



**Temperature-Dependent Development and Degree-Days Models of the
Peach Fruit Fly *Bactrocera zonata* (Saunders) and the Cucurbit Fly
Dacus ciliatus (Loew)**

**Badr El-Sabah A. Fetoh¹, A. A. Abdel Gawad², F. F. Shalaby²
and M. F. Elyme¹**

1-Plant Protection Research Institute, Dokki, Gize, Egypt.

2- Moshtohour Agriculture Faculty, Banha University, Egypt.

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ABSTRACT

The effect of temperature on the development and survival of the peach fruit fly *Bactrocera zonata* (Saunders) and the cucurbit fly *Dacus ciliatus* (Loew) (Diptera: Tephritidae) from the egg to the adult stage were studied in the laboratory under 5 different constant temperatures: 20, 25, 30, 35 and 40°C. The developmental time of the eggs, larvae and pupae was significantly decreased with increasing temperature from 20 to 35°C for *B. zonata* and from 20 to 40°C for *D. ciliatus*. At 40°C only, *B. zonata* entered pupation but did not emerge to the adult, while *D. ciliatus* pupae completed to adults. Furthermore, the preoviposition, oviposition and postoviposition periods were significantly decreased with increasing temperature from 20 to 35°C for *B. zonata* and from 20 to 40°C for *D. ciliatus*. The lower developmental thresholds, thermal constants and lethal high temperatures for different life stages of both flies were also estimated. The results will be useful for predicting the flies population dynamics and geographical distribution, which would help developing the flies' management strategies.

1. INTRODUCTION

The fruit flies are one of the most important insect pest groups of horticulture production and export throughout the world. Over 4500 species that occur worldwide, about 50 species are regarded as major pest species; where about 30 species are of minor economic importance. Twenty four of the major pest species occur within the Pacific region. Dacine fruit flies are very economically important group of Diptera. There are approximately 700 known species of Dacine fruit flies, and the rate of discovery of new species suggests that there is over thousand species in total (Fletcher, 1987, Robison and Hooper, 1989). Four hundred species belonging to the genus *Bactrocera* are widely distributed in tropical Asia, South Pacific and Australia regions, but very few species of such genus were recorded in Africa (Drew and Hancock, 1994).

The peach fruit fly, *Bactrocera zonata* (Saunders) is one of the most harmful species of family Tephritidae.

It is a polyphagous species, but is particularly a pest of peach, mango and guava. It also infests some vegetables as a secondary pest.

It is a significant pest in many countries such as India, Pakistan, Indonesia, Sri-Lanka, Vietnam, Thailand, Burma, Nepal and Bangladesh. Publications from Pakistan show that it is possibly more important than *B. dorsalis* (Kapoor, 1993).

In Egypt, *B. zonata* is now established and widespread. The cucurbit fly, *Dacus ciliatus* (Loew) was recorded for the first time in Egypt by Azab and Kira (1954) as a serious pest on cucurbitaceous fruits, which continued till 1980 and disappeared, then reappeared again after nearly 23 years, causing serious damage to cucurbitaceous plants (Fetoh, 2006).

The importance of the seasonal prediction of the occurrence of insects for developing control strategies has led to multiple formulations of mathematical models that describe the developmental rate in relation to temperature. For degree-days models to be relevant for pest management, a comparison of heat units required in the laboratory and the estimates in the field are necessary. Under field conditions, the generation time can vary with microclimatic factors, population genetics and host quality. Knowledge of the variation in generation time of field populations is consequently essential for the development of a phenological model (Pitcairn *et al.*, 1992). To develop a useful degree-days model, it is also necessary to predict the occurrence of the first emergence and timing of the maximum flight period of *B. zonata* and *D. ciliatus* flies in the fields.

The aims of this work were to develop a degree-day model concerning different biological stages and to determine the lower threshold temperatures, required degree-days and development times of *B. zonata* and *D. ciliatus*. These data will be used for predicting optimum time in the control strategy of the pest.

2. MATERIALS AND METHODS

2.1 Effect of different temperature degrees and thermal units on both of *Bactrocera zonata* and *Dacus ciliatus*:

A culture of adult flies of *B. zonata* and *D. ciliatus* was maintained in the laboratory in Vegetable Pests Research Department, Plant Protection Research Institute, Egypt, at $25\pm 2^{\circ}\text{C}$, $80\pm 10\%$ R.H. and L12:D12 photoperiod. Eggs of *B. zonata* were collected from an artificial egg-lying devices offered to the colony for 4 hours according to Duck and Quilici (2002). Eggs of *D. ciliatus* were collected from small marrow fruits used as deposited sites according to Fetoh (2006). Larvae of *B. zonata* were reared on bran diet described by Tanaka *et al.* (1969). Larvae of *D. ciliatus* were reared on small marrow fruits according to Fetoh (2006). Pupae were obtained by sieving the sandy layers at the bottom of rearing containers for both of *B. zonata* and *D. ciliatus*.

