MODELING THE CHANGES IN THE POPULATION GROWTH PATTERNS OF PINK BOLLWORM *PECTINOPHORA GOSSYPIELLA* (SAUND.)

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Abstract

The present study was completed during three successive cotton-growing seasons (1996-1998). Monitoring the changes in the population density was achieved when number of male moths of *Pectinophora gossypiella* (Saund.) was considered based on pheromone trap catches. The obtained results revealed that *P. gossypiella*, after emerging from the diapausing stage, underwent two distinct broods; the first had two generations, while the second possessed 4-5 overlapping field generations. The 2 generations of the first brood emerged during the period from half of April till half of June and proved to be suicidal since the fruiting structures suitable for infestation are not available. The 4 generations of the second brood extended during the period from early of June to the end of December. The number and durations of generations were estimated based on both zero of development (11.97°C) and the accumulated thermal units needed for completing one generation (487 DDs). The present field and laboratory studies introduce valuable information to establish a profitable model when adopting I.P.M. programs.

Key words: Pink bollworm, *Pectinophora gossypiella*, modeling, heat units, degree-days, zero of development.

INTRODUCTION

Pink bollworm (PBW), *Pectinophora gossypiella* (Saund.) has become a notorious pest of cotton in Egypt within the past decade, major outbreaks of this pest have occurred causing severe damage (El-Saadany *et al.*, 1975) and economic yield losses (60%, Schwartz 1983). Many attempts have been made for improving pest control management and recommendations are now based on preservation of beneficial insects and the utilizing of economic decision population levels (El-Shaarawy *et al.*, 1975; Singh and Sandhu 1993). It seems important to predict dates of peaks, number of field gen-

erations and size of each. In the present study, the simultaneous effect of main physical environmental (abiotic) factors was estimated.

The accumulated heat units (DDs) were needed for completing one generation was calculated and the deviations between the expected and observed generations were accordingly estimated.

The close relation between the expected and the observed population figures for the pink bollworm populations is needed when the IPM programs are considered. The population cycles based on the relation between environmental abiotic factors were evaluated as well.

In fact, this study was carried out to establish a model for forecasting the dates of maximum occurrence of moths. The properties that were considered in the present work were: generation duration, number of field generations and date of peak. This was achieved through the following steps:

1- plotting the weekly number of captured moths opposite to the corresponding date of occurrence.

2- integrating the changes in the population cycles using both methods of Audemard & Milaire (1975), Jacob (1977) and bell shaped curves.

3- counting the accumulated heat units required for completing one generation expressed as day degree temperature (DDs) (Richmond *et al.*, 1983).

MATERIALS AND METHODS

The present work was carried out to throw light on the fluctuations in the population density of *Pectinophora gossypiella* (Saund.) during three successive cotton-growing seasons (1996, 1997 and 1998) in the Agricultural Research Station, Faculty of Agriculture, Ain-Shams University, Shalakan, Qalyubyia Governorate. Monitoring the fluctuations in the population density of *P. gossypiella* male moths was conducted by using the sex pheromone traps, which continued on weekly intervals during three successive years (1996-1998). Baited Delta traps were used. Traps were distributed in density of one trap/10 feddans and number of captured moths was recorded weekly, while pheromone capsules were replaced every 2-3 weeks by fresh one.

Traps were baited with the pheromone of *P. gossypiella* formulated in polyethylene vials, which consists of the two principal isomers of gossyplure.

Meteorological factors: The following weather factor figures were obtained from the Egyptian Meteorological Authority at Kobri El-Kobba, Cairo as follows: Daily mean temperature; Daily maximum temperature; Daily minimum temperature; Daily mean nighttime temperature and Daily mean daytime temperature.

The number of the pink bollworm generations was calculated based on the number of weekly captured moths.

Statistical analysis of the data

1. Linear regression method: The theoretical development threshold values were determined according to the following:

A) The points obtained, when the time (y) in days were plotted against temperature (T) so that the distribution of these points indicates the course of temperature time curve.

B) The points obtained, when the reciprocal for time (1/y) in days were plotted against temperature (T), each of the reciprocals is multiplied by 100, so that the values on the ordinate (100/y) represent the average percentage of development made by the stage per day, at the given temperature. Therefore, the distribution of the points indicates the course of temperature- velocity curve. The value of the average percentage of development in one day that is presented within normal zone of development fitted to straight line by the method of least squares (Regression line).

