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ALTERNATIVE INFIELD REFUGE STRATEGIES FOR CONTROLLING CERTAIN COTTON KEY PESTS IN MIDDLE EGYPT

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Abstract

In cotton production, there are many factors that can reduce crop yield. One important cause is insects. Insects that cause loss to the fruit are frequently more destructive than those that damage leaves, stems and roots. Cotton in Egypt is subjected to yield and quality losses by arthropod insects. The Cotton leaf worm (CLW), *Spodoptera littoralis* and the Cotton bollworms, pink bollworm (PBW), *Pectinophora gossypiella* and spiny bollworm (SBW), *Earias insulana* cause the greatest part of yield losses resulted from nearly one million feddans cultivated annually.

This study describes an improvement in insect control practices directed against feeding insects (i.e., CLW, PBW and SBW) by integration of monitoring, biological control, cultural, behavioral, genetic and bio-insecticides that can serve as a base for the formulation of biologically- based new approach of integrated management of cotton key pests. Field studies were conducted during 1999 and 2000 at Minia Governorate, middle Egypt. Experimental area was about 150 feddans of cotton (Giza, 80) during 1999 and 2000 cotton seasons. Five programs were evaluated: 1-Prediction models based on the Pheromone trap catches. 2-Bio insecticides such Agreen (contains *Bacillus thuringiensis agypti*) and Spinosad. 3- Insect Growth Regulators (Consult: Anti molting compound produced by Dow Agroscience; Cascade: Anti molting compound produced by American Cyanamid; Mimic Molting accelerating compound produced by Rhorm and Haas.). 4- Plant growth regulators and Defoliants (Pex: Cotton leaf defoliant and Cytokin: Growth promoting and fruiting hormone compound produced by Rhorm and Haas). 5- Augmentation of *Trichogramma sp.* various combinations of the tested components were formulated and applied in commercial cotton fields in two successive seasons. Percent of infestations, cotton yield and population density of both natural enemies and sucking pests were used as criteria for evaluation of various programs.

Introduction

Cotton growers in Egypt have experienced severe economic losses from cotton pests due to reduced yields, low lint quality and increased costs of insecticides. (Burrows et al, 1982). Chemical control has not provided a long term solution for cotton pest problems because of the high costs, environmental impact and related problems (insecticide-resistant insect strains, the reduction of pest insect natural enemies, and the resurgence of pest populations in the absence of natural enemies and the occurrence of secondary pests). Insecticide control also, focuses on attacking localized populations on a farm by farm basis. In contrast to this approach, area -wide suppression and management has evolved with increasing awareness of the limitations of attacking local infestations which represent only a small part of the total pest populations (Knipling, 1979). The negative effects of insecticides could be reduced by: timing insecticide applications to coincide with presence of key pests and absence of natural enemies (Heyerdahl and Dutcher, 1985), reducing application rates (Poehling, 1990) and frequency (Boethl and Ezell, 1978). Several prediction models have been developed to aid cotton pest management efforts. Simple degree-day model for forecasting cotton bollworm spring emergence patterns has been developed (Sevacherian et al., 1977; Huber et al., 1979). Recently Baseley and Adams (1%6) used field data to determine the optimal lower and upper threshold temperatures and the accumulation starting dates for predicting the spring emergence and for estimating the generation peaks over the growing season. Along with weather forecasts , such models permit growers to time control activities better and make best use of tactics such as delayed planting to minimize the avoidance of emerging moths. Gossyplure- baited traps have proved to be highly effective for the early- season detection and population monitoring of moth populations (Baseley et al. 1977), (Gutierrz et al., 1977) coupled a physiologically based cotton plant model to a temperature dependant PBW model to examine the impact of weather on insect-plant interactions.

