A SIMPLE EMPIRICAL MODEL FOR PREDICTING THE DEVELOPMENT AND FIELD GENERATIONS OF SOME COTTON INSECT PESTS IN EGYPT

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ABSTRACT

Field studies conducted during 2000 cotton growing season in three Governorates, to detect the adult population of the pink bollworm, *Pectinophora gossypiella* and cotton leafworm, *Spodoptera littoralis* using funnel pheromone traps. Field generation numbers, life table parameters for field, thermal requirements and heat unit's accumulation was used. *Pectinophora gossypiella* showed 3 generations in cotton, *Spodoptera littoralis* was found to have 4 generation in cotton. Generations occurred at an average of 553 and 445 DD's for pink bollworm and cotton leafworm respectively.

INTRODUCTION

Cotton in Egypt, is subjected to yield and quality losses by insect pests. The Pink bollworm (PBW), *Pectinophora gossypiella* and Cotton leafworm, (CLW), *Spodoptera littoralis* are remaining the most destructive pests causing significant losses to the yield. Larvae feeding within boll basis most economic losses caused by these pests. PBW and CLW are major cotton pest in Africa and the Middle East (Pearson, 1958; Avidov & Harpaz, 1969). Since the larvae penetrate the bolls soon after hatching, efficient control by insecticides is hard to achieve. In addition, application of toxic insecticides may result in increased pest resistance to insecticides, interference with the activity of beneficial insects, environmental pollution, and hazards to public health. The reduction of insecticidal applications in cotton is, therefore, of great correspondence. Cotton bollworm has a number of difficult problems regarding sampling techniques, i. e. (A)- larvae feed inside the green bolls causes special difficult in estimation the population density in the developmental stages of these insect pests. (B)- PBW and CLW have variable numbers of annual generations. Amin et al (1999) found that PBW showed four generations. CLW found to has seven overlapping generations annually by many authors (Bishara 1926, Abdel-Badie 1977 and Dahi 1997). The indiscriminate use of insecticides has caused a number of problems to various ecological niches around the world including Egypt. Hence there is a growing necessity and interest in the use of Ecological approaches for management these pests.

The rates of development in insects under natural conditions are largely determined by temperature. In most microenvironments, temperature is characterized by daily and seasonal cyclic variations with superimposed irregular fluctuations. However, studies of insect development rate most often involve experiments performed under constant temperatures (Howe 1967). In the development and application of development-rate models, it is always assumed that development rate at a given temperature is independent of thermal regime, whether the model is linear or nonlinear in relation to temperature. This assumption is also inherent in efforts to derive development-rate models from data obtained under varying temperatures, such as the work by Dallwitz & Higgins (1978). According to this assumption, development rate follows a definite function with respect to temperature, when other factors are equal, and the amount of development can be calculated by ac-cumulating the fraction of development per unit time; i.e., rate summation (Kaufmann 1932). The procedure may be expressed as:

$$D = f\ r\ [T\ (t)]\ DT$$

Where development D is a function of temperature, T, which in turn is a function of time, t, and the development rate, r; adjusts instantaneously to temperature. The above assumption is fundamental to the formulation of development-rate functions for phenological models. Attempts to study the validity of this assumption are numerous in entomological literature, and both positive and negative results have been reported (Hagstrum & Hagstrum 1970, Ratte 1984). Life table studies are fundamental to not only demography but also too general biology. In such studies, development tunes and survival rates of each stage, longevity of adults, and the daily fecundity of females are recorded for every individual. Using elementary statistics, means and standard deviations can be calculated. In traditional life-table analysis, these means are used to calculate age-specific survival rates and age-specific fecundity using either the

Leslie matrix (Leslie 1945) or Birch's method (Birch 1948). These procedures have been widely used by researchers in many different fields (Laing 1969, Shib et al. 1976, Cave & Gutierrez 1983, Vargas et al. 1984, Carey & Vargas 1985). However, variation in development rate is well known, even when a population is kept under constant laboratory conditions. The range of variation depends on many factors (for example, temperature and food). To assume that all individuals have the same development rate is biologically unrealistic and may be misleading. Therefore, ignorance of such variation when using either the Leslie matrix or Birch's method should be carefully considered. The method of incorporating this variation is the use of distributed delay theory in modeling (for example, Gutierrez et al. 1984, Plant & Wilson 1986). On the other hand, Chi & Liu (1985) developed an age-stage life table theory for both sexes, incorporating variable developmental rates among individuals. In comparison with the distributed de-lay models, Chi & Liu's model is different in that both sexes were included, and variation in development rates was integrated sequentially for all stages and expressed in the form of a stage distribution. The stage structure of a population can also be calculated in Chi & Liu's model. Furthermore, most life-table analyses have been concerned only with the "female" population. Most lepidopteran, coleopterast, and orthopteran pests are not parthenogenetic, however, and both males and females are economically important. Moreover, the development rate may differ between the sexes. Susceptibility to either chemical or biological control agents may be quite variable among stages and sexes. These and many other differences among stages and sexes explicitly point out the inadequacy of the female age-specific life table. In addition, whether to calculate the intrinsic rate of increase of a "female" population or of the population as a whole is a central question in ecology. In the theoretical model of Chi & Liu (1985), the population parameters are calculated with respect to both sexes and incorporating variable developmental rates among individuals. However, the major obstacle in taking the variable developmental rates and tire male population into account is the difficult and tedious work of applying the age-stage, two-sex life table theory to the raw data analysis.