C) The developmental threshold and the accumulated degree-day (DD's) values are theoretically the points at which the velocity line crosses the temperature axis is "the threshold of development in degree centigrade" (^{o}C).

2. The possibility of predicting the changes in the pink bollworm populations densities based on accumulated heat units: The role of temperature was evaluated through long-term monitoring studies to establish an index for the thermal units required to complete a given stage or entire life cycle. So, temperature data were transferred into heat units and serve as a useful tool for forecasting insect population dynamics and accordingly time of occurrence in the cotton fields.

3. Heat units calculation: The relationship between heat units required for completing one generation expressed as physiological time (DDs ^{o}C) and the population dynamic of the tested cotton pest was studied during 1997 and 1998 seasons.

Where : $H = \sum_{j-1}^{E} Hj$

H = Number of heat units to emergence

Hj = (max. + min.)/2 - C if max.> C & min. > C.

= $(max. - C)^2/2(max. - min.)$, if max.> C & min. < C.

= 0 if max. < C & min. < C.

C = Threshold temperature

4. Number of expected generations: To determine the number of the annual generations of *P. gossypiella*, the developer formula of Jasic (1975) was adopted. The first and last dates of appearance along with number of generations were determined based on sex pheromone traps data.

The temperature values were calculated by the mean of maximum and minimum temperature figures. The DDs were calculated by multiplying d by (t-x) and then were accumulated as summation of heat units. The activity periods (population cycles) were calculated by dividing the accumulated temperature on the effective temperature (y), according to the following formula:

$$g = \frac{d(t-x)}{y}$$

Where:

g = the number of probable generations.

d = the number of days in the examined period.

t = mean temperatures during the examined period.

x = the thermal threshold.

y = the total effective temperatures required for the insect development.

Daily Degree days (DDs) were calculated from the daily maximum and minimum temperatures (°C), with developed threshold value estimated at constant temperatures carried out before and zero of development equals 10.97°C. The following formula was used for computing the heat units according to Richmond *et al.* (1983)

RESULTS AND DISCUSSION

Approximated number of annual field generations of *P. gossypiella* according to the theoretical equations.

I. The seasonal activity and number of field generations: The weekly numbers of *P. gossypiella* male moths captured by sex pheromone traps were recorded and data were kept during the period extended from early May to the last week of December 1996. For 1997 and 1998 seasons, this period was extended from 1st January to 31st December.

1996 cotton growing season

a. The first brood (suicidal emergence): The integration of the data in Table 1 indicates that the PBW male moths of the first brood started to appear with reliable numbers during May. A few numbers of moths resulting from this brood escaped and survived, thus forming the 2nd brood, which is considered the most economically important. The number of moths increased quite enough to build a strong peak on 20th of June. The further integration of the seasonal activity curves indicates that the duration of this period of activity lasted for about 12-14 weeks, Fig. 1.

b. The second brood (effective emergence): The PBW moths of this 2nd brood started to appear in sex pheromone traps from the 4th week of June and extended to early of December. The second brood of moths consisted of four distinct peaks representing, theoretically, four overlapping generations.

Moths of the first generation started to appear in cotton fields of Qalyubyia Governorate possibly from mid June up to late of July. The maximum number of moths took place during the 20th of June. Moths of the second generation took place around late June and continued up till late of August. The duration of this generation lasted for 9 weeks. Its peak occurred on the 3rd week of August.

The duration of the third generation extended for 9-11 weeks from early August up to the 2nd week of October. It was observed that a great portion of this generation's larvae entered the diapausing stage during November.

It appears from the data in Table 1 that moths of the fourth generation were first detected in sex pheromone traps during October. Moths were trapped in the field for about 10-11 weeks; i.e. to the 2nd half of December. All larvae of this generation entered into diapausing stage in both green and dried bolls that usually remained attached to cotton stalks till cotton growing season of the next year.

1997 cotton growing season

a. First brood: Careful integration of the data tabulated in Table 1 and Figs. 1 & 2 indicate that pink bollworm moths were first detected in cotton fields during the second week of April. The reliable occurrence extended to the end of June. The duration of this emergence lasted for about 10 weeks. The great portion of *P. gossypiella* survivors failed to continue its life span in spite of very few numbers of larvae, which escaped, developed during the second period of activity.

b. The second brood: The second period of activity occupied the period from mid of June to the 2nd half of December. This brood demonstrates four distinct peaks representing four overlapping generations of moths.