Heat unit for predicting pest and crop phonology a Degree-day summation can be effectively used to project the emergence of overwintering PBW moths and the availability of suitable host material for pest reproduction (Gutierrz et al, 1977; Sevacherian et al., 1977 and Adams, 1996). These temperature based forecasts are important for pinpointing the times to begin pheromone trap sampling and plant observations to validate the occurrence of fruiting cotton, which in turn can identify potential problem areas. The relative magnitude and time of occurrence of pheromone- baited trap catches of the early season PBW indicate moth emergence from over-wintering populations that initiate infestations in the current years crop. The number of male moths caught 3-5 days prior to the first squaring cycle of cotton are positively correlated to the flower infestations during the first fruiting cycle whereas the number of PBW larvae in boils during the first fruiting cycle are positively correlated to the flower and boll infestations during the second fruiting cycle. Therefore, careful monitoring of pheromone traps and early season flower infestations can provide, useful information for estimating the extent and magnitude of the moth population that will subsequently oviposit and produce economic infestations of larvae in boll. Development of phonology models has also enabled practitioners of biological control to anticipate the development of various life stages of pest species. This allows augmentative or anundative release of beneficially such various parasites or predators, when the most susceptible life stage of the pest species are present The incorporation of biotechnology in the biological control of pests has resulted in some novel approaches for the control of cotton key pest species.

Extensive studies have been made to find out how agro-ecosystem influence pest population dynamics and how these situations can be changed to profit in a heifer way from the pest control mechanisms such as natural enemies which nature provides freely (Lentern, 1987). Such models permit growers to time control activities better and make best use of tactics such as delayed planting to maximize the avoidance of emerging moths. Spring irrigation simulates early emergence and can be timed to increase suicidal emergence (Baseley and Adams, 1995). Supplemental management strategies designed to exploit low-level, early -season population increases are particularly desirable. This vulnerable period provides an opportunity for additional, environmentally acceptable control methods.

This work has been undertaken to evaluate the proposed program as biologically -based, multi - component and area-wide program for cotton key pest management in Middle Egypt.

Materials and Methods

Field studies were conducted during 1999 and 2000 at Minia Governorate, middle Egypt to study and evaluate the biologically based management program of cotton key pests. Experimental area was about 150 feddans of cotton (Giza, 80) during 1999 and 2000 cotton seasons.

Prediction Models

Several models from very simple to very detailed have been developed to aid PBW and SBW management efforts. Several sampling degree[day models for forecasting spring emergence patterns have been developed by (Sevacherian et al., 1977 and Plant protection research team for the last ten years).

A. The upper thresholds were estimated using linear regression equations where y is the developmental time. The lower threshold in this equation is the value of I when y = **0.** The accumulated heat units for cotton pests were determined according to Sevacherian methods.
Recently, we use field data to determine the optimal lower and upper threshold temperatures and accumulation starting dates for predicting the spring emergence and for estimating the generation peaks over the growing season. Along with weather factors, such models permit growers to time control activities better and make best use of tactics such as delayed planting to maximize the avoidance of emerging moths.

B. We coupled a physiologically based cotton plant model to temperature- dependent PBW model to examine the impact of weather on the insect -plant interactions. The results provided insight into the potential for P8W population development in Middle Egypt. The insect model was later modified to reflect more accurately the effect of the fruit age on the PBW biology and to incorporate the effects of insecticide and pheromone applications on pest control Simulation was used to construct hypotheses concerning the comparative profitability of various pest control strategies based on the use of pesticide.

CBW Larval Age -Structure

A semi weekly examination of bolls was conducted, using the cracking method to determine percent of infestation as well as proportion of larval age categories (small, medium and large).

Cotton Fruiting Structures

Field observations were conducted on the Egyptian cotton (Giza, 80). The experimental area consisted of 25 feddans .100 plants were inspected daily for different fruiting structures. Campbell et al. (1974) reviews the calculations and assumptions used for estimating Degree-day. The estimated threshold for cotton growth and development is l2c (Gutierrz et al., 1975).