The number of days between observable events, such as cotton seedling emergence and first squares of the duration of insect generations can characterize the growth and development of plants and insects. The number of days between events, however, may be misleading because growth rates vary with temperatures. The measurement of events can be improved by expressing development units in terms of the temperature and time. The deviation between events is then based on accumulated degrees per unit time above a lower temperature re-presenting a threshold of growth.

The present work aimed to predicate the population size of PBW and CLW using pheromone traps (2000) in three Governorates i.e. Sharkia, Bani-Sweif and Minia. Field generation numbers were estimated. Life table parameters for field data were established. Thermal requirements and accumulation heat units were used.

MATERIAL & METHODS

This study was carried out during 2000 cotton growing season in three Governorates, i.e. Sharkia, Bani-Sweif and Minia (Sharkia in Lower Egypt and Bani-Sweif and Minia in Middle Egypt). The experimental area in each location was about 30 feddans cultivated by cotton. Funnel pheromone traps were baited with the specific pheromone capsules of PBW and CLW. The PBW lure formulation is 1:1 mixture of (Z, Z)-7,11-hexadecadienyl acetate (Z, 7,Z11-16: Ac) and (Z, E)- 7,11-hexadecadienyl acetate (Z, 7, Z11-16: Ac). CLW capsule pheromone consist of 1:1 mixture of (Z, 9 E11-Tertradecadienyl Acetate) and (Z, 9 E12-Tertradecadienyl Acetate). Traps were installed during the period extended from January to December 2000. Traps were examined every three days and the numbers of the captured adult moths recorded. New pheromone capsules were replaced every two weeks in hot weather and 3-4 weeks in cold weather.

Field Generations:

The numbers and duration of annual generations of PBW and CLW were worked out by: Richmond *et al* formula (1983) using daily minimum and maximum air temperature that adopted to compute the heat units' summation as a first step in forecasting the occurrence peaks and generation duration.

Life table parameters:

The definition of the innate capacity for increase (rm), as the maximal rate of increase attained at any, particular, combination of temperature, moisture, quality of food, and so on, when the quantity of food, space and other animals of the same kind are kept at an optimum and other organisms of different kinds are excluded from the experiment. This is an approximate definition because it does not mention the distribution of ages in the population.

The intrinsic rate of natural increase take into account the change in birth rates and death rates with age. The rate of increase of a population which has an assumed constant age-schedule of births and deaths and which is increasing in numbers in an unlimited space is given by:

$\delta N/\delta t = bN - dN$

Where t denotes time and b and d are constants representing the instantaneous birth rate and death rate. Now b - d is the infinitesimal rate of increase which is the innate capacity for increase, rm. Hence

$\delta N/\delta t = rm\ N$ In the integration form

$Nt = N0e\ rmt$ Where

N0 = number of insects in time zero

Nt = number of insects in time t,

rm = innate capacity for increase,

e = base of Naperian logs

Net reproductive rate (Ro) was calculated according to Birch (1948) formula: rm= Loge Ro / T.

The sex ratio of the two tested pests almost equal (1:1), hence, captured male moths were used to determine the growth rate (rm) according to the fore equations.

RESULTS AND DISCUSSION

1-SEASONAL FLUCTUATIONS:

1-1-Pink bollworm, *Pectinophora gossypiella*

Figs (1-3) illustrating the numbers adult males of PBW caught by funnel pheromone traps during 200-cotton season in three Governorates, i.e. Sharkia, Bani-Sweif and Minia (Sharkia in Lower Egypt and Bani-Sweif and Minia in Middle Egypt).

1-1-1-Sharkia Governorate

During the 2000 season (Fig. 1) the flight activity of PBW, as total number of adults was recorded throughout the seven months (April to October). Also, from the obtained results it could be seen that the insect has two pronounced periods of flight activity, one in spring during May and the other one in the Summer during June-October (Fig. 1). On the other hand, Male moths were started the attraction by lure traps on April 28th with an average of 9 moths/ trap/3 days, then the population increased gradually to reach the first peak 85 moths/ trap on May 22nd. That considered the important peak because it represents the over-wintering peak, for building up the next generations in cotton. The obtained data presented more details about the relation between the effect of temperature on the flight activity and its period (Fig.1). Statistical analysis was carried out, and a positive correlation ($r2 = 0.9929$) was found between the accumulated thermal units (DD's) and the corresponding population peaks. Real peaks were found to be not less than 5 weeks, accordingly, nine peaks were determined (Fig.1). The first one represents adults coming from the suicidal emergence on May 22. The next eight peaks, P1, P2 P3, P4, P5, P6, P7 and P8 were on 15th and 30th of July 17 and 29th of August 4, 16th, and 25th of September 7 October, respectively. The fore eight peaks were distributed in three broods that represent three generations. P2 and P3 made the brood of first generation. The second brood considered the offspring of the first one. This generation also was formed from two peaks i.e. P4 and P5. The third brood was consists of four peaks i.e. P6, P7, P8 and P9. This brood was the biggest one and formed the third generation that will enter diapause and came from the second one.