The reliable occurrence of the first generation took place on the 3rd week of June and continued to the end of July, thus lasting for 7-8 weeks. The weekly number of moths/trap increased gradually to form the second generation, which lasted for 10-11 weeks from the 2nd half of June up to mid of August. The highest occurrence of this generation took place on first of July.

The third generation extended for 10-11 weeks, i.e. between early of August and continued to late of September. Moths of the fourth generation occurred on mid of September. This generation continued up to early of November for 10-11 weeks. A great portion of this generation larvae entered the diapause stage.

An exceptionally fifth generation occurred and it was quite weak and numbers of captured PBW moths representing this generation were recorded from the early of October up to beginning of the next year (1998). Hence, more than 90% of these second brood larvae were diapaused.

1998 cotton growing season

a. The first brood: Data tabulated in Table 1 and Figs. 1 & 2 indicate that the duration of this brood started on end of April. During the following months the number of moths increased gradually forming a small peak on 26th May, then decreased sharply

during the second half of June and early July.

b. The second brood: This brood of PBW also consisted of four successive peaks of moths' activity, thus revealing the presence of four overlapping generations from June and continued to the second half of December.

It appears from the data in Table 1 that the first generation lasted for 10 weeks from early of June to the 4th week of July. Number of captured moths increased reaching a distinct peak on 16th of July. Moths of the second generation were first detected in pheromone traps during late of June and continued to mid August (10 weeks). The maximum occurrence was observed on 14th of July.

The duration of the third generation continued from the 1st half of August and extended in reliable numbers up to the end of September. A considerable number of larvae turned to diapause during October and November. Moths of the fourth generation occurred during the 3rd week of August up to the mid of November. All larvae of this generation tended to enter diapause stage. Moths of the fifth and last generation were captured in scarce numbers during the period extended from mid of October and continued during the following months of the next year.

Generally speaking, four or five peaks were integrated during the 2nd brood of moths representing 4-5 generations as determined by the number of captured male moths during the period extended from May and June till the end of October and November in the three investigated seasons.

In Argentina, Zago (1964) showed that PBW completed six generations. Results of Ahmed (1979) in Pakistan indicated that maximum activity occurred from February to May with distinct peaks in February, March and April. Ingram (1980) in Egypt, showed that the PBW pheromone trap catches were very closely correlated with boll damage. Catches of 8-9 moths in one night represented a 10% level of boll damage. Qureshi *et al.* (1984) mentioned that the adults of *P. gossypiella* remained active throughout the year with minimum intensity during the hot period (May-July). Adult emergence in March-April proved to be suicidal, since no fruiting bodies were available in the field. Gupta and Agarwal (1983) reported highly significant differences between weekly catches of adult males of *P. gossypiella* in cotton fields. Four peaks were observed in late July, early September, late September and the 3rd week of November. The population levels were relatively low after November.

Data obtained by the authors from previous Laboratory studies revealed that the

Table 1. Theoretical calculated approximate number and duration of *P. gossypiella* generations (1996, 1997 and 1998 seasons) at Qalyubyia Governorate.

Generation No.	Duration		Generation in Weeks	Peak
	From	To		
1996 *				
1st Brood				
2nd brood				
1st	Mid of June	4th week of July	8	20th of June
2nd	4th week of June	Mid of August	9	22nd of August
3rd	1st week of August	2nd week of October	11	26th of Sep.
4th	Mid of October	2nd week of December	12	21st of November
1997				
1st Brood	2nd week of April	End of June	10	20th of May
2nd brood				
1st	Mid of June	End of July	7	10th of June
2nd	Late of June	Mid of August	10	1st of July
3rd	1st week of August	Late of September	10	26th of August
4th	Mid of September	Early of November	10	30th of Sep.
5th	Early of October	End of December	12	21st of October
1998				
1st Brood	End of April	Mid of June	9	26th of May
2nd brood				
1st	Early of June	End of July	9	16th of June
2nd	3rd week of June	2nd week of August	10	14th of July
3rd	Early of August	End of September	11	25th of August
4th	3rd week of August	2nd week of November	12	15th of Sep.
5th	1st week of October	End of December	13	27th of October