2.2 Biological parameters:

Incubation period of eggs, percentage of hatchability, larval duration, pupal duration, percentage of pupation, emergence of adults and longevity of females and males were tested at five constant temperature degrees, using incubators with fluorescent lamp (20 watt). The tested temperatures were: 20, 25, 30, 35 and 40°C . Three replicates were used for each eggs, larvae, pupae and adults for both of *B. zonata* and *D. ciliatus*. Each replicate had 100 individuals from each stage of the studied flies

2.3 Statistical analysis:

Theoretical development thresholds were calculated according to the linear regression method as follows:

- 1- The points obtained when the time (y) in days is plotted against temperature (T) in degree centigrade so that the distribution of these points indicates the course of temperature time curve. The relationship in hyperbolic was commonly observed in many insects species according to Bean (1961); Miyashit (1971) and Nasr *et al.* (1980).
- 2- The points obtained when the reciprocal for time (1/y) in days are plotted against temperature (T) in

degree centigrade, each of the reciprocals is multiplied by 100, so that the values on the ordinate (100/y) represent the average percentage development made by the stage per day at the given temperature. Therefore, the distribution of the points indicates the course of temperature velocity curve according to Davidson (1944). Theoretically, the point at which the velocity line crosses the temperature axis is the threshold of development in degree centigrade ($^{\circ}\pm C$).

- 3- Thermal units required to complete development of each stage was determined according to the equation of thermal summation as follows:

$$K = y (T - t_0)$$

Where:

y= Development duration (in days) of a given development stage.

T= Experimental temperature in degree centigrade.

t_0 = Temperature threshold of development stage in degree centigrade.

K= Thermal units (degree – days).

Thermal units also can be calculated as the reciprocal of regression

coefficient multiplied by 100 as follows:

$$K = 1/b \times 100$$

Where (b) = regression coefficient (Campbell and Mackauer, 1975)

3. RESULTS AND DISCUSSION

3.1 Effect of different temperature degrees and thermal units on both of *Bactrocera zonata* and *Dacus ciliatus*:

3.1.1. The eggs:

The obtained data in Table (1) show that the time required for egg development in both of the peach fruit fly, *B. zonata* and the cucurbit fly, *D. ciliatus* decreased gradually with increasing temperature degrees from 20 to 40°C. The mean incubation period of *B. zonata* eggs ranged from 11.30±1.50 days at 20°C to 1.80±0.30 days at 40 °C and 6.30±2.10 days at the optimum temperature 25 °C. The mean incubation period as Rate of development (%) was significantly increased with increasing temperature degrees from 20 to 40 °C and varied from 3.19 to 23.19%.

Table 1: Effect of different constant temperature degrees on the incubation period, rate of development, hatchability and thermal requirements of *Bactrocera zonata* and *Dacus ciliatus* eggs

Temp. °C	<i>Bactrocera zonata</i>				<i>Dacus ciliatus</i>			
	Incubation Period in days (Mean±S.D.)	Rate of development (%)	Hatchability Rate (%)	Thermal units* (DD)	Incubation Period in days (Mean±S.D.)	Rate of development (%)	Hatchability Rate (%)	Thermal units* (DD)
20	11.30±1.50 a	3.19	76.00±3.60 d	36.10	5.30±0.60 a	2.59	82.70±3.60	13.85
25	6.30±2.10 b	8.19	97.70±2.5 0a	51.84	3.80±0.30 b	7.59	90.30±2.50	29.12
30	3.00±1.00 c	13.19	90.70±1.20 b	39.56	2.50±0.50 c	12.60	95.70±1.20	31.49
35	2.50±0.50 cd	18.19	80.70±2.10 c	45.46	2.00±0.00 cd	17.60	99.00±2.10	35.20
40	1.80±0.30 d	23.19	66.00± 6.50 e	42.51	1.00±0.00 d	22.60	99.70±6.60	22.60
b	-	-	-	0.02	-	-	-	0.04
k	-	-	-	43.20	-	-	-	26.80

*Thermal units (DD) based on development threshold of 16.80°C for *Bactrocera zonata* and 17.40°C for *Dacus ciliatus*.

The numbers with same letter is non significant.

b = Regression coefficient.

K = Thermal units (degree-days)

F value= 15.59, R-Square=0.839 and Prob > F =0.029 for *B. zonata* .

F value= 16.61, R-Square= 0.847, Prob >F=0.027 for *D. ciliatus*.

