC, respectively (Figure, 1). It appears from the previous results that there was an inverse relationship between the net reproductive rate and temperature degrees, whereas the highest value (12.286) at 25°C was approximately one and half higher than pest individuals reared on (8.49) 35°C. It is evident that the reproductive potential of pests preferred the temperature of 25ºC. The duration of *C. maculatus* generation reared on horse bean as shown in figure (1) was the longest one in comparison with those reared on cowpea or chickpea. The generation time lasted about 38.83, 27.13, and 25.39 days at 25, 30 and 35ºC, respectively. So, there was an inverse relationship between the generation time and temperature degrees, whereas the highest value was (38.83) at 25°C and the shortest one (25.39 days) at 25°C. On contrary, the highest value of intrinsic rate of increase (r_m) was (0.084) at 35°C and the lowest one (0.062 females/female/day) at 25°C.

Discussion

The obtained data revealed that cowpea beetle showed different fertility tables parameters (net reproductive rate, intrinsic rate of increase and the generation time) in their responses to legume seed species and temperature degrees. The obtained results obviously indicated that the highest net reproductive rate (R0) was obtained (15.28 females/ female) at 30 °C when *C. maculatus* fed on cowpea and the lowest rate (4.179 females/female) at 30 °C when *C. maculatus* fed

on horse been seeds. At 35 °C, C. *maculatus* fed on cowpea exhibited the highest intrinsic rate of increase (0.126 females/ female/ day). These parameters were markedly reduced when the pest fed on chickpea and horse bean. These results agree with those of Anandamay (2012) that fecundity of *C. maculatus* was higher when reared at 30°C than those reared at 20, 25, and 35°C. Similar results were obtained by (Borude *et al*., 2012) that *C. chienesis* exhibited different net reproductive rate and intrinsic rate of increase in response to the host. The present study revealed that the generation time from embryonic development to adult emergence of *C. maculatus* reared on cowpea, chickpea or horse bean was shortest at 35°C and longest at 25°C; whereas cowpea fed insects had a faster generation time at 35°C. These results agree with those of Anandamay (2012) that the developmental time from egg hatching to adult emergence of *C. maculatus* exhibited a positive correlation with temperature ranging from 20 to 35°C.

2.Thermal units' requirements for development of *C. maculatus* reared on legume seeds (cowpea, horse bean and chickpea).

The influence of different constant temperatures (25, 30 and 35 ºC) and host seed species (cowpea, chickpea, and horse bean) on the duration of each developmental stage of *C. maculatus* as well as on thermal units required to complete the development was estimated.

On the duration of each developmental stage of *C. maculatus*.

The egg stage (Embryonic development): Data represented in table (4) showed that the incubation period as affected by both temperature and host seed species. With respect to the effect of temperature, the time required to complete embryogenesis of the cowpea beetle gradually decreased as the temperature increased from 25 to 35 ºC. At 35 ºC, the incubation period was 4.06 ± 0.4, 5.03 ± 0.5, and 4.96±0.35 days on cowpea, chickpea, and horse bean, respectively. Whilst the longest incubation periods (7.96 ± 0.6, 9.86± 0.35, and9.76±0.5 days) were recorded at 25 ºC on cowpea, chickpea, and horse bean, respectively. The incubation periods at 30, and 35 ºC were significantly shorter than those at 25 ºC. As seen in table (4) the obtained results revealed that the eggs produced from females raised on cowpea significantly hatched early compared to eggs of females raised on chickpea or horse bean. So, embryonic development is associated with the seed species that raised the female.

larva- pupal stages: A negative relation seems to exist between temperature and the developmental time of the larva-pupal stages. The average *C. maculatus* (Larval + Pupal) stage durations varied from (23.3±1.58, 24.8±1.05, and 27.43±0.55 days) at 25ºC to (13.2±0.44, 15.83±1.2, and 17.23±0.75 days) at 35ºC on cowpea, chickpea, and horse bean seed, respectively. While the developmental periods of *C. maculatus* (Larval + Pupal) stage on all tested seeds occupied a middle rank at 30ºC (Table,4). Regarding the effect of host seeds, the results illustrated that cowpea followed by chickpea was suitable for the development of larval-pupal stages in comparison with horse bean at all temperature degrees. As seen in table (4) the developmental duration of the larvae and pupal stages reared on horse beans was significantly longer (27.43±0.55, 20.83±0.76, and 17.23±0.75 days) than those reared on cowpea (23.3±1.58, 16.5±0.44, and 13.2±0.44) or chickpea (24.8±1.05, 19±0.2, and 15.83±1.2 days) at 25, 30, and 35 ºC, respectively.