* The first brood was not detected since monitoring during 1996 began on May

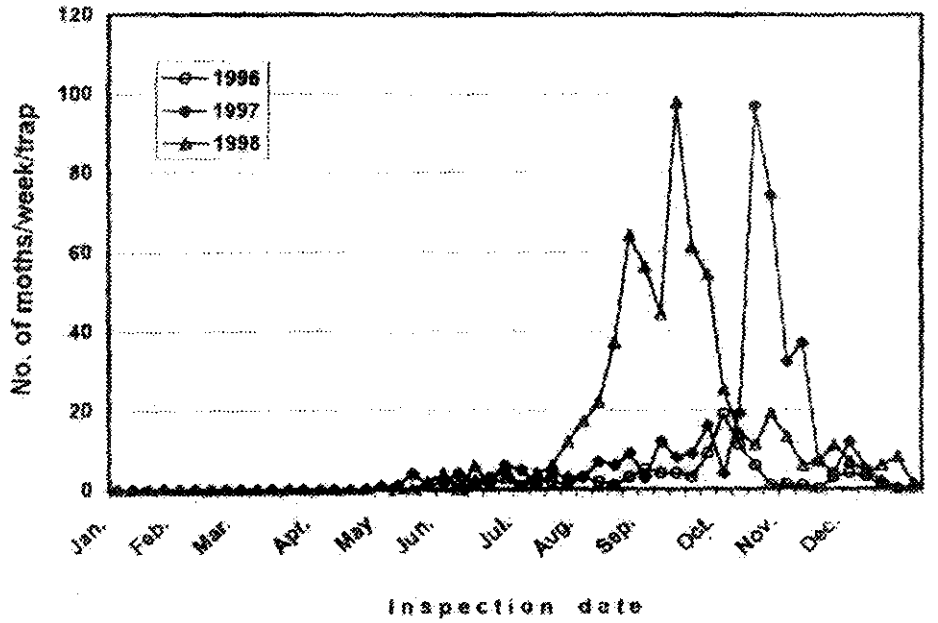

Fig. 1 : The seasonal fluctuations of *P. gossypiella* moths as indicated by pheromone traps during three successive years (1996-1998) at Qalyubyia Governorate

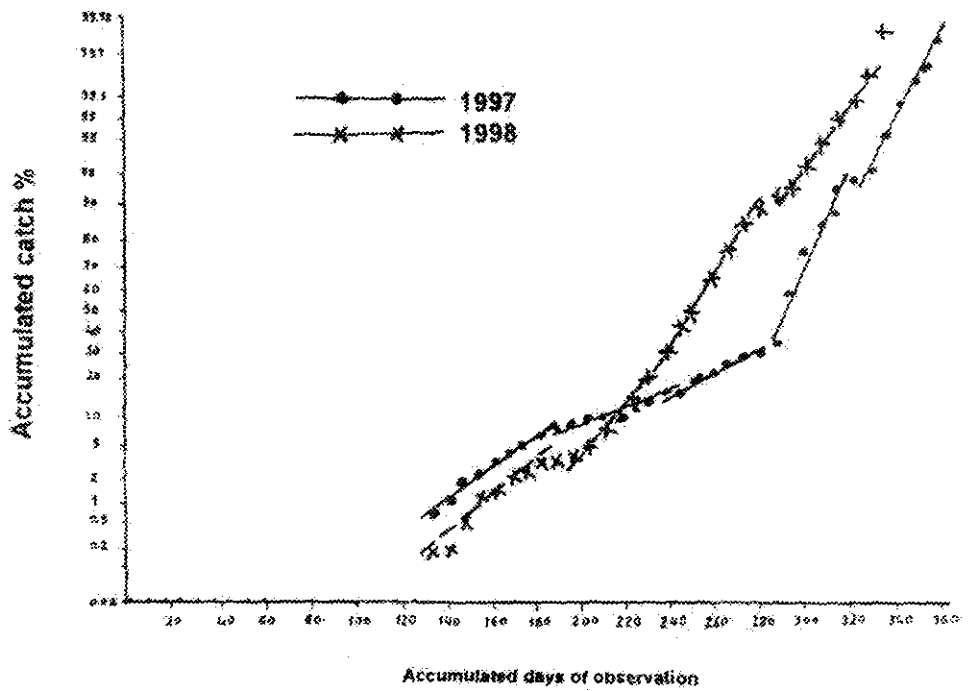

Fig. 2 : Estimated number of *P. gossypiella* field generations based on Audemard and Milaire (1975) and Jacob (1977) method at Qalyubyia Governorate.

physiological threshold of development value was estimated as 11.97oC and the total accumulated thermal units needed for completing one generation of *P. gossypiella* was 478 DDs. These requirements were taken as basis to specify the date of the real peaks and dates of generations during the three tested seasons.