The eggs hatchability rate % of *B. zonata* has fluctuated with different temperatures used from 66.00-97.00% at 40°C and 25°C, respectively. Thermal units on the tested temperature were: 36.10, 51.84, 39.56, 45.46 and 42.51 DD for eggs of *B. zonata* reared on temperature degrees from

20 to 40 °C. Thermal units (DD) were based on development threshold of 16.80°C for eggs of *B. zonata*. These results have the same trend with that of Rahman (1939) who recorded incubation period from 2 to 3 days, Christeson and Foote (1960) from 1 to 3 days, Rebison (1984) from 2 to 4 days, Rana

et al. (1992) from 2 to 6 days, El-Minshawy *et al.* (1999) from 3 to 5 days, FAO (2000) from 2 to 3 days, Mohamed (2000) from 3 to 4 days, El-Gendy (2002) from 2.1 to 2.7 days and Duyck *et al.* (2004) from 1.8 to 2.1 days for *B. zonata*.

Similar results were reported in case of *D. ciliatus* where the mean incubation periods of eggs were 5.30 ± 0.60 days and 1.00 ± 0.00 day from 20 to 40 °C and 3.80 ± 0.30 days at the optimum temperature 25 °C. The rate of development (%) has ranged from 2.598 to 22.600% that significantly increased with increasing temperature degrees from 20 to 40 °C. The hatchability rate % in contrast to *B. zonata*, increased from 82.70 to 99.70% from 20 to 40 °C, respectively. Thermal units on the tested temperature were: 13.85, 29.12, 31.49, 35.2 and 22.60 DD. Thermal units (DD) were based on development threshold of 17.40°C for eggs of *Dacus ciliatus*. Weems (2002) mentioned that the duration period has ranged from 2 -4 days in the field around the

year. Fetoh (2006) reared the eggs of *D. ciliates* at 25 °C. and found that the egg duration period was 3.0 days. Vayssières *et al.* (2008) on two species of Dacini: *Bactrocera cucurbitae* (Coquillett) and *D. ciliatus* Loew were reared at four different constant temperatures (15, 20, 25, and 30°C). The results led to the conclusion that *B. cucurbitae* had a faster egg incubation time than those of *D. ciliatus* independent of temperature.

3.1. 2. The larvae:

Table (2) showed that the larval period also varied with increasing the temperature degrees in significant manner. The mean larval duration was 33.70 ± 3.20 , 24.30 ± 4.00 , 16.70 ± 2.10 , 10.30 ± 1.50 and 6.70 ± 0.60 days from 20°C to 40 °C for *B. zonata*. Rate of development (%) was increased by raising temperature from 20°C to 40 °C and varied between 2.74 and 22.74. Pupation % was highest at 25°C (95.67%) while at 40 °C was the lowest (56.00%).

Table 2: Effect of different constant temperature degrees on the larval duration, rate of development, pupation percentage and thermal requirements of *Bactrocera zonata* and *Dacus ciliatus* larvae.

Temp. °C	<i>Bactrocera zonata</i>				<i>Dacus ciliatus</i>			
	Larval	Rate of	Pupation	Thermal	Larval	Rate of	Pupation	Thermal
	duration	development %	%	units*	duration	development %	%	units*
	in days			(DD)	in days			(DD)
20	33.70 ± 3.20 a	2.74	75.70 ± 4.90 d	92.39	12.00 ± 2.10 a	10.24	84.33 ± 4.00 e	122.80
25	24.30 ± 4.00 b	7.74	95.67 ± 2.10 a	188.40	9.00 ± 1.00 b	15.24	93.00 ± 3.00 d	137.10
30	16.70 ± 2.10 c	12.74	92.30 ± 2.50 b	212.40	7.30 ± 0.60 c	20.24	96.30 ± 1.50 c	148.40
35	10.30 ± 1.50 d	17.74	84.70 ± 3.50 c	183.40	6.30 ± 0.60 d	25.24	97.70 ± 0.60 b	159.80
40	6.70 ± 0.60 e	22.74	56.00 ± 3.60 e	151.60	4.20 ± 0.80 e	30.24	99.00 ± 1.00 a	126.00
b	-	-	-	0.01	-	-	-	0.01
k	-	-	-	169.00	-	-	-	139.00

*Thermal units (DD) based on development threshold of 17.30°C for *Bactrocera zonata* and 9.80°C for *Dacus ciliatus*.

The numbers with same letter is non significant.

b = Regression coefficient.

K = Thermal units (degree-days)

F value= 72.11, R-Square= 0.973 and Prob >F= 0.014 for *B. zonata*.

F value=97.58, R-Square= 0.970, Prob >F= 0.002 for *D. ciliatus*.

