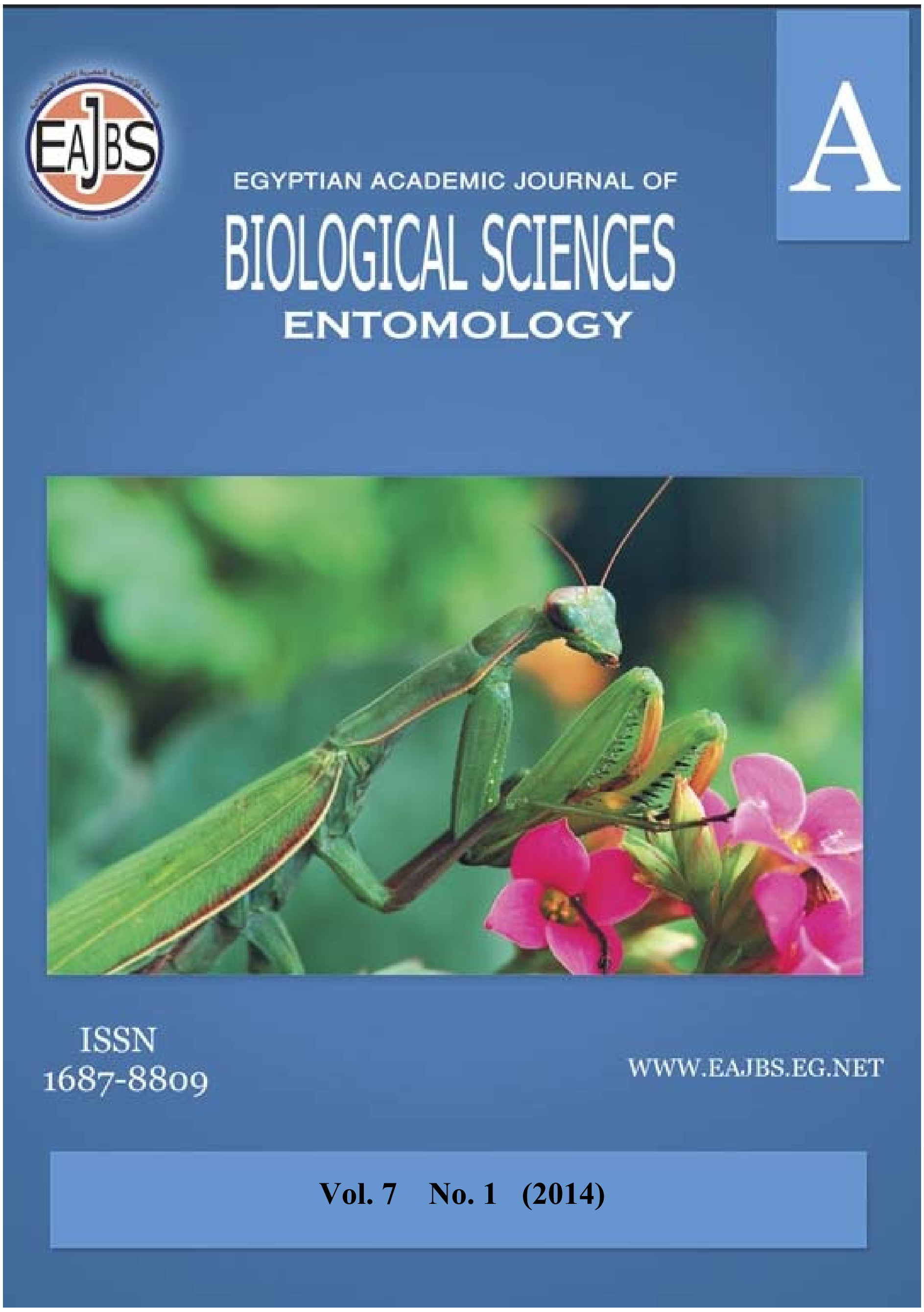

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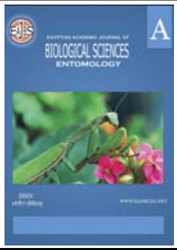

Combination Effect of Maternal Age and Temperature on the Rate of Increase of the Cowpea Weevil, *Callosobruchus maculatus* (F.)