Pre-oviposition period: Data in table (4) indicated that there was an inverse relationship between the pre-oviposition period and temperature degrees. The pre-oviposition periods on the cowpea, chickpea and horse bean were (0.96±0.028, 0.49 ±0.013 and 0.30±., 013), (1.07 ± 0.03, 0.58 ± 0.02 and 0.37 ± 0.028) and (1.17±0.03, 0.66±0.02 and 0.48±0.02) at 25, 30 and 35ºC, respectively. Statistical analysis of the obtained data showed that there were significant differences between the values of pre-oviposition periods at 25, 30, and 35ºC. Also, there were significant differences between the pre-oviposition periods of *C. maculatus* females reared on cowpea, chickpea, and horse bean. The pre-oviposition periods reared on the cowpea (were significantly shorter than those reared on chickpea or horse bean. It is revealed that the mean time required for maturation of the ovary and starting egg lying is associated with the supply of host seeds.

Table 4. Average developmental periods of different stages (eggs, larval-pupal stage, pre-oviposition, and developmental duration of generation) for cowpea beetle reared on certain host seeds (cowpea; chickpea; and horse bean) at certain temperature degrees.

Developmental stages	Temp.	Cowpea	Chickpea	Horse bean	L.S.D (p= 5%)
The incubation period (days)	25	7.96 ± 0.6	9.86± 0.35	9.76±0.5	1.33
	30	5.90 ± 0.4	5.5 ± 0.55	8.13±0.45	0.942
	35	4.06 ± 0.4	5.03± 0.5	4.96±0.35	0.941
L.S.D (p= 1%)		2.01	1.43	1.43	
Larval-pupal stage	25	23.3±1.58	24.8±1.05	27.43±0.55	1.99
	30	16.5±0.44	19±0.2	20.83±0.76	1.33
	35	13.2±0.44	15.83±1.2	17.23±0.75	1.489
L.S.D (p= 1%)		2.47	2.669	2.256	
Pre-oviposition period	25	0.96±0.028	1.07 ± 0.03	1.17±0.03	0.051
	30	0.49±0.013	0.58 ± 0.02	0.66±0.02	0.069
	35	0.30±0.013	0.37 ± 0.028	0.48±0.02	0.067
L.S.D (p= 1%)		0.05	0.066	0.057	
Developmental duration of generation	25	32.22	35.73	38.36	2.20
	30	22.89	25.08	29.62	1.489
	35	17.56	21.23	22.67	2.21
L.S.D (p= 1%)		3.77	2.85	1.88	

Total developmental periods (Generation): The mean duration of generation at different temperatures was calculated as the total mean duration of the total developmental periods (i.e., eggs, larva, pupa, and pre-oviposition periods). The obtained data in table (4) showed that the total developmental period of *C. maculatus* reared on cowpea, chickpea, and horse bean averaged (32.22, 22.89 and 17.56), (35.73, 25.08, and 21.23) and (38.36, 29.62, and 22.67 days) at 25, 30 and 35 ºC, respectively. There was a negative relationship between the generation longevity of *C. maculatus* and all tested temperature degrees. The shortest generation period was recorded at 35 ºC, whilst the longest was obtained at 25 ºC. Statistical analysis referred to that there are significant differences between the mean of generation longevity at 25ºC and corresponding ones at 30 and 35ºC. In general, as shown in table (4), the generation period of *C. maculatus* when reared at 25 ºC needed more than 40% of the time in comparison with those reared at 35 ºC on all tested seeds. With respect to the effect of legume seeds on *C. maculatus* generation period, the longest period was recorded

on horse beans, while the shortest one was obtained on cowpea seeds. The analysis of variance revealed the presence of significant differences between the generation periods and the tested legume seeds.

On the developmental threshold (t_0) and the average of thermal units in degree-days (DDs) required for the development of *C. maculatus*.

The developmental threshold (t_0) and the average thermal units required for the completion of development of the different developmental stages of *C. maculatus* reared on the tested legume seeds are summarized in table (5) and Figure (2).

Embryonic development: The calculated developmental threshold (t_0) for embryonic development was 15.04, 13.5, and 15.63 for eggs deposited by females raised on cowpea, chickpea, and horse bean, respectively. Regarding the average of thermal units in degree-days (DDs) required for the completion of the development of the egg stage on the different legume grains. They were 82.87, 104.10, and 101.45DDs on cowpea, chickpea, and horse bean, respectively. The obtained results revealed that the eggs produced from females raised on cowpea required low thermal units (82.87) compared to eggs of females raised on chickpea (104.10) or horse bean (101.45 DDs). So, thermal units are associated with the supply of the host that raised the female. The heat requirements for embryonic development vary according to the type of nutrition of the females.

Larval-pupal stages: The developmental threshold (t_0) for larval-pupal stages was 11.79, 7.28, and 7.91, on cowpea, chickpea, and horse bean, respectively. The average thermal units were 304.88, 436.65, and 452.58DDs, when *C. maculatus* larvae reared on cowpea, chickpea, and horse bean, respectively. The obtained results revealed that *C. maculatus* larvae reared on cowpea required lower thermal units in comparison with those reared on chickpea or horse bean.