Thermal units on the tested temperature were: 92.39, 188.40, 212.40, 183.40 and 151.60 DD for larvae of *B. zonata* reared on temperature degrees from 20 to 40 °C. Thermal units (DD) were based on development threshold of 17.30°C for the larvae of *B. zonata*. These results have the same trend with those carried out by Syed *et al.* (1970), Qureshi *et al.* (1974), Robison (1984), Tigavatan and Areekul (1984),

Fletcher (1987), Rana *et al.* (1992), El-Minshawy *et al.* (1999) and Mohammed (2003). There were some differences as recorded by Mohamed (1993) 21.0 days on guava, 60.0 days by Christenson and Foote (1960) and 30 days by Duyck *et al.*, (2004) at 15°C, respectively. At the 30 and 35 °C, the larval durations were shorter (4.80 & 5.00 days) than that obtained by Mohamed (2000) and close to that reported by Qureshi

et al. (1993) and Duyck *et al.* (2004). At 40 °C the larval duration was lower than that at 35°C, which was against that obtained by Mohamed (2000) and Duyck *et al.* (2004). Furthermore, Duyck *et al.* (2004) mentioned that the larvae of *B. zonata* when reared at 35°C had larval duration period longer than those reared at 30°C, while the larvae failed to pupate at 40°C.

D. ciliatus has the same trend, as it showed significant effect for temperature on the larval duration period, ranging from 12.00 and 4.20 days from 20 to 40°C and 9 days at the optimum temperature (25°C). The developmental rate (%) also was increased by raising temperature and ranged from 10.24 to 30.24%. Pupation (%) has in the same trend and ranged from 84.33 to 99.00 from 20 to 40°C, respectively. Thermal units on the tested temperature

were: 122.80, 137.10, 148.40, 159.80 and 126.00 DD for larvae of *D. ciliatus* reared on temperature degrees from 20 to 40 °C. Thermal units (DD) were based on development threshold of 9.80°C for the larvae of *D. ciliatus*. Weems (2002) and Fetoh (2006) mentioned that the larval duration period was 4- 6 days and 7.3 days, respectively.

3.1. 3. The pupae:

Data in Table (3) revealed that the impact of various temperature degrees on the pupation periods showed an ascending significant effect for temperature degrees on the pupal duration periods and descending effect on the percentage of pupation. The pupation periods were 47.67±2.50, 14.33±0.60, 7.80±0.30 and 6.67±0.60 days at 20, 25, 30 and 35°C, respectively.

Table 3: Effect of different constant temperature degrees on the pupation period, rate of development, emergence rate and thermal requirements of *Bactrocera zonata* and *Dacus ciliatus* pupae.

Temp. °C	<i>Bactrocera zonata</i>				<i>Dacus ciliatus</i>			
	Pupal Period in days (Mean±S.D.)	Rate of development (%)	Emergence rate %	Thermal units* (DD)	Pupal Period in days (Mean±S.D.)	Rate of development (%)	Emergence rate (%)	Thermal units* (DD)
20	47.67±2.50a	2.85	76.00±1.70 d	135.80	6.67±0.50 a	6.46	78.00±2.60 d	43.08
25	14.33±0.60 b	7.85	77.67±1.50 c	112.50	5.00±0.00 b	11.46	88.33±2.80 c	57.31
30	7.80±0.30 c	12.85	97.67±1.50 a	100.70	4.00±0.00 c	16.46	94.00±1.70 b	65.85
35	6.67±0.60 d	17.85	93.00±2.70 b	119.00	2.33±0.60 d	21.46	97.00±1.70 a	50.08
40	0.00±0.00 e	0.00	0.00±0.00 e	0.00	2.00±0.00 e	26.46	98.00±3.60 a	52.92
b	-	-	-	0.01	-	-	-	0.02
k	-	-	-	117.00	-	-	-	53.80

*Thermal units (DD) based on development threshold of 17.20 °C for *Bactrocera zonata* and 13.50°C for *Dacus ciliatus*.

The numbers with same letter is non significant.

b = Regression coefficient.

K = Thermal units (degree-days)

F value= 23.73, R-Square= 0.97 and Prob >F=0.144 for *B. zonata* .

F value=88.36, R-Square=0.96, Prob >F= 0.002 for *D. ciliatus*.

No emergence to adults from pupae occurred in case of *B. zonata* at 40°C. The percentage of live pupae varied between 76.00% and 93.00%. There were increasing in the percentage of emergence of adults from pupae from 76.00±1.70, 77.67±1.50 to 97.67±1.50 % at degrees from 20°C to 30°C, while a sudden decrease occurred to 93.0% at 35 °C. The pupal development rate was 2.85, 7.85, 12.85, 17.85 and 0.00% from 20°C to 40°C, and no pupal development occurred at 40°C. The thermal units were decreased with increasing the temperature degrees and ranged from 135.80, 112.50, 100.70, 119.00 and 0.00 DD. Thermal units

(DD) were based on development threshold of 17.20 °C for the pupae of *B. zonata*.