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ABSTRACT

The cowpea weevil, *Callosobruchus maculatus* (Coleoptera: Chrysomelidae), is the most serious insect pest attacking stored pulses in tropical and subtropical regions. The effects of maternal age on offspring fitness of the cowpea weevil have been previously studied, but the combined effects of maternal age and temperature are reported here for the first time. Adult longevity was negatively correlated with temperature, and female longevity was longer than males. The number of eggs deposited daily was negatively correlated with maternal age for the tested temperatures. Females required 24 hours longer at 20°C and 25°C and 12 hours longer at 30°C than males to develop from egg to the adult stage. The mean intrinsic rates of increase were 0.06, 0.10, and 0.15 at 20, 25, and 30°C, respectively. There was a significant positive correlation between maternal age and development time at 25°C. Percent survival was negatively correlated with the maternal age at 20 and 30°C. The effects of maternal age were not consistent at the three tested temperatures; therefore, there is a need for additional studies of the impact of maternal age on offspring quality under different biotic and abiotic conditions.

Keywords: Female longevity, intrinsic rate of increase, progeny, survival rate

INTRODUCTION

The seeds of cowpea, *Vigna unguiculata* (L) (Fabaceae), considered as an important legume, especially in tropical and subtropical countries (Abboud 2010, Diouf 2011). Stored cowpea seeds are subjected to insect infestations, which may cause severe damage (Umeozor 2005). The cowpea weevil, *Callosobruchus maculatus* (Coleoptera: Chrysomelidae), is the most destructive insect pest causing severe damage to cowpea seeds in storage (Obopile *et al*. 2011). Throughout tropical Africa, *C. maculatus* consumed 50-90% of cowpeas in storage annually (IITA 1989).

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Maternal age affects the fitness of offspring in many taxa (Lansing 1947, Parsons 1964, Mousseau & Dingle 1991, Priest *et al*. 2002, Ducatez *et al*. 2012). Fox *et al*. (2003) found that the proportion of eggs that hatched and larval survivorship for cowpea weevils both declined with increasing maternal age, while egg-to-adult development time increased substantially. Wasserman & Asmi (1985) found that survivorship of eggs laid during the first five days of maternal life was constant, and dropped thereafter; whereas, developmental periods of offspring increased with maternal age.

The intrinsic rate of increase is a basic parameter for understanding dynamics of insect populations (Birch 1948). Several studies have reported development and survival aspects of *C. maculatus*. Lale & Vidal (2003) found that egg-laying and progeny development of *C. maculatus* were optimal at 35^{o}C, and no adult progeny emerged at 40^{o}C. Giga & Smith (1983) studied the comparative ecology of two strains of *C. maculatus* (F.) at three temperature regimes (25, 30, and 35°C) and three relative humidity levels (60, 70, and 80% RH). The optimum temperature for reproduction of the cowpea weevil was approximately 30°C. Total oviposition was highest at 30°C, but survival from egg to adult was highest at 25°C for the Malawi strain and at 30°C for a Brazil strain. Larval development of both strains of *C. maculatus* was fastest at 35°C (Giga & Smith 1983). Ouedraogo *et al*. (1996) measured the intrinsic rate of increase of cowpea weevil from December to July; which were 0.09, 0.11, 0.14, 0.14, 0.16, and 0.16 at mean temperatures of 34.8, 26.1, 29.5, 32.5, 33.2, and 31.2^{o}C, respectively.

The combination effects of temperature and maternal age of cowpea weevils have received little attention in the literature. Therefore, the objective of the current research was to study the combination effects of maternal age and temperature on the offspring quality of *C. maculatus*.

MATERIALS AND METHODS

The current study was conducted at the Entomological Laboratory at the College of Food and Agricultural Sciences, King Saud University, Riyadh, Saudia Arabia. A stock culture of the *C. maculatus* was reared for several generations on cowpea seeds. Three temperature treatments (20, 25, and 30^{o}C) were evaluated in an experiment with 10 replicates. Each replicate contained 20 cowpea seeds in a Petri dish with a single newly emerged pair (male & female) of cowpea weevils. To obtain newly emerged adults, infested cowpea seeds were spread over a table andadults were picked individually as they emerged and the sex of each was determined (Bandara & Saxena 1995**)**. Cowpea seeds were removed and replaced with new ones each day until the death of the adult female. The collected seeds of each replicate were kept in separated Petri-dishes for each day.