Natural Enemies and Sucking Pests

To evaluate the comparative effects of using the biologically- based program and the regular program (conventional insecticides) for pest control on the natural enemy complex and sucking pest populations in cotton fields , weekly numbers of the main predators and sucking pests were carried out through the period from early July up to mid September for two successive cotton seasons. The direct counting method (Hafez 1960) was applied in samples of 25 randomized plants within the experimental location and replicated four times for each treatment.

Pheromone Trap Catches

Gossyplure-baited traps were used for the early- season detection and population monitoring of moth populations. (Baseley et al., 1985 and Henneberry and Naranjo, 1998). Pheromone traps were used as one for CLW/ 5 feddans , one for PBWI 30 feddans and one for SBW/25 feddans. Semi weekly catches were recorded for each.

Bio Insecticides and Chemical Insecticides

A. Bio insecticides

Agreen: "Bt" compound produced by agricultural genetic Engineering Research Institute, Agricultural Research Center, Egypt It contains *Bacillus thuringiensis agypti* distribute different profile with various combinations of genes from groups *cry 1, cry 2, cry 8,* and *cry 9.*

B. Spinosad

The first active ingredient in the naturally class of insect control products, was introduced by Dow Agroscience for control of Lepidopterous insects in cotton under the trade name of "Trace". Spinosad is naturally occurring mixture of two active components Spinosyn A and Spinosyn B.

C. Insect Growth Regulators

- Consult: Anti molting compound produced by Dow Agroscience.
- Cascade: Anti molting compound produced by American Cyanamid.
- Mimic Molting accelerating compound produced by Rhorm and Haas.

Plant Growth Regulators and Defoliants

- Pex: Cotton leaf defoliant
- Cytokin: Growth promoting and fruiting hormone compound produced by Rhorm and Haas

Program Evaluation

Various combinations of the tested components were formulated and applied in commercial cotton fields in two successive seasons. Percent of infestations, cotton yield and population density of both natural enemies and sucking pests were used as criteria for evaluation of various programs.

Results and Discussion

To avoid the unfavorable side effects of pesticides on beneficial insects, natural enemies and environment and to reduce outbreaks of cotton pests, alternative approach for integrated pest management (IPM) was initiated recently to minimize the role of chemical pesticides. Nowadays we are trying to develop this program to more safe and effective modified approach, mainly depend on the biological agents. It seems clear that the cotton key pests could be significantly reduced through area-wide management approaches. The successful development and implementation of this program will depend on a complete understanding of the pest biology and ecology and knowledge of how to integrate the wide array of available cultural, chemical and biologically based suppression tactics into an effective management system. The biologically-based modified 1PM program concentrates on formulation of compatible use of cultural and bio-control agents of natural enemies and products in the proper timing to maximize density and effectiveness of the existing natural enemies. Diapausing larvae of PBW are subjected to a number of adverse climatic and biological factors that result in moralities of 48-99% (Slosser and Watson, 1972; Bariola, (1983). However, in most cases survival occurs in sufficient numbers to develop economic levels 6f infestation the following year. The reproductive capability of emerging moths from the over-wintering generations and the survival of Fl generation eggs and larvae are adversely affected by several biological and environmental factors. Moth emergence before fruiting forms (3 day before cotton squiring (Bariola, 1978) are available as a source of larval food is termed suicidal (Adkisson et at., 1962). Proper timing of application should be determined according to certain advanced and accurate models for prediction. Among the many timing techniques use are accumulated degree days, plant stage, stage structure of pest populations and pheromone trap data are worthwhile tools to be incorporated into an integrated bio-based cotton pest management Here, we use some different ways for forecasting population peaks of pest-natural enemy complex as follows:

1. *Pheromone -Trap Catches:* Pheromone trap captures may provide a means for estimating field infestations and relating potentials of various population densities. Data presented in Fig. (1) indicate the population peaks for CLW, CBW and SEW in cotton fields. Four peaks for each were estimated. Several precautions should be taken into consideration when using pheromone trap catches to determine the pest peaks, one of them is the confusion could be happened at the peak population, specially at high densities of females which lead to high secretion of pheromone and, consequently higher concentration of natural pheromone than the synthetic pheromone in trap which, in final could result in lower catches and false results. The second is the false relationship between number of male moths in trap and the expected percent of boll infestation in the same area of trap as a result of inter

field movement of females specially during the first generation when the susceptible structures are not available in some fields.