This result has an opposite trend to Qureshi *et al.* (1993), and Duyck *et al.* (2004) who mentioned that the lowest temperature degree (15°C) and the highest degree (40°C) were not suitable for pupation of *B. zonata*.

Also, the data in Table (3) demonstrate that the duration of pupae was decreased with increasing the temperature for *D. ciliatus*. The longest pupal period of *D. ciliates* was 6.67 days, recorded at 20°C, while the shortest one (2.00) days was noticed at 40°C. Significant differences were

found between the pupal periods and different temperature degrees from 20°C to 40 °C. The pupal durations were 6.67±0.50, 5.00±0.00, 4.00±0.00, 2.33±0.00 and 2.00±0.00 days, respectively, at temperature degrees 20, 25, 30, 35 and 40 °C, respectively. The emergence to adult was also increasing with increasing the temperature degrees as 78.00±2.60, 88.33±2.80, 94.00±1.70, 97.00±1.70 and 98.00±3.60 % at temperature degrees from 20 to 40 °C, also the emergence to adult of *D. ciliatus* was on contrary to *B. zonata* where the emergence to adult was 98.0% in case of *D. ciliates* and 0.0% in case of *B. zonata* (no emergence to adult) at 40°C.

The pupal development rates of *D. ciliatus* were also increasing with the raising of the temperature degrees 6.5, 11.5, 16.5, 21.5 and 26.5 % from 20 to 40 °C, respectively. The mean thermal units required for development of pupae of *D. ciliatus* were 43.08, 57.31, 65.85, 50.08 and 52.92, respectively. Thermal units based on development threshold of 13.5°C for the pupae of *D. ciliatus*.

Weems (2002) mentioned that the pupae of *D. ciliatus* took from 8 to 12 days at the optimum temperature (25°C), Fetoh

(2006) found that the pupal period of *D. ciliatus* lasted 9.3 days at 25°C, that showed an opposite trend to the obtained data which indicated that the pupal period of *D. ciliatus* lasted for 5.0 days at 25°C.

Vayssières *et al.* (2008) recorded that the temperature threshold for the pupae of *D. ciliatus* reared at four temperature degrees (15, 20, 25 and 30 °C) was 11.20 °C, while in this present work was 13.5°C.

3.1. 4. The adult:

4.1. The male:

The results in Table (4) revealed that the male durations of *B. zonata* reared on different temperature degrees from 20 to 40°C were decreased in an ascending manner with raising the temperature degrees, as: 87.67±2.50, 65.67±7.40, 37.67±17.60, 16.67±2.90 and 0.00±0.00 days. In the opposite view, the male development rate was increased with raising the temperature degrees as: 5.24, 10.24, 15.24 and 20.24 % at temperature from 20 to 35°C, respectively. The mean thermal units required for development of the male of *B. zonata* were: 145.10, 184.40, 188.00 and 161.90 DD at 20, 25, 30 and 35°C, respectively. Thermal units were based on development threshold of 18.5°C for male of *B. zonata*.

Table 4: Effect of different constant temperature degrees on the male duration, rate of development and thermal requirements of *Bactrocera zonata* and *Dacus ciliatus*.

Temp. °C	<i>Bactrocera zonata</i>			<i>Dacus ciliatus</i>		
	Male duration in days	Rate of development %	Thermal units* (DD)	Male duration in days	Rate of development %	Thermal units* (DD)
20	87.67±2.50 a	5.24	145.10	47.67±2.50 a	1.74	82.68
25	65.67±7.40 b	10.24	184.40	14.33±0.60 b	6.74	242.40
30	37.67±17.60 c	15.24	188.00	7.80±0.30 c	11.73	363.80
35	16.67±2.90 d	20.24	161.90	6.67±0.60 d	16.73	390.50
40	0.00±0.00 e	0.00	0.00	5.20±0.00 e	21.73	188.40
b	-	-	0.00	-	-	0.00
k	-	-	318.00	-	-	253.50

*Thermal units (DD) based on development threshold of 18.50°C for *Bactrocera zonata* and 18.30°C for *Dacus ciliatus*.

The numbers with same letter is non significant.

b = Regression coefficient.

K = Thermal units (degree-days)

F value=171.85, R-Square=0.99, Prob >F=0.053for *B. zonata* .

F value=43.47, R-Square=0.96, Prob >F= 0.0225for *D. ciliatus*.

This disagrees with El-Minshawy *et al.* (1999) who reared *B. zonata* at 25 °C on the artificial diet and found that the male duration was 100 days, and Mohamed (2003) who found that the male adult of *B. zonata*

reared on artificial diet at 25°C lasted for 39.55 days, while it was here found that the male of *B. zonata* reared on artificial diet at 25 °C lived for 65.7 days at the same temperature degree (25 °C), and nearly

similar to El-Gendy (2002) who recorded that the male duration was 59.56 days for males of *B. zonata* at 25 °C on the artificial diet.