The following variables were recorded: female and male longevity, the number of eggs per day per female, the total number of eggs per female, the development time from egg depositing to adult, egg to adult survival, and sex ratio. Intrinsic rate of increase was measured using Howe's (1953) equation as follows: $r = \text{Log}(NS)/(T + 0.5L)$

Where: r = Intrinsic rate of increase, N= mean of number of eggs per female, T= development time, L = female adult longevity, and S= percent survival from egg to adult. Doubling time (D) was computed using DeLoach's (1974) formula as follows: $D = \log 2/r$

Data obtained from this experiment were subjected to a correlation coefficient test and two-way analysis of variance (ANOVA), and means were separated by least significant difference (LSD) using SAS (SAS 2008).

RESULTS

Temperature had a large effect on adult performance of *C. maculatus* (Table 1). Adult longevity was negatively correlated with temperature (P = 0.0001, r = -0.71 for males, and P = 0.0001, r = -0.62 for females). Male longevity was 9.8, 7.4, and 6.7 days at 20, 25, and 30°C, respectively. Female longevity was 11.5, 9.9, and 8.1 days at 20, 25, and 30°C, respectively. Moreover, female longevity was significantly higher than male longevity at same temperatures of 20 and 25°C (Table 1). The oviposition period of females was also negatively correlated with temperature (P = 0.003, r = -0.6). The oviposition period was 8.3 days at 20°C, but it decreased significantly to 5.5 days at 30°C. However, the oviposition period at 25°C (7.0 days) did not differ significantly from 20 or 30°C. The post-oviposition period was not significantly affected by temperature (Table 1).

Table 1: Mean (±SE) adult longevity of *Callosobruchus maculatus* at three temperatures.

Temperature	Female longevity in days			Male longevity in days
	Oviposition	Post-oviposition	Total	
20	8.3 ± 0.7 a	3.5 ± 0.6 a	11.5 ± 0.8 a*	9.8 ± 0.7 a*
25	7.0 ± 0.4 a	2.9 ± 0.7 a	9.9 ± 0.4 a*	7.4 ± 0.4 b*
30	5.5 ± 0.6 b	2.4 ± 0.8 a	8.1 ± 0.4 b	6.7 ± 0.3 b

Means followed by same letter within each column are not significantly different by LSD test at level of 5%.
Means followed with * within each row are significantly different by LSD test at level of 5%.

Fecundity increased with increasing temperatures (P = 0.0001, r = 0.67). There were 76.3, 108.7, and 113.7 eggs per female at 20, 25, and 30°C, respectively (Table 2).

Table 2. Mean (±SE) number of eggs per female, development time, percent of survival from egg to adult, and percent of emerged females and males of *Callosobruchus maculatus*.

Temp. °C	No. eggs per female	Development time in days			% survival from egg to adult	% Sex	
		Female	Male	Mean		Female	Male
20	76.3 ± 5.6 b	51.4 ± 0.2 a*	50.4 ± 0.4 a*	50.9 ± 0.2 a	83.7 ± 2.6 b	54.9 ± 2.6 a**	45.1 ± 2.6 a**
25	108.7 ± 4.6 a	34.7 ± 0.2 b*	33.6 ± 0.3 b*	33.1 ± 0.2 b	81.2 ± 2.8 b	56.1 ± 2.3 a**	43.9 ± 2.2 a**
30	113.7 ± 5.5 a	22.4 ± 0.2 c	21.9 ± 0.1 c	22.1 ± 0.1 c	92.4 ± 2.7 a	51.5 ± 1.6 a	48.4 ± 1.6 a

Means followed by same letter within each column are not significantly different by LSD test at level of 5%.
Means followed with * within each row are significantly different by LSD test at level of 5%.
Means followed with ** within each row are significantly different by LSD test at level of 1%.