2. *Heat Unit Accumulation Technique for Simulating Crop- Pest -Natural Enemy Relationship:* A simple linear regression of the rate of development and temperature for cotton plant. Phonology, cotton key pests (CLW, PBW and SEW) and main natural enemies conducted in cotton fields provided an excellent fitness to the data (r^2 0.91 - 0.94). Temperature thresholds-and requirements are presented in (tables, 4 and 9).
   a. Cotton pests: Data in Fig. (1) and Table (1) indicate the presence of four peaks for CLW and SBW and also, four peaks for PBW after the emergence of diapuse. About 550, 475 and 552 degree-day were required consequently for each peak of CLW, PBW and SBW.
   b. Fruiting structures for Cotton plants (Giza-80): Data in Table (2) revealed that cotton plants (Giza-80) under the weather conditions needs 1225 degree-day for flowering and setting of green bolls. Susceptible green bolls of 15-30 day age started at 1400-degree days.
   c. Bollworm population dynamics in relation to cotton fruiting structures: Fig. (2) illustrates the relationship between cotton fruiting structure and percentage of boll infestation. The fruit survivorship and age structure of fruiting population influence the dynamics of cotton growth and development and directly influence the population dynamics of bollworms. The seasonal distribution of ovipositional sites show that squares are not particularly attractive for the bollworm oviposition in comparison to the bolls.
3. *Larval Age Structure in the Infested Cotton Bolls:* Distribution of different categories of larval age (small, medium and large) were also estimated and the obtained data (Fig. 3) confirmed a higher proportion of the small larvae (nodules, newly hatched and first instar larvae) early in each generation and during the egg population peaks. At the middle of generation time most of the larvae are in the prepupal stage and most of infested bolls have the emerging bolls. This method enable to detect the generation starts point, which is considered as the proper timing for control initiation. In conclusion, data in Table (1), clearly indicate the presence of four peaks 0 at 473, 1160, 1685 and 2254 (CLW); at 1400, 1875, 2350 and 2825 (PBW) and at 1330, 1850,2380 and 2920 HU (SEW).

Egg Sampling Techniques

Depending on the heat unit summation, pheromone trap catches larval age structure and egg sampling techniques for scheduling the bollworm control, the proper timing must coincide with the egg population peaks or the early beginning of hatched larvae.

Natural Enemies

Maximize the Role of Existing Natural Enemies: Numerous arthropod predator species are found in Middle Egypt cotton fields and many are capable of feeding on one or more stages of The pest (Table, 3). The egg and first instar larvae are most vulnerable to perdition. The later stage larvae developing within fruiting forms are protected. Oviposition occurs or vegetative cotton plant parts until mid-July. During this period, the egg and young larvae searching for suitable fruiting forms are exposed to high risk from perdition. Later in the season moths oviposit under the calyx of green boils and the eggs are protected, to some extent, from predators. Some of these eggs can be reached and destroyed by predators (Irwin et 21. 1974). Data presented in Table (3) , indicate that the biologically-based program enhanced population density of natural enemy whereas, the insecticide-based program resulted in high reduction of the natural enemy populations ranged from 77.8 to 95.6 %. Consequently, high values for reduction of sucking pest populations was achieved in the biologically - based program averaged from 83 to 87%.