D. ciliatus, on the other hand showed also ascending decrease in the male durations from 47.67±2.50, 14.33±0.60, 7.80±0.30, 6.67±0.60 and 5.20±0.00 days when reared on the temperature degrees from 20 to 40 °C. The development rates of male showed an opposite trend increasing with raising the temperature degrees from 20 to 40°C as: 1.74, 6.74, 11.73, 16.73 and 21.73% with thermal requirements were: 82.68, 242.40, 363.80, 390.50 and 188.40 DD's. Thermal units were based on development threshold of 18.3°C for males of *D. ciliatus*. Fetoh (2006) mentioned that the male of *D. ciliatus* has mean duration of 19.70 days, ranging from 14-25 days when reared at 25°C, while the present work shows that the male of *D. ciliatus* has mean duration of 14.30 days.

3. 4.2. The female:

3. 4.2.1. The preoviposition:

The data in Tables (5) and (6) indicate that there were an inverse relationship between the average period of the preoviposition for both of *B. zonata* and *D. ciliatus* and the temperature degrees, i.e. the

mean time required for maturation of ovary and beginning to lay eggs decreased as the temperature degrees increased. The average of the preoviposition period of *B. zonata* was significantly different: 27.67±2.50, 18.00±2.00, 12.33±0.60, 8.00±2.00 and 0.00±0.00 days at temperature degrees 20, 25, 30, 35 and 40°C, respectively.

However, Qureshi *et al.* (1993) found that at temperature degrees of 15 °C and 35 °C the females of *B. zonata* failed to deposit eggs. On the other hand, El-Minshawy *et al.* (1999) reported that the females of *B. zonata* took from 45 to 60 days in the preoviposition period at 25 °C. Moreover, Duyck *et al.* (2004) mentioned that the ovarian maturation of *B. zonata* had narrow range at the temperature degrees of 25-30 °C, while in this study it was 18.0 days at 25 °C and 12.3 days at 30°C with differences nearly 6.0 days.

The average of the preoviposition period of *D. ciliatus* was significantly different being 6.67±0.50, 6.00±0.00, 5.00±0.00, 3.00±0.00 and 2.00±0.00 days at 20, 25, 30, 35 and 40 °C, respectively. Weems (2000) mentioned that the preoviposition period of *D. ciliatus* was at least 4.0 days and Fetoh (2006) indicated that the preoviposition period of *D. ciliatus* ranged from 2 to 3 at 25 °C.

Table 5: Effect of different constant temperature degrees on the preoviposition, oviposition, postoviposition periods, rate of development and thermal requirements of *Bactrocera zonata* and *Dacus ciliatus* adult females.

Temp. °C	<i>Bactrocera zonata</i>					<i>Dacus ciliatus</i>				
	Preoviposition period in days	Oviposition period in days	Postoviposition period in days	Rate of development (%)	Thermal units* (DD)	Preoviposition period in days	Oviposition period in days	Postoviposition period in days	Rate of development (%)	Thermal units* (DD)
20	27.67±2.50 a	67.33±3.60 a	12.33±2.50 a	12.67	352.20	6.67±0.50 a	28.00±2.40 a	21.67±2.90 a	8.80	180.60
25	18.00±2.00 b	55.00±5.00 b	8.00±1.00 b	22.67	583.70	6.00±0.00 b	23.33±2.90 b	126.67±2.50 b	18.80	299.67
30	12.33±0.60 c	34.33±1.10 c	6.00±1.70 c	32.67	580.33	5.00±0.00 c	20.67±1.33 c	11.67±2.90 c	28.80	389.33
35	8.00±1.00 d	18.00±2.00 d	4.67±1.50 d	42.67	446.70	3.00±0.00 d	14.33±1.10 d	8.33±1.50 d	38.67	350.10
40	0.00±0.00 e	0.00±0.00 e	0.00±0.00 e	0.00	0.00	2.00±0.00 e	7.67±1.10 e	4.33±0.60 e	49.00	234.10
b	-	-	-	-	0.01	-	-	-	-	0.01
k	-	-	-	-	244.50	-	-	-	-	178.10

*Thermal units (DD) based on development threshold of 14.80°C for *Bactrocera zonata* and 14.40 °C for *Dacus ciliatus*.

The numbers with same letter is non significant.

b = Regression coefficient.

K = Thermal units (degree-days).

F value=147.44, R-Square=0.99, Prob >F= 0.007 for the preoviposition, F value=72.43, R-Square=0.99, Prob >F= 0.086 for oviposition and F value=14.61, R-Square=0.83, Prob >F= 0.032 for postoviposition of *B. zonata*.