1-1-2- Bani-Sweif Governorate

Fig (2) illustrates the seasonal abundance of PBW in Bani Sweif Governorate during 2000 cotton growing season. As it appears from the figure there are 13 peaks demonstrate the activity of PBW male moths. The 13 peaks are distributed in four broods. P1 and P2 represent the first brood that coming from the suicidal emergence and happened during the period extended from 19/5 to 25/5. The first generation consisted of P3, P4, and P5 that happened on 15th, 24th and 30th of June. The third brood consists of five peaks i. e. P6-P10 that extended from mid July until the third week of August and considers the main period of activity. The fore peaks represent the PBW second generation. These peaks happened on 12/7, 21/7, 2/8, 8/8 and 17/8 respectively. Third generation (termination generation) occurred during the third week of August until 1 October. This generation consists of three peaks (P11-P13). The observed peaks appeared on 9/1, 16/9 and 1/10 respectively.

1-1-3- Minia Governorate

Data in Table (3) and Fig (3) summarizes the field generations and peaks of activity of PBW during 2000 season in Minia Governorate. The first generation was established from the suicidal emergence. The emergence of adult moths started from 12 April and continued until the end of May. This generation showed four peaks of moth's activity. The four peaks were recognized on 5th, 17th, and 26th of June and 17th of July respectively. The second generation (second brood), two distinguished peaks were clearly identified as P5, and P6. The brood of activity of F2 occurred during a narrow period of time (July-August). These peaks happened on 7th and 28th of August. The third generation was happened in 2 peaks i.e. P7 and P8 on 15th of September and 12th of October respectively.

1-2- Cotton leafworm, *Spodoptera* littoralis

Cotton leafworm, CLW, behavior and its damage to cotton plants is completely different than PBW. CLW existing allover the year with no diapause or dormancy. The CLW is a Pollyphegous insect that has a wide range of hosts for feeding, it feeds on the cotton leaves, buds, flowers and bolls.
The main goal of this point is to study the flight activity of male moths of CLW to estimate the number and occurrence dates, thereafter bind the peaks of moth occurrence with the corresponding thermal units and estimated the number of generations with observed and predicted peaks to accurate the timing and method of control in cotton fields during 2000-season.

1-2-1-Sharkia Governorate

The actual figures of the number of male moths/trap/3 nights are presented in Table (4) and graphically illustrated in Fig. (4) through the above mentioned season. Data in Table (4) demonstrated those four main peaks of male moths occurring during the investigated season. The four main peaks occurred during a period extended from the 10th of May to the 10th of Oct. It is evident from the data that the occurrence of male moths by the 10th of May was in relatively low number (only 2.25 male moths/trap/3 nights) and increased gradually to reach its main peak on June 12 where the number reached an average of 25.25 males. The number and date of occurrence of male moths main peaks appeared during the investigation period were 28.25 males at the 12th of June; 173.5 males at the 27th of June; 55.25 males at the 2nd of August and 27 males at the 1st of Sep. A minor peak occurred during this period (11th of August) (Fig. 4).

1-2-2- Bani-Sweif Governorate

The seasonal fluctuation of the Spodoptera littorals male moths during 2000 season in Bani-Sweif Governorate revealed the same trend of Sharkia Governorate, where three main peaks with highly average of male moths appeared during the above mentioned period with five minor peaks, (Fig. 5). The number of captured male moths started relatively higher in this location than the previous one and tended to increase gradually till reaching the first main peak (116.25 males) on May 31. The average of male moths recorded of 163.5 and 251 males at the 14th of August and 25th of September respectively. The Five minor peaks were recorded on June 12 with an average of male moths 93.5; July 27 (43.5); August 20 (132.5) and 16th of September (123.5). The smoothing of these data using running mean average for three days intervals revealed three distinguished peaks that the main peaks.

1-2-3- Minia Governorate

Data illustrated in Fig (6) show the seasonal fluctuations of CLW in Minia Governorate during 2000 cotton growing season. As it appears the moths was recorded since 23 April. Moth's numbers were attracted to the traps in regular pattern and then happened one shot at the second of July, where the numbers were reached to 378 moth/trap/week. This means that there were one big peak and four relatively small. The five small peaks were recorded on May 21, June 4, August 20 and September 17. The average number of captured moths were 99, 118, 35 and 49 respectively.

<u>2-ESTIMATION OF FIELD GENERATIONS</u>:

The numbers and duration of annual generations of PBW and CLW were worked out by: Richmond et al formula (1983) using daily minimum and maximum air temperature that adopted to compute the heat unit's summation as a first step in forecasting the occurrence peaks and generation duration.

2-1-Generation of Pink bollworm, *Pectinophora gossypiella*

2-1-1-Sharkia Governorate

According to Naranjo, and Martin (1993). The lower threshold for PBW development was used as 12.6 oC. Degree-day accumulations required for each stage of development: start of spring emergence: 655.6, peak of spring emergence: 486.1, and of spring emergence1250.0 and summer generation time (adult to adult): 444.4 DD's. The author in unpublished work found the lower threshold for PBW development was 12.97 oC for Sharkia PBW biotypes, and summer generations need 554.32 DD's for completion of one generation. Working out with these finding, the spring peak happened on May 22nd with summation heat units from 1 January 1006.87 DD's. Table (7) and Fig. 1 demonstrated the occurrence of observed and predicted PBW peaks. The accuracy of prediction ranged from -3 to +3 days proceeding the real observed peaks.

2-1-2-Bani-Sweif Governorate

Table (8) summarizes the field generations of PBW in Bani-Sweif Governorate during 2000 cotton growing season. The calculation of heat units' summation was based on the lower and upper thresholds of 12.84 and 33 oC. The DD's required for completing one generation is 579.37 DD's. The accuracy of prediction ranged from -2 to +2 days proceeding the real observed peaks.