Augmentation of Trichogramma for Suppression of Bollworm Population: During the last two decades, egg parasitoids have been widely used against several pests infesting several economic crops. (Lili-Ying, 1994). Augmentative release of laboratory-reared Trichogramma sp. An egg parasitoid of PEW has shown some promise for early-season control. In large scale cotton fields, biweekly release of this parasitoid significantly reduced boll infestations during July in comparison with control plot Parasitoid released also increased the yield by 10-13% and reduced seed damage by 22-50%. The parasitoid is well adapted to the temperature conditions of Middle Egypt and readily attacks the eggs of other Lepidopteron pests in cotton and is currently available from several commercial ancestries. The potential for PBW control by T. bactrae is best in the early Season when PBW eggs are deposited mainly on vegetative plant surface The results indicate that the parasitoid only attacks 7-15% of the eggs laid under the calyx later in the season, a level insufficient for pest control (Naranjo et al., 1992a).

Egg parasitoid, however, are almost exclusively used through in undative releases, in order to increase the parasitization rate sufficiently to reduce crop damage. Biology and thermal requirements of the native species of Trichogramma are studied. The objective is to select the best performance to be produced in the laboratory and to be used for in undative release T. evanesces was mass-reared and released from 0-3 times in different treatments of cotton fields. It was very successful in fining and parasitizing the eggs of host The overall parasitism was about 24.5% on PBW eggs, 19.6.6% on SBW and 6.2% on CLW. A thermal constant of 166.2 degree-day and developmental thresholds of 11.4 (developmental zero) and 34.5 (upper threshold) was determined for T. evanesces. These results are very close to those obtained by Erra et al, 1991, 1994. (Table 5).

Developmental Times and Emergence Rates Under Various Temperature and RH. Regimes
An intensive relationship between temperature and development time was observed in the thermal range studied. The range 20-32 was adequate *for T. evanesces* whereas the 16 c was deleterious (Table 6). Similar results were obtained by many authors studying other Trichogramma species (Parra et al. 1991, 1994). The higher parasitization rate was observed at 32 ^{o}C. There also, were a trend of longer life cycles at 70-90% RH. There were no statistical interaction between temperature and relative humidity (Table, 6). Relative humidity affected mainly parasitoid mortality, which was higher at 70% RH. Longevity was longer to some extent, at lower RH. levels.

Evaluation of Different Programs
According to the reduction percentages of CLW and, or CBW infestations in different programs, it is evident that the program of three sprays of Agreen and three applications of the parasitoid Trichogramma achieved the highest rate of reduction reaching 91.3% for CLW and 71.5 and 79.3 for PBW and SBW, followed by the program of one spray of Cascade, two sprays of Agreen and two applications of the egg parasitoid. Inferior, came the program of one application for Mimic, Agreen and Trichogramma (Table 4).

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Table 1. CLW and CBW populations in Minia Cotton Fields (Average of two seasons).

Peaks	CLW		PBW		SBW	
	Date	HU	Date	HU	Date	HU
1	11-17/4	473	10-30/5	800	15-30/6	1330
2	10-19/6	1160	26/6-8/7	1400	18-30/7	1850
3	10-13/7	1685	01-10/8	1875	26/8-6/9	2380
4	24-27/8	2234	9-15/9	2350	10-20/10	2920
5			9-20/10	2825		

Table 2. Fruiting Structure of Cotton (Giza-80) in relation to the accumulation heat units Minia Cotton Fields (Average of Two seasons).

Date	Hu	Fruit branches	Buds	Flowers	Green bolls
8/6	1065	4.0 1	1.2		
14/6	1142	7.2	15.2		
20/6	1228	9.6	21.4	0.6	1
26/6	1341	12.5	26.5	1.8	1
2/7	1396	13.6	29.5	3.2	1.2
8/7	1485	15	36.6	6 5.	2
14/7	1566	15.6	31.5	5.7	7.6
20/7	1648	17.2	38.6	6	11
26/7	1734	17	34.2	4.6	7.6
1/8	1821	18.2	36.5	3.5	22.3
7/8	1913	19.2	38.4	3.6	29.2
13/8	2006	18.6	30.2	2.5	20.2
19/8	2095	17.8	26.5	1.7	28.5
25/8	3183	19	2 1.2	1.2	25
31/8	2270	18.6	16.6	0.6	22.5
6/9	2349	19.3	12.5	0.2	20.6
12/9	2428	20.2	12 1	7.5	
18/9	2505	20	11.6		