F value=56.01, R-Square=0.96, Prob >F= 0.017 for the preoviposition, F value=236.63, R-Square=0.99, Prob >F=0.004 for oviposition and F value=120.60, R-Square=0.99, Prob >F=0.02 for postoviposition of *D. ciliatus*.

3. 4.2.2. The oviposition:

The results in Table (5) indicate that the mean oviposition period of *B. zonata* varied significantly 67.33 ± 3.60 , 55.00 ± 5.00 , 34.33 ± 1.10 and 18.00 ± 2.00 days and decreasing with increasing the temperature degrees from 20 to 35 °C, respectively.

These results are different from those obtained by El-Minshawy *et al.* (1999) where the oviposition period ranged from 70 days to 90 days at 25°C., while Rana *et al.* (1992), El-Gendy (2002), Mohamed (2003) recorded 14.8, 117.5 and 3-7 days for adult females reared on artificial diet at 25 °C.

For *D. ciliatus*, the oviposition period also showed significant variation being 28.00 ± 2.40 , 23.33 ± 2.90 , 20.67 ± 1.33 , 14.33 ± 1.10 and 7.67 ± 1.1 days and decreased with increasing the temperature degrees from 20 to 40 °C, respectively. Generally, the oviposition period of *B. zonata* was longer than that of *D. ciliatus*. These results opposite to those obtained by Fetoh (2006), who found that the oviposition period of *D. ciliatus* ranged from 7 to 10 days, when reared at 25 °C.

3. 4.2.3. The postoviposition:

There were inverse relationships between the mean duration of the

postoviposition periods of both *B. zonata* and *D. ciliatus*. For *B. zonata* it was 12.33 ± 2.50 , 8.00 ± 1.00 , 6.00 ± 1.70 and 4.67 ± 1.50 days at 20, 25, 30 and 35 °C, respectively. These results have the same trend with El-Minshawy *et al.* (1999), El-Gendy (2002) and El-Naggar (2004) and in the opposite trend with Rana *et al.* (1992), who recorded 28 days for the postoviposition period for females of *B. zonata* at 25 °C.

For *D. ciliatus*, the means of postoviposition periods were 21.67 ± 2.90 , 12.67 ± 2.50 , 11.67 ± 2.90 , 8.33 ± 1.50 and 4.33 ± 0.60 days, respectively. These results have an opposite trend with Fetoh (2006), who mentioned that the postoviposition period of *D. ciliatus* ranged from 3 to 4 days at 25 °C.

3.4.2.4. Female longevity:

Data in Table (6) indicate that the females longevity of *B. zonata* and *D. ciliatus* was affected by the temperature raising. The means of female longevity decreased as a result of increasing the temperature degrees from 20 to 35 °C in case of *B. zonata* and from 20 to 40 °C in case of *D. ciliatus*.

Table 6: Effect of different constant temperature degrees on the female duration, rate of development and thermal requirements of *Bactrocera zonata* and *Dacus ciliatus*:

Temp. °C	<i>Bactrocera zonata</i>			<i>Dacus ciliatus</i>		
	Female duration in days	Rate of development %	Thermal units* (DD)	Female duration in days	Rate of development %	Thermal units* (DD)
20	107.33 ± 3.80 a	12.67	352.20	56.33 ± 1.50 a	8.80	180.60
25	81.00 ± 7.00 b	22.67	583.67	42.00 ± 1.67 b	18.80	299.70
30	52.67 ± 1.50 c	32.67	580.33	37.33 ± 2.50 c	28.80	389.40
35	30.67 ± 4.00 d	42.67	446.67	25.67 ± 0.67 d	38.67	350.10
40	0.00 ± 0.00 e	0.00	0.00	13.33 ± 1.80 e	49.00	234.10
b	-	-	0.01	-	-	0.01
k	-	-	244.50	-	-	178.10

*Thermal units (DD) based on development threshold of 14.80°C for *Bactrocera zonata* and 14.40°C for *Dacus ciliatus*.

The numbers with same letter is non significant.

b = Regression coefficient.

K = Thermal units (degree-d degree-days)

F value= 56.01, R-Square= 0.96, Prob >F= 0.017 for *B. zonata*.

F value=95.51, R-Square= 0.97, Prob >F=0.002 for *D. ciliatus*

The female longevity of *B. zonata* showed decreasing in the longevity period (107.33 ± 3.80 , 81.00 ± 7.00 , 52.67 ± 1.50 and 30.67 ± 4.00 days) and increasing in the

development rate (12.67, 22.67, 32.67 and 42.67%), respectively. The thermal requirements were: 352.20, 583.70, 580.30 and 446.70 DD at temperature degrees 20,

25, 30 and 35 °C, respectively. Thermal units based on development threshold of 14.8°C for female of *B. zonata*.