2-1- 3- Minia Governorate

The same pattern of Bani-Sweif Governorate, happened in Minia Governorate. The calculation of heat units' summation was based on the lower and upper thresholds of 12.84 and 33 oC. The DD's that required for completing one generation is 579.37 DD's. Table (9) summarizes the field generations of PBW in Minia Governorate during 2000 cotton growing season. The accuracy of prediction ranged from -1 to +3 days proceeding the real observed peaks.

The obtained results were found to be in a harmony with the finding of many authors in different countries in the world. Rice and Reynolds, 1971 revealed that the first population peak (the emergence of moths from over-wintering larvae) occurs in mid-May, the second in July and the subsequent peaks ca. 35 days apart, depending on temperature. Beasley and Adams in California used 13.9/32.8-degree C thresholds, the degree-days for one generation, adult to adult, was determined to be 492 DD. These field-derived thresholds corresponded well with thresholds obtained by some researchers using constant temperature laboratory trials. Amin and Abdel-Meguid (1993) In Egypt used heat accumulation for timing of PBW occurrence in Menoufia Governorate. They found that the cyclic population peaks happened at intervals of 470 ± 0.624 DDS.

2-2-Generation of Cotton leafworm, *Spodoptera littoralis*

The aim of this part of investigation is the studying of using heat summation technique to predict CLW population peaks to determine the influence of temperature in the emergence and development of this insect population.

2-2-1-Sharkia Governorate

Using the lower threshold (12.91 0C) previously estimated from the laboratory experiments, it was found that the average of thermal units 454.55 DD's was (Table 4). The successive population peaks followed the peak of winter generation occurred in cycles which differed in period and length during cotton growing season. The dates of observed and predicted peaks of generation depended mainly on the highest number of males catches (for observed) and the accumulation thermal units (for predicted). Table (10) shows the observed and predicted peaks and the devotion from each other.

2-2-2- Bani-Sweif Governorate

The lower threshold for this Governorate was (12.57 0C) and the heat units required completing one generation is 476.16 DD's. From data in table (5) and Fig (5), it appears that CLW had three distinguished generations during cotton growing season. CLW population appeared during the tested season depended mainly on the number of male moths occurred during May and early June where the males occurred during that period emerged from the brood reared on Berseem and other host plants during winter. If the occurrence of the male moths was high during May, the insect population should be high during the main successive occurrence and vise versa, but the next generation that coming from May and June are very weak. The explanation of this case may be due to two reasons a) Hand picking of CLW egg masses during May and subsequent low generation numbers b) the insecticidal application for PBW at the beginning of July. Table (11) illustrated the observed and predicted generations of CLW and the devotion of the accuracy.

2-2-3- Minia Governorate

The lower threshold for this Governorate was (12.57 0C) and the heat units required completing one generation is 476.16 DD's like Bani-Sweif Governorate. From data in table (6) and Fig (6), it appears that CLW had three distinguished generations during cotton growing season. The most important peak happened on July 2 forming the biggest generation (second generation in cotton. The first generation formed from a brood contains two peaks (May 21 and June 4). The third generation also contained two peaks; August 20 and September 17. The relation between observed and predicted peaks appears clearly in Table (12).

3- LIFE TABLE PARAMETERS:

Any insect living in a particular environment be expected to grow at a certain rate, to live for a certain period, and to produce a certain number offspring, usually spread over a certain span of its life. For any one species, each individual in the population will have its own particular speed of development, longevity, and fecundity at different ages in its life. It is usually more useful however, to speak of the mean values for the population. There will be a mean rate of growth of individuals in the population; a mean longevity which is more usefully considered as a distribution of ages at which different individuals die; and a mean fecundity, which is more usefully considered as mean birth-rates at different ages of the mothers. The values of these means are determined in part by the environment and in part by a certain innate quality of the animal itself. This quality of an animal we may call its innate Capacity for increase (rm). Nevertheless, the innate capacity for increase is a quality which is just as characteristic of the species as is, for example, its size it is, however, a character that is more difficult to measure and define, since it may vary widely in different environments. The analogy with size may be carried a little further, for it is well known that for some insect the size may vary with such components of the environment as temperature, moisture, food, and so on. Nevertheless, as a rule, ordinary variations in the environment may not make much difference to the size of the insect, and it is often sufficient to define size without any special reference to the environment from which the animal has come. On the other hand, relatively small changes in one or another component of the environment may result in enormous differences in the ani-mal's innate capacity to increase; so when this character is being considered, it is always necessary to define very carefully the particular environment in which the animal is living.

In the present work we tried to measure the environmental effect on the intrinsic rate of increase in different locations that may be different ecological systems.

3-1-1- Pink bollworm, *Pectinophora gossypiella*

3-1-1-Sharkia Governorate

Data in Table (1) show the life tables parameters of PBW in different generations in the 2000 cotton-growing season. As it appears from the table, the three generations had almost equal (rm) values (0.038,0.027 and 0.0252) respectively, consequently the (Ro) value were at the same range (4.63, 6.054 and 4.95) respectively. The finite rate of natural increase (λ) also followed the same pattern and its values were (1.0427, 1.0283 and 1.0262) for the three generations respectively. The generation time (T) in the distinguished generation was almost the same (36.6, 32.3 and 35.25 days).

3-1-2- Bani-Sweif Governorate

The careful examination of the data represents in Table (2) for Bani-Sweif Governorate gave the conclusion of that obtained in Sharkia Governorate. (r_m) values were: 0.0058 for the first generation, 0.0077 for the second and 0.005087 for the third one. (Ro) value were 1.99, 1.79 and 1.57 for the three generations respectively. The finite rate of natural increase (λ) values were 1.006, 1.008 and 1.005 respectively. The generation time (T) in the distinguished generation was (38.2, 45.8 and 48 days) respectively.