Table 3. Mean Number/Plant Of Certain Natural Enemies And Sucking Pests In Biologically Based And Insecticides-Based Cotton Pest Management Programs, Minia Cotton Fields During 1999 And 2000 Seasons.

	Natural Enemies		Mean No./Plant		
	1999		2000		
	B	A	B	A	% Reduction
C.undecimpuctata	6.5	0.6	5.4	0.8	88.3
Orius spp.	14.5	0.6	8.2	0.4	95.6
Scymnusspp.	8.5	0.6	7.6	1.2	88.8
P. alferii	2.6	0.3	3.2	0.3	89.6
True spiders	7.5	2.3	6.5	1.5	72.8
Average	7.92	0.9	6.2	0.85	87.1
		sucking pests			
Aphid	5	36.5	5.5	44.2	87.4
Jassid	6	40.2	6	33.6	83
Whitefly	4	22.6	4.5	26	85.8
Mite	4	25.3	6	32	83.3
Average	4.6	31.2	5.6	33.8	84.9

Table 4. Comparative efficacy of certain bio-compounds and convention insecticides against cotton key pests in Minia Cotton Fields During 1999 And 2000 Seasons.

Treatment	% Reduction in CLW and CBW infestation						
	No. sprays			CLW	CBW		
	O	A	T		PBW	SBW	Total
Agreen (Bt)	0	3	0	90.2	33.2	41.6	37.4
	0	3	3	91.3	71.5	79.3	75.4
	0	3	2	91	60.4	69.5	65
	0	2	3	78.5	56.3	60.2	58.3
	2	2	2	69.2	52.3	55.5	54
Trichogramma	0	0	3	6.2	24.5	19.6	22.1
Cascade (IGR)	1	2	0	83.5	36	44.6	40.3
	2	1	0	80.5	35	40.3	37.7
	1	1	3	72	77.5	73	75.3
	2	1	2	80.5	34.5	43	38.8
	1	2	2	84.3	74	75.5	74.8
Consult (IGR)	1	2	0	80.2	34.3	40.5	37.4
	2	1	0	78.6	30.3	37.5	33.9
	1	1	3	70	73.2	69.5	71.4
	2	1	2	77.6	33	40.6	36.8
	1	2	2	81.3	70.5	73	71.8
Mimic (IGR)	1	2	0	81.2	37.5	43	40.3
	2	1	0	79.5	33	44.5	38.8
	1	1	3	72.6	75.1	66.3	70.7
	2	1	2	75.4	36.2	39	37.6
	1	2	2	79.6	68.7	74.3	71.5
Spinosad	1	0	0		44.5	89.5	67
	1	0	2		56.3	91.5	73.9
	1	1	1	66.9	61.2	93	77.1
Conventional Program		3		71.5	66.3	60.5	63.4

Table 5. Thermal requirements for the egg parasitoid *Trichogramma evanesces* Minia Cotton Fields (Average of Two seasons).

Natural enemy/ pest	To	Tu	Degree-day
Trichogramma Evanieces	11.4	34.5	166.2
Sodoptera littoralis (CLW)	12.1	36.5	334.5
Pectinophora gossypiella (PBW)	12.66	35	478.5
Earius insulana (SBW)	11.65	36.5	367.6
Aphis gossypii (Aphid)	9.3	37.4	133
Bemisia tabaci (Whitefly)	10.3	36	184.8
Tetranychus urtica (Mite)	12.2	35.5	164.8

Table 6. Egg to adult development and emergence rate of *T. evanesces* on cotton bollworm eggs at different temperatures and R. H. %.