Pre-oviposition period: The lower threshold of pre-oviposition development (t_0) was 20,67, 19.89 and 17.92, on cowpea, chickpea, and horse bean, respectively (Table, 5). Regarding the developmental thresholds, the data obviously cleared that, the raising of temperature accelerated the rate of development of the female ovary and reached faster maturation. The average thermal units required for the completion of pre-oviposition periods in the tested legume grains are summarized in table (5). The average thermal units were 4.34. 5.64 and 8.15 DDs, when *C. maculatus* was reared on cowpea, chickpea, and horse bean, respectively. The obtained results revealed that the pre-oviposition period of *C. maculatus* females reared on cowpea required lower thermal units in comparison with those reared-on chickpea or horse bean.

Generation development:

Data represented in table (5) cleared that the lower threshold of the generation development (t_0) was 13.06, 9.93 and 10.74 ºC on cowpea, chickpea, and horse bean, respectively. The average thermal units required for the completion of generation periods were 385.91, 524.68, and 555.82DDs, when *C. maculatus* was reared on cowpea, chickpea, and horse bean, respectively. The obtained results revealed that the generation period of *C. maculatus* reared on cowpea required lower thermal units in comparison with those reared-on chickpea or horse bean. So, thermal units required for the completion of generation are associated with the host seed species.

Table 5. Developmental threshold and thermal units required for developmental stages of cowpea beetle reared on cowpea; chickpea; and horse bean at different temperature degrees.

Developmental stages	development threshold (to) and Av. thermal units.	Cowpea	Chickpea	Horse bean
Incubation period	t_0	15.04	13.5	15.63
	Av. thermal units (DDs)	82.87	104.10	101.45
Larval-pupal stage	t_0	11.79	7.28	7.91
	Av. thermal units (DDs)	304.88	436.65	452.58
Pre-oviposition period	t_0	20.67	19.89	17.92
	Av. thermal units (DDs)	4.34	5.64	8.15
Developmental duration of generation	t_0	13.06	9.93	10.74
	Av. thermal units (DDs)	385.91	524.68	555.82

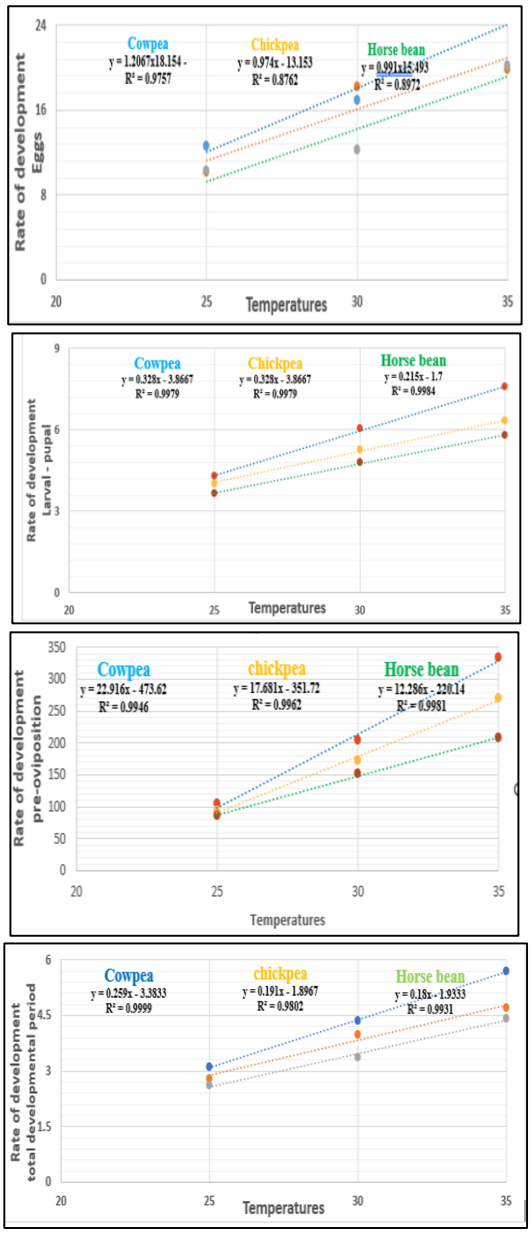

Figure 2.The regression line of the relation between the rate of development of cowpea beetle developmental stages (eggs, larval- pupal, pre-oviposition and total developmental period) reared on cowpea, chickpea, and horse bean) at different constant temperatures.