3-1--3- Minia Governorate

Minia pattern was slighting different of the fore two patterns (Sharkia and Bani-Swief). The first two generations had positive (rm) values, but the third one had negative value, this may be due to the intensive use of pesticides in this area. Data in Table (3) gave the summary of life table parameters. The (r_m) values were 0.0137, 0.0187 and -0.01313 respectively. According to the negative (rm) value in the third generation, the (Ro) and (λ) values were affected, but the generation time did not affected that were 42.3, 40.6 and 40 days respectively.
The examination of the above results did not show big differences of life table parameters within the three tested locations. The slight differences obtained may be due to the planting date in every Governorate that led to existing of the plant receptors in different times

3-2-Cotton leafworm, *Spodoptera littoralis*

3-2-1-Sharkia Governorate

Data in Table (4) show the life tables parameters of CLW in different generations in the 2000 cotton-growing season. As it appears from the table, the four generations had different (rm) values (0.0661, -0.66, 0.028 and zero) respectively. The negative and zero values revealed that the population was declined and the decline happened in the middle of season that corresponding the insecticidal application for PBW, which its effect extended directly to CLW population. As a result of the application treatment all the parameters affected. Ro values were fluctuated also and were 8.81 for the first generation, 0.161 the second generation, 0.000028 for third and zero for the fourth one. The finite rate of natural increase (λ) also followed the same pattern and its values were (1.072, 0.9397, 0.6971 and 0.3233) for the four generations respectively. The generation time (T) in the distinguished generation was almost the same (31.1, 29.3, 29 and 30 days).

3--2-2- Bani-Sweif Governorate

In Bani-Sweif Governorate the situation was quit different than in Sharkia. CLW had only three generations in cotton. The first two generations showed negative (rm) values (-0.01337 and -0.01051) respectively while the third one was positive (0.01667). The explanation of this case means that insecticidal application started earlier, so first and second generations affected, while the population recovered gradually and showed slow increase in population growth. As usual the rest of life table parameters were affected showing poor Ro and (λ) values, while the generation time (T) was normal (Table 5).

3-2-3- Minia Governorate

Table (6) and Fig (6) expressing the real situation in Minia Governorate during cotton growing season. Because Minia is the extension area of Bani-Swief, the situation there is similar. Positive and poor (r_m) value for the first generation and negative for the next two generations (0.0315, -0.0203, and -0.02391) respectively. The net reproductive rate (Ro) values were 3.644, 0.478 and 0.453 for the three generations respectively. The finite rate of natural increase (λ) values were 1.032, 0.9808 and 0.9770 respectively.

These results agree with those obtained by Abdel-Badie (1977) and Mohamed (1977) on S. littoralis; Clement et al, 1979 on A. ipsilon; Potter et al, 1981 on *H. virescens* and Moftah et al, 1988 on *P. gossypiella*. These results would reduce the monitoring period for PBW and CLW on cotton field by allowing checking of sex - lure traps only at critical periods. Also, it is better for good prediction to have periods between predicted dates and actual observed dates as short as possible and to be before not after observed dates. This should also minimize generally the costs of control. On the other hand, when the accumulated degree- days above threshold of development for generation confirmed (or did not differ significantly) from those calculated from laboratory study, however, these techniques are considered as valuable tools in pest management programs. Life table parameters also, help in the evaluation of IPM program in cotton fields.

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Table (1) Field Life Table parameters for PBW in Sharkia. 2000

Generations		DD's	R_0	r_m	T	λ
First	22/5 to 30/6	560	0.0588	-0.0745	38	0.9281
	9/6 to 15/7	549.62	86	0.1237	36	1.1317
	24/6 to 30/7	566.67	10.769	0.0660	36	1.0682
Average		**558.76**	**32.276**	**0.0383**	**36.666**	**1.0427**
SD ±		**8.5920**	**46.833**	**0.1019**	**1.1547**	**0.1041**
Second	15/7 - 17/8	546	1.8720	0.0195	32	1.0197
	30/7 - 1/9	526.04	0.4928	-0.0221	32	0.9781
	30/6 - 2/8	524.26	15.8	0.083637	33	1.0872
Average		**532.1**	**6.0549**	**0.0270**	**32.333**	**1.0283**
SD ±		**12.070**	**8.4675**	**0.0532**	**0.5773**	**0.0550**
Third	17/8 -22/9	560.68	0.9192	-0.0024	35	0.9975
	1/9 - 07/10	549.88	2.1159	0.0202	37	1.0204
	2/8 - 4/9	524.26	15.8	0.0836	33	1.0872
	4/9 - 10/10	547	0.9864	-0.0003	36	0.9996
Average		**545.45**	**4.9554**	**0.0252**	**35.25**	**1.0262**
SD ±		**15.307**	**7.2505**	**0.0402**	**1.7078**	**0.0419**