	Developmental times in days					
Temp.	**50**	**SD**	**70**	**SD**	**90**	**SD**
16	30.2	0.07	29.7	0.06	29.5	0.06
20	19.6	0.05	19.4	0.5	19.3	0.4
24	13	0.03	12.8	0.04	19.1	0.3
28	10.2	0.01	10.1	0.01	10	0.02
32	7.4	0.02	7.3	0.02	7.3	0.01
	Emergence rate %					
16						
20	59.6	1.3	77.5	2.2	92	3.1
24	60.5	1.5	78.3	2.4	93.5	2.9
28	62.2	1.4	80.3	1.9	94.3	2.2
32	61.5	2.1	79.6	2.1	94.5	1.8

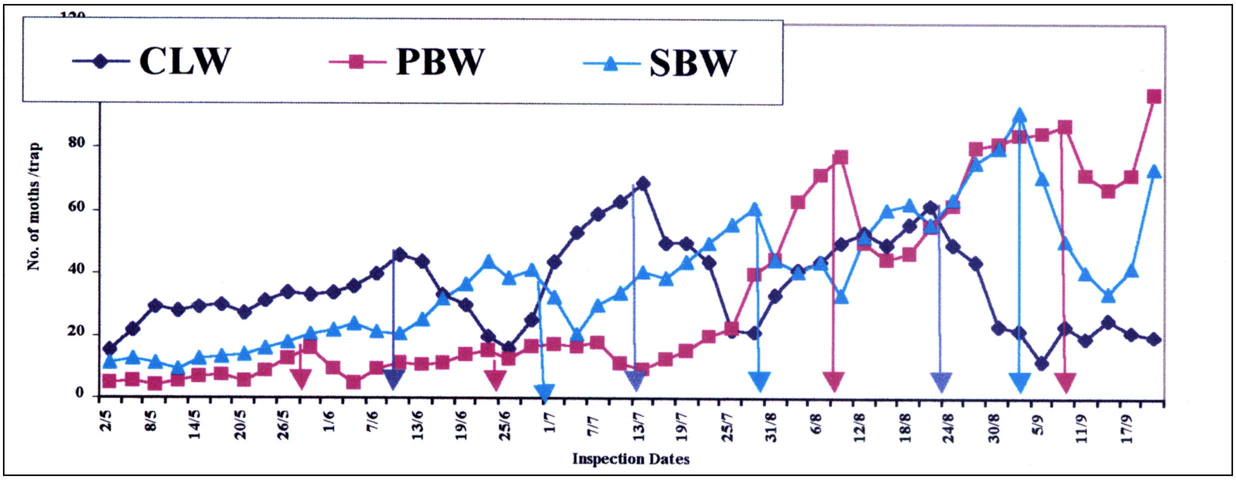

Figure 1. Fluctuations in population density of main cotton pests male moths, CLW, PBW, and SBW and their predicted peaks in Mina cotton fields (Average of two seasons).