II- The approximated number of the annual generations: Careful integration of the data in Tables 2-4 demonstrates the expected number of *P. gossypiella* generations at Qalyubyia district during 1996, 1997 and 1998 seasons. It is a well-known fact that the first occurrence of PBW moths commonly take place as early as January and continued up to May and June, thus forming the suicidal emergence brood of moths resulted from overwintering *P. gossypiella* larvae. This unreliable occurrence is considered not quite important due to the absence of its preferred host plant in that time. According to the calculated heat units accumulated (DDs) during the fore-mentioned months, *P. gossypiella* underwent 2 generations.

By mid-June, the favorable cotton fruiting stages, i.e. squares, flowers and green bolls are commonly occurred fit enough for feeding, thus giving the chance to go through the second period of real activity (brood). According to the temperature figures prevailed from June up to December, the accumulated heat units revealed that *P. gossypiella* had 4-5 generations during that period from which 2-3 generations are the most important from the economic point of view, Table 2-4.

From these results it appears the close harmony between the observed and expected population cycle when either the distribution curves or the method of Audemard and Milaire (1975) along with the calculation of accumulated heat units was adopted for predicting the number of generations of *P. gossypiella* in cotton fields.

Toscano *et al.*, (1979) mentioned that male moths of *P. gossypiella* exhibited cyclic population peaks at intervals of 231276±1154 DDs. These findings should reduce the monitoring period for pink bollworm on cotton by allowing checking of sex-lure traps only at critical periods. Moftah *et al.* (1988) suggested that trap catch data, as related to day-degrees, may be used to describe seasonal male trap catch increases as a reflection of increasing *P. gossypiella* populations and that male trap catches and day-degree relationships provide the potential for developing an economic level decision-making tool.

Generally, it could be concluded that determination of the developmental threshold value and the accumulated thermal units (DDs) required to complete a generation should have valuable information in predicting cotton infestation when a good parame-

ters expressed as dates of peak occurrence of male moths which represented the actual observed peaks and the corresponding expected generations are considered. The obtained results will be helpful when successful I.P.M. control tactics for cotton pest are designed.

The precise knowledge of appropriate dates of bollworm moths appearance from the one hand and number and duration of its field generations form the other, are considered as a true basic information for IPM programs. Results of many authors confirm this point; Bishara (1936) reported that maximum emergence of *P. gossypiella* moths from the resting larvae occurred between April and mid-May. Moderate numbers emerge during June and July and occasionally until September. El-Sayed and Rustom (1960) mentioned that maximum emergence of moths from the diapausing larvae occurred between March 19 and April 27 with the first increase in temperature in the next year. The same results were obtained by Stern and Sevachenan (1978) in California; Ahmed (1979) in Pakistan; Abdel-Megeed et al. (1979) in Egypt. Qureshi *et al.* (1984) in Pakistan, believed that *P. gossypiella* adult emergence in March-April proved to be suicidal since no fruiting bodies are available in the field for them to infest. Hossein (1990) found that moth activity formed two conspicuous annual broods, the first extended from April to early July and the second from about mid-May to the end of November. Romeila (1997) concluded for his work that *P. gossypiella* had two main periods of moths' activity; the first extended from March to June and consisted from 1-2 generations. The second period, however, from late June to late November during which moths underwent four field generations.

Table 2. The calculated number of ***P. gossypiella*** generations as determined by DD° at Qalyubyia Governorate during 1996.