Table (2) Field Life Table parameters for PBW in Bani Swief, 2000

Generations		DD's	R_0	r_m	T	λ
First	22/5-30/06	572.2	0.261905	-0.03526	38	0.965357
	15/6-27/07	594.8	3	0.029692	37	1.030137
	3/6-12/07	591.5	0.920635	-0.00212	39	0.997882
	16/5-24/06	576.3	0.857143	-0.00406	38	0.995952
	12/6-21/07	572.9	4.933333	0.040923	39	1.041772
Average		**581.54**	**1.994603**	**0.005836**	**38.2**	**1.00622**
SD ±		**10.774**	**1.942706**	**0.030208**	**0.836**	**0.030335**
Second	30/6-14/08	559.4	2.363636	0.01955	44	1.019742
	27/7-16/09	575.23	2.159	0.016	49.00	1.016
	12/7-01/09	559	0.310345	-0.02438	48	0.975918
	24/6-02/08	523	3.2	0.029824	39	1.030274
	21/7-10/09	560	0.918919	-0.00173	49	0.998276
Average		**555.32**	**1.790464**	**0.007797**	**45.8**	**1.008009**
SD ±		**19.320**	**1.162088**	**0.021283**	**4.324**	**0.021326**
Third	14/8-01/10	578.4	2.538462	0.020251	46	1.020458
	2/8-22/09	588.4	0.604167	-0.01008	50	0.989973
Average		**583.4**	**1.571314**	**0.005087**	**48**	**1.005215**
SD ±		**7.0710**	**1.367753**	**0.021446**	**2.828**	**0.021556**

Table (3) Field Life Table parameters for PBW in Minia, 2000

Generations		DD's	R_0	r_m	T	λ
First	15/5-26/06	564.5	1.9642	0.01646	41	1.01660
	8/6-20/07	600.3	0.7	-0.00849	42	0.99154
	3/5-17/6	570.8	4.3157	0.03323	44	1.03379
Average		**578.533**	**2.3266**	**0.01373**	**42.333**	**1.01398**
SD ±		**19.1118**	**1.8349**	**0.02099**	**1.5275**	**0.02124**
Second	26/6-07/08	601	1.1181	0.00266	42	1.00266
	20/7-31/08	581.9	11.857	0.06031	41	1.06217
	17/6-26/07	563.14	0.7682	-0.00676	39	0.99326
Average		**582.013**	**4.5812**	**0.01873**	**40.666**	**1.01936**
SD ±		**18.9302**	**6.3035**	**0.03631**	**1.5275**	**0.03736**
Third	7/8-15/09	536.6	1.2195	0.00522	38	1.00523
	31/8-12/10	564.8	0.8433	-0.00415	41	0.99585
	26/7-06/09	578.5	0.1904	-0.04044	41	0.96036
Average		**559.966**	**0.7511**	**-0.01313**	**40**	**0.98715**
SD ±		**21.3640**	**0.5206**	**0.02411**	**1.7320**	**0.02366**

Table (4) Field Life Table parameters for CLW in Sharkia , 2000

Generations		DD's	R_0	r_m	T	λ
First	10/5-12/6	445.9	38.777	0.11430	32	1.12109
	25/5-27/6	474.7	86.75	0.13947	32	1.14966
	6/6-6/7	450.4	0.1906	-0.05524	30	0.946262
Average		457	41.906	0.066181	31.333	1.072341
SD ±		15.4929	43.364	0.105899	1.1547	0.110118
Second	12/6-12/7	457.4	0.0114	-0.14896	30	0.861604
	27/6-27/7	474.18	0.0302	-0.11284	31	0.893296
	6/7-2/8/	435	5.3902	0.062392	27	1.06438
Average		455.5267	1.8106	-0.06647	29.333	0.93976
SD ±		19.65706	3.1000	0.113048	2.0816	0.109081
Third	12/7-11/8	481.02	26.25	0.108922	30	1.115076
	27/7-23/8	443.9	0	0	27	0
	2/8-1/9	480.4	0.4886	-0.02387	30	0.976415
Average		468.44	8.9128	0.028351	29	0.697163
SD ±		21.25452	15.016	0.070789	1.7320	0.607729
Fourth	11/8-10-9	475.8	0.4	-0.03054	30	0.969919
	23/8-22/9	463.1	0	0	30	0
	1/9-1/10	461.3	0	0	30	0
Average		466.7333	0	0	30	0.323306
SD ±		7.903375	0	0.017634	0	0.559983

Table (5) Field Life Table parameters for CLW in Bane Swief, 2000

Generations		DD's	R_0	r_m	T	λ
First	16/5-18/6	480.93	1.716981	0.016381	33	1.0165
	12/6-12/7	464.64	0.085333	-0.08204	30	0.9212
	31/5-30/6	451.87	2.152688	0.025557	30	1.0258
Average		465.8133	1.318334	-0.01337	31	0.9878
SD ±		14.56549	1.089807	0.059649	1.732	0.0579
Second	18/6-18/7	466.98	0.203297	-0.0531	30	0.9482
	12/7-14/8	470.93	12.8125	0.079701	32	1.0829
	30/6-30/7	447.8	0.174825	-0.05813	30	0.9435
Average		461.9033	4.396874	-0.01051	30.66	0.9915
SD ±		12.3725	7.28816	0.078167	1.154	0.0791
Third	18/7-20/8	463.19	10.72973	0.074157	32	1.0769
	14/8-16/9	444.8	0.785366	-0.00755	32	0.9924 78
	30/7-4/9	444.8	0.785366	-0.00755	32	0.9924
	30/8-25/9	480	1.307305	0.007656	35	1.0076
Average		458.1975	3.401942	0.016678	32.75	1.0174
SD ±		16.92395	4.891384	0.038984	1.5	0.0403