Development time was highly correlated with temperature (P = 0.0001, r = 0.98). The development times at 20 and 25°C were 2.3 and 1.5 times greater than at 30°C, respectively. Development from egg to adult took 50.9, 33.1, and 22.1 days at 20, 25, and 30°C, respectively (Table 2). Development time from egg to adult was longer for females than males at all temperatures in the current study.

Percent survival from egg to adult fluctuated with temperature (P = 0.03, r = 0.37), and it was 83.7, 81.2, and 92.4% at 20, 25, and 30°C, respectively (Table 2). The sex ratio of offspring was biased toward females at 20 (54.9%) and 25°C (56.1%); however, it was not significant at 30°C (Table 2).

The intrinsic rate of increase was highly affected by temperature (*P* = 0.0001, r = 0.82). The mean intrinsic rates of increase were 0.06, 0.10, and 0.15 at 20, 25, and 30^{O}C, respectively (Table 3). Moreover, the time required for the population to be doubled was highly negatively correlated with temperature (*P* = 0.001, r = -0.83). Only 4.5 days were required for the population to be doubled at 30^{o}C; whereas, 11.1 and 6.6 days were required at 20 and 25^{o}C, respectively.

Table 3: Mean (±SE) intrinsic rate of increase and doubling time of *Callosobruchus maculatus* at three temperatures.

Temperature	Intrinsic rate of increase	Doubling time in days
20	0.06 ± 0.002 c	11.1 ± 0.4 a
25	0.10 ± 0.001 b	6.6 ± 0.1 b
30	0.15 ± 0.001 a	4.5 ± 0.2 c

Means followed by same letter within each column are not significantly different at 5% level by the LSD test.

Maternal age influenced the number of eggs, offspring survival, and development time at each of the three temperatures (Tables 4, 5, and 6). The number of eggs deposited daily was negatively correlated with the maternal age for all tested temperatures. The correlation values were *P* = 0.0001, r = -0.61, *P* = 0.0001, r = -0.77, and *P* = 0.0001, r = - 0.84 at 20, 25, and 30^{o}C, respectively. The numbers of eggs laid on the first day after mating were 18.7, 27.8, and 35.4 at 20, 25, and 30^{o}C, which represent 24.5, 25.5, and 31.1% of the total eggs, respectively.

Table 4: Effect of maternal age of *Callosobruchus maculatus* on the mean number (±SE) of eggs, percent of survival, and development time of offspring at 20^{o}C.

Maternal age in days	No. eggs	% survival from egg to adult	Development time in days		
			Male	Female	Mean
1	18.7 ± 2.2 a	91.7 ± 4.4 a	50.3 ± 0.1 a	50.9 ± 0.2 ab	50.7 ± 0.2 a
2	11.7 ± 1.6 b	78.0 ± 9.4 ab	50.2 ± 0.2 a	51.3 ± 0.3 ab	50.8 ± 0.2 a
3	11.1 ± 1.4 b	82.3 ± 5.1 ab	50.7 ± 0.2 a	51.6 ± 0.3 ab	51.3 ± 0.3 a
4	10.9 ± 0.7 cbd	75.4 ± 8.7 ab	50.6 ± 0.3 a	51.3 ± 0.3ab	50.9 ± 0.4 a
5	11.0 ± 1.5 cb	62.6 ± 8.7 b	50.3 ± 0.3 a	50.8 ± 0.4 b	50.6 ± 0.4 a
6	6.9 ± 0.9 de	75.0 ± 9.4 ab	50.2 ± 0.3 a	51.8 ± 0.3 a	50.9 ± 0.4 a
7	6.0 ± 1.4 cde	56.9 ± 11.4 b	50.7 ± 0.3 a	51.7 ± 0.4 ab	50.8 ± 0.5 a

Means followed by same letter within each column are not significantly different at 5% level by the LSD test.

Table 5: Effect of maternal age of *Callosobruchus maculatus* on the mean number (±SE) of eggs, percent of survival, and development time of offspring at 25^{o}C.