Month	Mean temperature		DDo	d	d*DD°		No. of generations
	Max.	Min.					
January	19.80	7.05	1.921	31	59.55		
February	21.22	8.11	2.704	29	78.42		
March	23.37	9.88	4.141	31	128.37		2
April	26.13	10.87	5.822	30	174.66		
May	32.93	15.92	11.625	31	360.38	Suicidal emergence	
June	33.45	18.09	12.970	30	389.10		
July	32.64	20.51	13.775	31	427.03		
August	33.94	21.12	14.730	31	456.63		
September	33.96	18.79	13.575	30	407.25		4
October	29.06	16.15	9.805	31	303.96		
November	26.19	13.73	7.155	30	214.65	Effective emergence	
December	21.96	9.15	3.275	31	101.53		
Total					**3101.51**		

Table 3. The calculated number of ***P. gossypiella*** generations as determined by DD° at Qalyubyia Governorate during 1997.

Month	Mean temperature		DDo	d	d*DD°		No. of generations
	Max.	Min.					
January	18.80	6.10	1.417	31	43.93		
February	17.70	5.08	0.951	28	26.63		
March	19.26	7.04	1.707	31	52.92		2
April	22.38	9.83	3.656	30	109.68		
May	31.35	14.97	10.360	31	321.16	Suicidal emergence	
June	33.86	19.74	14.000	30	420.00		
July	33.82	20.20	14.210	31	440.51		
August	32.30	19.78	13.240	31	410.44		
September	31.54	18.00	11.970	30	359.10		4
October	28.50	16.78	9.840	31	305.04		
November	25.85	13.15	6.700	30	201.00	Effective emergence	
December	20.00	8.30	2.215	31	68.67		
Total					**2759.07**		

Table 4. The calculated number of ***P. gossypiella*** generations as determined by DD° at Qalyubyia Governorate during 1998.

Month	Mean temperature		DDo	d	d*DD°		No. of generations
	Max.	Min.					
January	18.63	7.40	1.513	31	46.90		
February	20.20	8.27	2.295	28	64.26		
March	21.42	7.90	2.747	31	85.16		2
April	29.43	13.32	8.585	30	257.55		
May	32.28	17.30	11.990	31	371.69	Suicidal emergence	
June	34.64	19.50	14.270	30	428.10		
July	35.30	20.12	15.210	31	471.51		
August	36.85	21.37	16.310	31	505.61		
September	36.25	19.23	14.940	30	448.20		5
October	33.36	16.63	12.190	31	377.89		
November	26.90	14.70	10.700	30	321.00	Effective emergence	
December	22.60	9.40	5.900	31	182.90		
Total					**3560.77**		

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نموذج للتنبؤ بالتغيرات المستقبلية فى نشاط مجاميع فراشات دودة اللوز القرنفلية

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٢ - قسم بحوث الديدان القارضة - معهد بحوث وقاية النبات - مركز البحوث الزراعية - الجيزة - ج.م.ع
٣ - قسم بحوث سمية المبيدات لمجتمعات الآفات - المعمل المركزي للمبيدات - مركز البحوث الزراعية - الجيزة - ج.م.ع

أجريت الدراسة بمحافظة القليوبية فى مصر على مدى ثلاث سنوات متتالية (١٩٩٦ - ١٩٩٨) بأخذ قراءات أسبوعية لذكور فراشات دودة اللوز القرنفلية والتى تم جمعها بإستخدام المصايد الفرمونية خلال الفترة من يناير حتى ديسمبر بإستثناء العام الأول والذى أخذت فيه النتائج بدءاً من شهر مايو حيث جمعت النتائج فى جداول خاصة بذلك . تشير النتائج المتحصل عليها إلى أنه - بعد الخروج من طور السكون - كان للحشرة فترتى حضنة فى كل عام وكان لها جيلان فى فترة الحضنة الأولى ، بينما إستمرت من ٤ - ٥ أجيال حقلية متداخلة خلال فترة الحضنة الثانية . إستمر خروج فراشات فترة الحضنة الأولى خلال الفترة من منتصف أبريل حتى النصف الأول من شهر يونية وهى تعتبر أجيالاً إنتحارية حيث لا تتوافر التراكيب الثمرية المناسبة للأصابة فى تلك الفترة . تستمر أجيال فترة الحضنة الثانية (أربعة) خلال الفترة من بداية يونية الى نهاية ديسمبر . وقد قدر عدد ومدة تواجد هذه الأجيال حسابياً على أساس أن صفر النمو لهذه الحشرة يبلغ ١١,٩٧ م° وأن الوحدات الحرارية التراكمية اللازمة لإكمال جيل واحدتبلغ ٤٨٧ وحدة حرارية .