Table (6) Life Table parameters for CLW in Minia, 2000

Generations		DD's	R_0	r_m	T	λ
First	21/5-2/7	475.17	3.818182	0.032677	41	1.0332
	23/4-4/6	489.62	3.470588	0.030349	41	1.0308
Average		482.39	3.644385	0.031513	41	1.0320
SD ±		10.217	0.245786	0.001646	0	0.0016
Second	2/7-13/8	482.06	0.079365	-0.0618	41	0.9400
	4/6-9/7	492.61	2.110169	0.021336	35	1.0215
Average		487.33	1.094767	-0.02023	38	0.9808
SD ±		7.4599	1.435996	0.058784	4.242	0.0576
Third	13/8-17/9	482.4	1.633333	0.01443	34	1.0145
	9/7-13/8	495.73	0.120482	-0.06224	34	0.9396
Average		489.06	0.876908	-0.02391	34	0.9770
SD ±		9.4257	1.069747	0.054216	0	0.0529

Table (7) Observed and predicted PBW peaks in Sharkia, 2000

Peaks	Observed	Predicted	Deviation
P1	**22/5**	**overwintering**	
P2	**15/7**	**18/7**	**-3**
P3	**30/7**	**26/7**	**+3**
P4	**18/8**	**17/8**	**+1**
P5	**29/8**	**30/8**	**-1**
P6	**4/9**	**3/9**	**+1**
P7	**16/9**	**16/9**	**0**
P8	**25/9**	**23/9**	**+2**
P9	**7/10**	**3/10**	**+4**

Table (8) Observed and predicted PBW peaks in Bani-Sweif, 2000

Peaks	Observed	Predicted	Deviation
P1	**19/5**	**Overwintering**	
P2	**25/5**	**22/5**	**+3**
P3	**15/6**	**16/6**	**-1**
P4	**24/6**	**22/6**	**+2**
P5	**30/6**	**30/6**	**0**
P6	**12/7**	**11/7**	**+1**
P7	**21/7**	**22/7**	**-1**
P8	**2/8**	**2/8**	**0**
P9	**8/8**	**7/8**	**+1**
P10	**17/8**	**16/8**	**+1**
P11	**1/9**	**2/9**	**-1**
P12	**16/9**	**16/9**	**0**
P13	**1/10**	**3/10**	**-3**

Table (9) Observed and predicted PBW peaks in Minia, 2000

Peaks	Observed	Predicted	Deviation
P1	12/4	Overwintering	
P2	21/4	Overwintering	
P3	30/4	Overwintering	
P4	15/5	Overwintering	
P5	24/5	Overwintering	
P6	5/6	6/6	-1
P7	17/6	15/6	+2
P8	26/6	27/6	-1
P9	17/7	17/7	0
P10	7/8	6/8	+1
P11	28/8	28/8	0
P12	15/9	18/9	-3
P13	12/10	10/10	+2

Table (10) Observed and predicted CLW peaks in Sharkia, 2000

Peaks	Observed	Predicted	Deviation
P1	12/6	11/6	+1
P2	27/6	27/6	0
P3	18/7	12/7	+6
P4	2/8	3/8	-1
P5	11/8	15/8	-4
P6	1/9	30/8	+2

Table (11) Observed and predicted CLW peaks in Bani-Sweif, 2000

Peaks	Observed	Predicted	Deviation
P1	3/6	4/6	-1
P2	12/6	12/6	0
P3	27/7	26/7	+1
P4	14/8	15/8	-1
P5	20/8	21/8	-1
P6	16/9	19/9	-3
P7	25/9	25/9	0

Table (12) Observed and predicted CLW peaks in Minia, 2000

Peaks	Observed	Predicted	Deviation
P1	21/5	22/5	-1
P2	4/6	4/6	0
P3	2/7	2/7	0
P4	20/8	19/8	+1
P5	17/9	17/9	0