Discussion

The developmental time from embryonic development to pre-oviposition period of *C. maculatus* reared on all tested legume seeds was shortest at 35°C and longest at 25°C. The results are going in line with the findings of Lale and Vidal (2002). They reported that progeny development in *C. maculatus* reared on bambara groundnut (*Vigna subterranea*) seeds were optimal at 35°C. Similar conclusions was reported by Anandamay (2012) that the developmental time from egg hatching to adult emergence of *C. maculatus* reared on grass pea seeds was shortest at 30°C and longest at 25°C. These results agree with previous results from Mobarakian *et al*., (2014) that the pre-imaginal developmental time of cowpea weevil, *C. maculatus* reared on chickpea decreased with increasing temperature from 15° C to 35°. The obtained results cleared that the embryonic developmental period. of *C. maculatus* varied according to temperature. Kutcherov (2020) demonstrated that the embryonic developmental period of *C. maculatus* from early cleavages up to hatching varied according to temperature, whereas the shortest period was 3.63 days at 31.6° C. With respect to influence of the legume seed species on the development of *C. maculatus*, insects fed on cowpea had a faster embryonic, larva- pupa developmental time, pre-oviposition, and generation developmental time than those reared on horse bean or chickpea at all temperature degrees. The present results was accordance with those published by Swella and Mushobozy (2009). They stated that *C. maculatus* recorded the shortest developing period on cowpea in comparison with chickpea seeds. Also, Jehajo and Memon (2020) reported that the developmental period of *C. maculatus* was longer on black gram while shortest on cowpea and green gram. Also, the obtained results agree with those published by Nisar *et al.,* (2021). They stated that the minimum growth period of *C. maculatus* was recorded on mung bean, followed by cowpea, kabuli chickpea, and desi chickpea. Moreover, the developmental span of *C. maculatus* from egg to adult was differ across on cowpea variety (Boeke *et al*., 2004 and Uddin and Adesiyun, 2012). The obtained results cleared that the average thermal unit's requirement for *C. maculatus* development differed on the different legume seed species. These results coupled with those obtained by Mobarakian *et al.,* (2014); Kutcherov (2020); and Omar & Mahmoud, (2020). Moreover, Daglish *et al.,* (2021) explained that average thermal unit's requirement for development of cowpea beetle differ depending on the strain of the insect.

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جدول الخصوبة والمتطلبات الحرارية لتطور خنفساء اللوبيا المرباة على بذور بقوليات مختلفة

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الملخص

يهدف هذا البحث إلى تقييم تأثير درجات الحرارة وأنواع الحبوب البقولية (اللوبيا، الحمص، وفول الحصان) على جداول الخصوبة، ومدة مراحل النمو، والوحدات الحرارية المتراكمة اللازمة لتطور خنفساء اللوبيا. أشارت النتائج في جداول الخصوبة إلى أن المعدل الجوهري للزيادة (r_m) لخنفساء اللوبيا التي تمت تربيتها على اللوبيا كان أعلى (0.062، 0.109 و0.126) من تلك التي تمت تربيتها على الحمص (0.061، 0.046، و 0.112) أو فول الحصان (0.062، 0.076 و0.084 أنثى/أنثى/يوم) عند 25 و30 و35 درجة مئوية. كانت هناك علاقة عكسية بين فترة الجيل ودرجات الحرارة، حيث أظهرت الحشرة التي تمت تربيتها على اللوبيا أقصر مدة للجيل (35.43، 24.82، 19.92 يومًا) مقارنة بتلك التي تمت تربيتها على الحمص (40.23، 30.77، 22.69 يومًا) أو حبة الحصان (38.83، 27.13، 25.39 يوما) عند 25، 30 و35 درجة مئوية على التوالي. البيض الناتج من الإناث التي ربيت على اللوبيا يفقس مبكرًا بشكل ملحوظ مقارنة ببيض الإناث التي تربى على الحمص أو فول الحصان. وفيما يتعلق بمراحل نمو اليرقات والعذارى، كانت اللوبيا يليها الحمص مناسبة لتطور مراحل اليرقات والعذارى مقارنة بفول الحصان. وقد كانت فترات ما قبل وضع البيض للإناث التي تربى على اللوبيا أقصر بكثير من تلك التي تربى على الحمص أو فول الحصان. كانت هناك علاقة عكسية بين فترة الجيل وجميع درجات الحرارة المختبرة. بلغ متوسط الوحدات الحرارية المتراكمة اللازمة لنمو البيض الذي وضعته الإناث التي تمت تربيتها على اللوبيا والحمص وفول الحصان 82.87 و104.10 و101.45 درجة يوم على التوالي. وكان متوسط الوحدات الحرارية اللازمة لفترة نمو اليرقات والعذراء، وفترة ما قبل وضع البيض، ومدة الجيل الكامل المربى على اللوبيا والحمص وفول الحصان (304.88, 436.65, 452.58 DDs) (4.34, 5.64 , 8.15 DDs) (385.91, 524.68, 555.82 DDs)على التوالي.