Maternal age in days	No. eggs	% survival from egg to adult	Development time in days		
			Male	Female	Total mean
1	27.8 ± 2.8 a	81 ± 0.05 a	31.4 ± 0.1 e	31.6 ± 0.2 e	31.6 ± 0.1 e
2	23.4 ± 4.1 ab	75 ± 0.05 a	32.1 ± 0.2 de	32.8 ± 0.2 d	32.5 ± 0.2 d
3	18.0 ± 2.1 bc	66 ± 0.06 a	33.1 ± 0.5 cd	33.7 ± 0.5 cd	33.4 ± 0.5 c
4	13.5 ± 1.8 cd	72 ± 0.08 a	33.5 ± 0.3 c	33.9 ± 0.2 c	33.9 ± 0.2 c
5	13.6 ± 1.6 cd	71 ± 0.09 a	33.8 ± 0.5 c	34.2 ± 0.3 c	34.2 ± 0.4 c
6	8.8 ± 1.7 de	76 ± 0.04 a	34.9 ± 0.3 b	36.2 ± 0.2 b	35.5 ± 0.2 b
7	7.2 ± 2.5 de	65 ± 0.06 a	38.7 ± 0.1 a	39.1 ± 0.2 a	38.8 ± 0.1 a

Table 6: Effect of maternal age of *Callosobruchus maculatus* on the mean number (±SE) of eggs, percent of survival and development time of offspring at 30°C.

Maternal age in days	No. eggs	% survival from egg to adult	Development time in days		
			Male	Female	Total
1	35.4 ± 2.3 a	88.3 ± 4.8 a	22.2 ± 0.1 a	22.4 ± 0.2 abc	22.4 ± 0.2 a
2	24.1 ± 2.9 b	85.4 ± 9.8 a	22.1 ± 0.1 ab	22.9 ± 0.3 a	22.5 ± 0.2 a
3	20.8 ± 2.4 b	87.7 ± 9.8 a	21.7 ± 0.1 bc	22.0 ± 0.7 c	21.9 ± 0.1 b
4	14.1 ± 2.6 c	77.8 ± 13.1 ab	21.4 ± 0.2 c	22.1 ± 0.2 bc	21.8 ± 0.2 b
5	10.1 ± 1.9 cd	73.9 ± 12.9 ab	22.2 ± 0.2 a	22.3 ± 0.2 ab	22.3 ± 0.2 a
6	6.2 ± 1.4 de	50.0 ± 16.7 bc	22.2 ± 0.1 a	22.6 ± 0.1 abc	22.5 ± 0.1 a
7	2.9 ± 0.7 e	32.5 ± 13.9 c	22.4 ± 0.1 a	22.3 ± 0.1 bc	22.5 ± 0.1 a

Means followed by same letter in each column are not significantly different at 5% level by the LSD test.

The results showed that there was a significant positive correlation between the maternal age and development time at 25°C (P = 0.0001, r = 0.85). Eggs deposited on the first day required 31.6 days to reach the adult stage, whereas, eggs deposited on the seventh day required 38.7 days to reach the adult stage (Table 5). However, there was no significant correlation between maternal age and development time at 20 or 30°C (Tables 4 and 6).

Survival was negatively correlated with the maternal age (P = 0.01, r = - 0. 31 and P = 0.0001, r = -0.44) at 20 and 30°C, respectively. The highest survival percentages from egg to adult were 91.7% and 88.3% for eggs of the first day of the maternal age (Tables 4 and 6). However, there was no significant correlation between maternal age and percent survival at 25°C (Table 5).

DISCUSSION

Temperature is one of the most important factors affecting the performance and distribution of species (Wagner *et al*. 1984). *Callosobruchus maculatus* is a tropically adapted beetle (Ouedraogo *et al*. 1991, Zannou *et al*. 2003). Studies have shown that the performance of cowpea weevils increased with increasing temperatures from 20 to 35°C (Giga & Smith 1986, Ouedraogo *et al*. 1996, Lale &Vidal 2003, Mahmood & Salih 2007).

Adult longevity of *C. maculatus* was decreased significantly with rising temperature, and female longevity was longer than male longevity. Fox & Stillwell (2009) found that females lived only 18% longer than males when reared at 20°C, but females lived 35, 43, and 42% longer when reared at 25, 30, and 35°C, respectively. In contrast, Mahmood & Salih (2007) found that the mean adult longevity was 14.4, 10.3, 7.2, and 3.5 days for males, and 12.7, 8.0, 6.0, and 4.2 days for females at temperatures of 20, 25, 30, and 35°C, respectively.