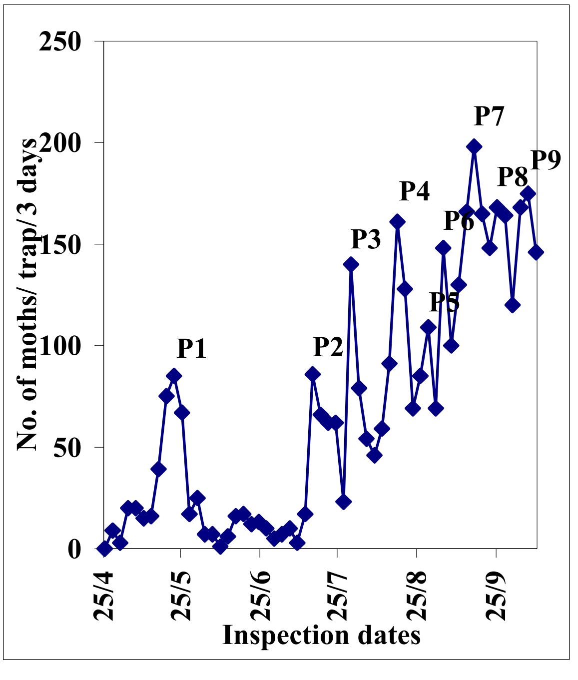

Fig. (1) seasonal fluctuations of PBW in Sharkia, 2000

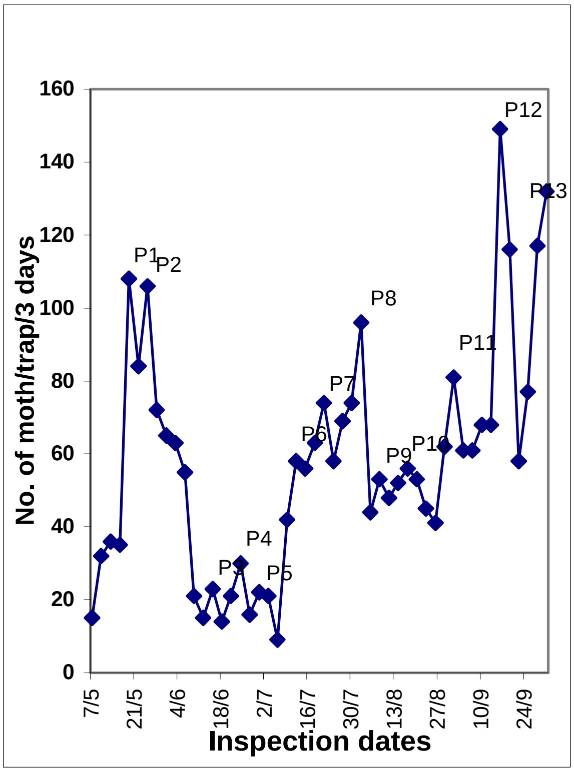

Fig. (2) seasonal fluctuations of PBW in Bani-Sweif, 2000

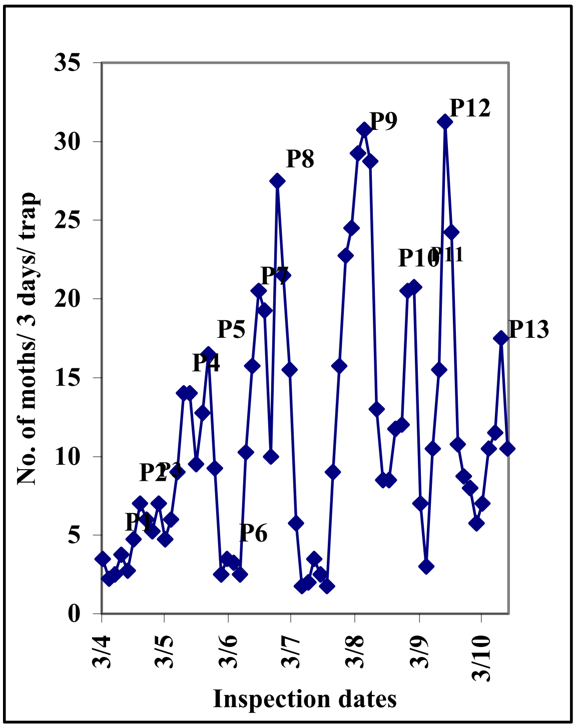

Fig. (3) seasonal fluctuations of PBW in Mini, 2000

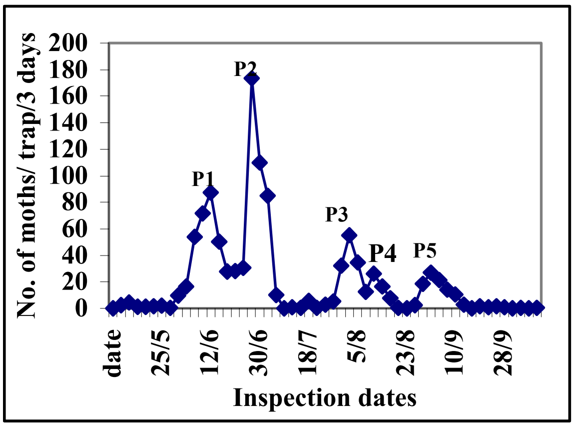

Fig. (4) seasonal fluctuations of CLW in Sharkia, 2000

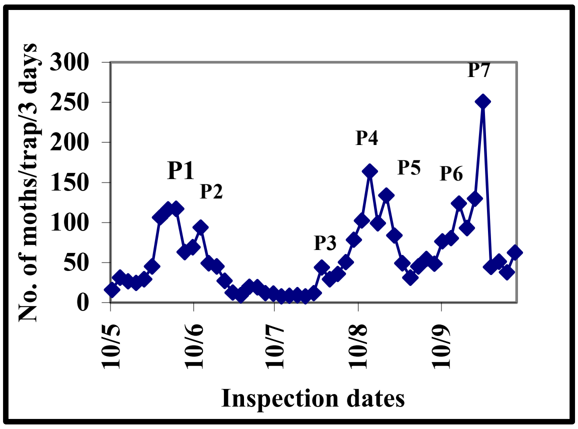

Fig. (5) seasonal fluctuations of CLW in Bani-Sweif, 2000

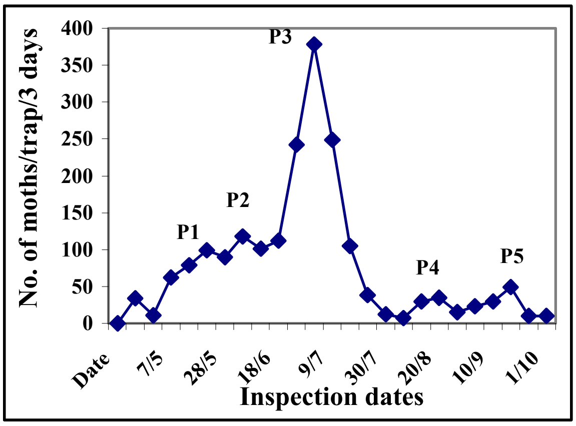

Fig. (6) seasonal fluctuations of CLW in Mini, 2000