El- Minshawy *et al.* (1999) recorded 145 days, El-Gendy (2002) recorded 82.5 days and Mohammed (2003) recorded 43.20 days for females reared on the artificial diet at 25 °C.

Also, the female longevity of *D. ciliatus* showed decreasing in the longevity period (56.33±1.50, 42.00±1.70, 37.33±2.50, 25.67±0.60 and 13.33±1.80 days) and increasing in the development rate (8.8, 18.8, 28.8, 38.7 and 49.0%), respectively. The thermal requirements were: 180.60, 299.70, 389.40, 350.10 and 234.10 DD at temperature degrees of 20, 25, 30, 35 and 40 °C, respectively. Thermal units were based on development threshold of 14.40°C for females of *Dacus ciliatus*. Fetoh (2006) mentioned that the females' mean longevity of *D. ciliatus* was 34.3 days and ranged from 28 to 45 days at 25 °C. The results show that the females' mean longevity of *D. ciliatus* was 42.0 days at 25 °C.

Temperature is one of the most important factors affecting the developmental rate through various life stages of fruit fly (Fletcher, 1987). One of the most commonly used models for describing a relationship between temperature and development rate in insects is the linear approximation (Uvarov, 1931; Wagner *et al.* 1984). However, insect development is non-linear at the extremes of high and low temperature and several non-linear models are available to describe developmental rate and estimate temperature thresholds more precisely. In this research the linear model was used because the temperatures under examination lie, for the most part, within the linear portion of development and it provides a straightforward comparison of physiological time with previous work on fruit flies (Vargas *et al.* 1996; Thierry and Serge, 2000; Yuan *et al.* 2005). Meanwhile, the non-linear model was used for egg, larval and pupal stages because the developmental time increased when the temperature was above

33°C and the linear equation would not account for this. *B. dorsalis* is another prevalent fruit fly whose pest infestations occur all year round in most of Yunnan, China (Ye, 2001). Furthermore, Vargas *et al.* (1996) estimated from linear regression the thermal constant for total development of *B. dorsalis* to be 358 degree-days and the lower temperature threshold of eggs, larvae and pupae to be 11.8, 5.6 and 9.3°C. The lower temperature threshold of preoviposition in *B. dorsalis* was reported to be 12.44°C (Yuan *et al.* 2005). This study demonstrated that the temperature requirement seems much higher through all the life stages for *B. zonata* and *D. ciliatus*. Biological parameters like developmental zero and the thermal constant are supposed to be the limiting factors in the geographic distribution for the fruit flies (Ye, 2001). Therefore, thermal requirements explain the reason that distribution range for *B. correcta* is much narrower in comparison with *B. dorsalis* (Liu *et al.* 2005). The results may also help to understand the life cycle strategy of *B. zonata* and *D. ciliatus* in its breeding areas. No oviposition was observed at 18°C for *B. correcta* adults (Lui and Ye, 2009), even at this temperature the adult fly remains surviving. In this present work both *B. zonata* and *D. ciliatus* can survive and lay eggs at 20°C. The evidence proved that thermal requirement is higher for oviposition than for development. However, at the lower temperature like 18°C, development period for the adults is much prolonged. Similar phenomenon was commonly found in other *Bactrocera* fruit flies, which was regarded to be reproductive "diapause" (Fletcher, 1987). Probably, *B. correcta* adults take a similar strategy to overcome somewhat lower temperatures and on the contrary to our study on *B. zonata* and *D. ciliatus*. Establishment of experimental populations is essential for laboratory studies (Yuan *et al.* 2003) and temperature plays a key role in the insect breeding process (Thierry and Serge, 2000). According to Liu and Ye (2009), the temperatures from 30 to 33°C appear to be the most suitable for egg, larva and pupa development of *B. correcta*. The

preoviposition time is shortened greatly with the temperature higher than 33°C. The development, survival and reproduction of fruit flies are also influenced by the species and quality of hosts, especially at the larval stage. Carey (1984) reported that larval development of *Ceratitis capitata* increased from 1 week in favorable hosts such as mango and tomato to more than 3 weeks in quinces. Kamala and Abraham (2002) noticed that the developmental time of *B. dorsalis* varies with the host fruit species. Compared with the artificial diet, the development of larva is slow in natural hosts, because of the quick depletion of food material due to faster ripening and subsequent spoilage of fruit (Kamala and Abraham, 2002). The study results were obtained in the base of breeding with artificial diet. Therefore, these biological parameters for the fly will be changed when it feeds with other type of host food. However, it provides basic information on the bionomics of the fruit fly. This study constitutes a first step before analyzing more complex ecological relations. For example, these data, combined with results of other studies on trapping and population fluctuations, could be useful in the construction of computer simulation models of fruit fly population dynamics that will enable better monitoring and management of these destructive pests.

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