The maternal age effects on development and survival of offspring were recorded in this study. Maternal age had marked effects on offspring fitness of *C. maculatus*, which and has also been reported for other insect species (Hercus & Hoffman 2000, Fox *et al*. 2003, Rasanen & Kruuk 2007). Cowpea weevil offspring developing from eggs from older mothers were apparently at a disadvantage relative to offspring from eggs produced from younger mothers. These offspring also have a higher immature mortality and adults generally take longer to develop to sexual maturity (Wasserman & Asami 1985, Fox 1993, Fox & Dingle 1994).

Other studies have shown that additional factors may affect the influence of maternal age on offspring quality. Fox & Reed (2010) found that the rate of offspring fitness of cowpea weevil declined with maternal age and was significantly greater in inbred than outbred beetles. However, Moore & Harris (2003) found that there was no difference in hatch rate or larval viability between the offspring of young and old mothers of the cockroach, *Nauphoeta cinerea*, and the reproductive potential of the daughters of young and old mothers was the same. Yılmaz *et al*. (2008) found that increasing the age of the mothers of *Drosophila melanogaster* does not result in decreased offspring longevities in general.

The interactions of maternal age effects and temperature on offspring fitness have received little attention. In the current study, the maternal age affected development time at 25°C, but not at 20 and 30°C. Moreover, maternal age effects on percent survival were at 20 and 30°C in this study, but not at 25°C. Maternal age appears to influence the quality of offspring, but the effects of maternal age was not consistent at the three tested temperatures in this study. Therefore, there is a need for additional studies of the impact of maternal age on offspring quality under different biotic and abiotic conditions.

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ARABIC SUMMARY

تأثير عمر الأباء و الأمهات و درجات الحرارة علي معدل الزيادة في سوسة اللوبيا المبقعة

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2- قسم وقاية النبات-كلية العلوم-جامعة الملك سعود- الرياض - السعودية

3- قسم الأحياء-كلية العلوم-جامعة تبوك- تبوك - السعودية

تعتبر خنفساء اللوبيا (F.) *Callosobruchusmaculatus* التابعة لعائلة خنافس البقول Chrysomelidae رتبة غمدية الأجنحة Coleoptera من أخطر الآفات الحشرية التي تهاجم البقول المخزنة في المناطق الاستوائية وشبه الاستوائية من العالم . وقد تناولت هذه الدراسة عامل الحرارة كمؤثر بيئي مهم على تكاثر هذه الحشرة، حيث أظهرت النتائج وجود ارتباط سالب بين طول عمر البالغ ين سلبا مع درجة الحرارة، وكان طول عمر الإناث أطول من الذكور. فقد ارتبط عدد البيض الموضوع يوميا سلبا مع عمر الإناث عند جميع درجات الحرارة التي تم اختبارها (20 و 25 و 30 درجة مئوية). فالإناث تحتاج 24 ساعة زيادة عن الذكور ليحدث تطور من البيضة حتي الحشرة الكاملة عند درجتي حرارة 20، 25 درجة مئوية بينما تحتاج حوالي 12 ساعة أطول من الذكور عند درجة حرارة 30 درجة مئوية للتطور من البيضة الي الحشرة الكاملة، وتراوحت معدلات الزيادة بين 0.06، 0.10 و 0.15 عند درجات الحرارة 20 و 25 و 30 درجة مئوية على التوالي. من جانب أخر، أوضحت النتائج أن هناك علاقة إيجابية ذات دلالة إحصائية بين عمر الأم و الوقت اللازم للتطور عند درجة حرارة 25 درجة مئوية. وقد ارتبطت فترة حياة الحشرة مع عمر الأم عند درجتي حرارة 20 و 30 درجة مئوية.كما وجد أن عمر الأم لا يتأثر بنسب ثابتة عند درجات الحرارة الثلاث (20 و 25 و 30 درجة مئوية)، وبالتالي هناك حاجة لإجراء دراسات إضافية لمعرفة تأثير عمر الأم على نوعية النسل الناتج تحت مختلف الظروف الحيوية وغير الحيوية.