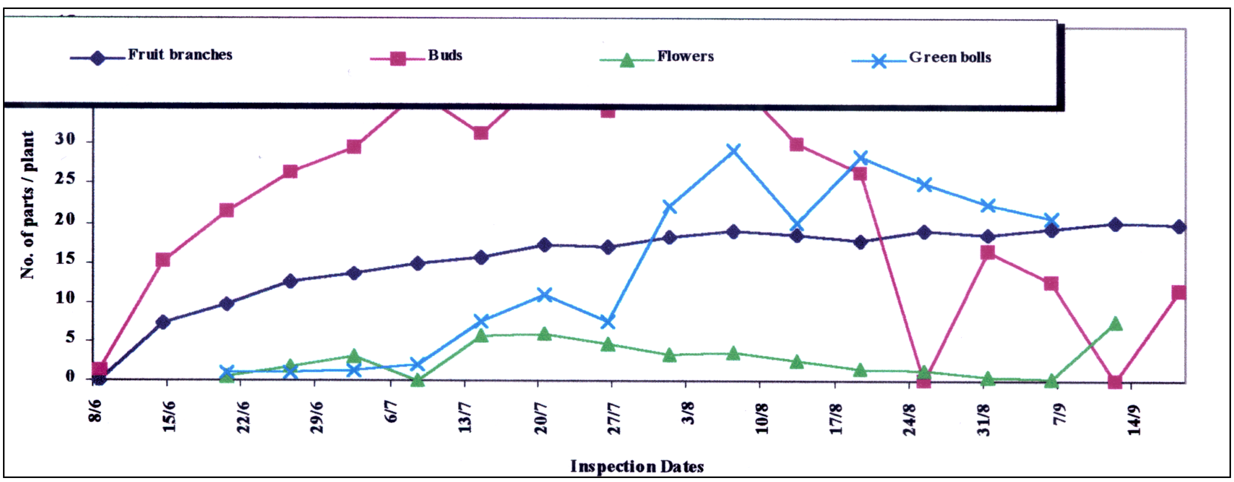

Figure 2. Fruiting structure of cotton Giza 80 in Minia (Average of two seasons).

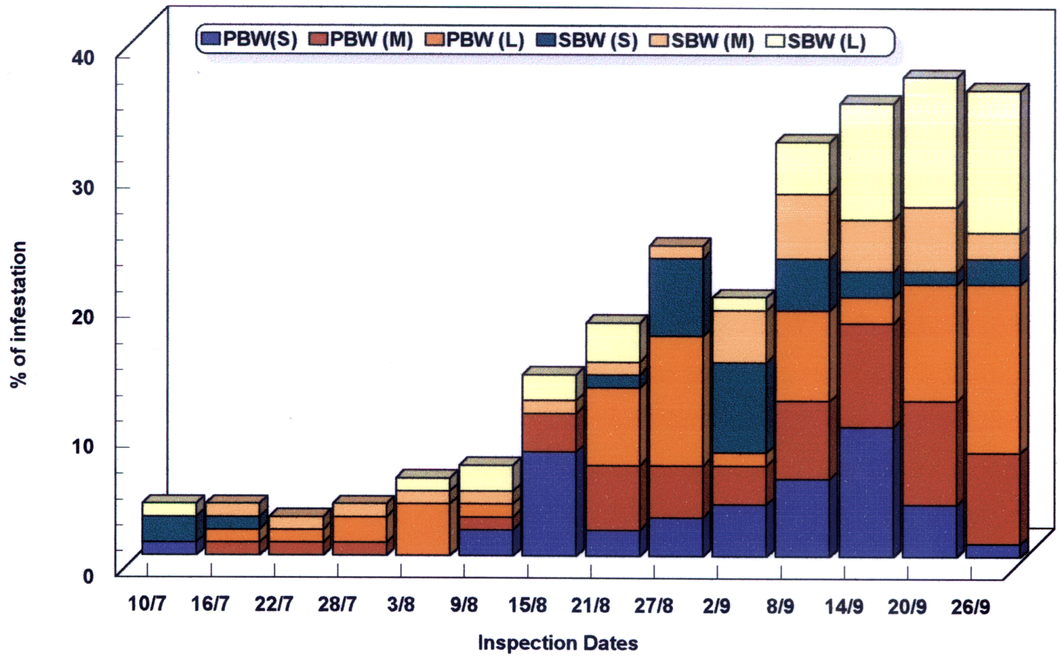
PBW(S)
PBW (M)
PBW (L)
SBW (S)
SBW (M)
SBW (L)
40
30
20
10
0
% of infestation
10/7
16/7
22/7
28/7
3/8
9/8
15/8
21/8
27/8
2/9
8/9
14/9
20/9
26/9
Inspection Dates

Figure 3.