

## **Integrated management strategies for control of 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; losses extend to oil contents in the seeds. The cotton leaf worm (CLW), *Spodoptera littoralis*, the pink bollworm (cotton bollworm) (PBW), *Pectinophora gossypiella* and spiny bollworm (SBW), *Earias insulana* cause the greatest number of yield losses from nearly one million hectares 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, behavioural and genetic aspects, and bio-insecticides that can serve as a basis for the formulation of a biologically-based new approach of integrated management of key cotton pests. Field studies were conducted during 2004 and 2005 at Minia Governorate, Middle Egypt. The experimental area was about 150 hectares of cotton (Giza-80). Five programs were evaluated. Percentages of infestations, cotton yield and population density of both natural enemies and sucking pests were used as criteria for evaluation of various programs.

**Key words:** *Spodoptera littoralis*, *Pectinophora gossypiella*, *Earias insulana*, *Bacillus thuringiensis*, Spinosad, anti-moulting, *Trichogramma*, prediction models, cotton

### **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, reduction of natural enemies of pests, 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 that 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 the presence of key pests and the absence of natural enemies, and by reducing application rates and frequency. Several prediction models have been developed to aid cotton pest management efforts. A simple degree-

day model for forecasting cotton spring emergence patterns of bollworm has been developed (Sevacherian et al., 1977; Huber et al., 1979). Baseley and Adams (1995) 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 the 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 monitoring of moth populations (Baseley et al., 1995; Gutierrez et al., 1977) coupled with a physiologically based cotton plant model to a temperature-dependent PBW model to examine the impact of weather on insect-plant interactions.

A heat unit for predicting pest and crop phenology and a degree-day summation can be effectively used to project the emergence of over-wintering PBW moths and the availability of suitable host material for pest reproduction (Gutierrez et al., 1977; Sevacherian et al., 1977). 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 year crop. The number of male moths caught 3–5 days prior to the first squaring cycle of cotton is positively correlated to the flower infestations during the first fruiting cycle whereas the number of PBW larvae in bolls during the first fruiting cycle is 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 phenology models has also enabled practitioners of biological control to anticipate the development of various life stages of pest species. This allows augmentative release of such beneficially various parasites or predators, when the most susceptible life stages 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 key pest species affecting cotton.

Extensive studies have investigated the influence of agro-ecosystems on pest population dynamics, to determine how they can be made profitable in a healthier manner, from pest control mechanisms such as natural enemies, which nature freely provides. Such models permit growers to time control activities more effectively and make the 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 & 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 a biologically-based, multi-component and area-wide program for management of key pests in cotton, in Middle Egypt.

## MATERIALS AND METHODS

Field studies were conducted during 2004 and 2005 at Minia Governorate, Middle Egypt, to study and evaluate the biologically-based management program of key cotton pests. The experimental area was about 150 hectares of cotton (Giza-80) during the 2004- 2005 cotton seasons.

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

The accumulated heat units for cotton pests were determined according to Sevacherian methods. 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, these models permit growers to time control activities more effectively and make the best use of tactics such as delayed planting to maximize the avoidance of emerging moths. We coupled a physiologically based cotton plant model with a temperature-dependent PBW model to examine the impact of weather on the insect-plant interactions. The results provided insight into the potential for PBW 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 pesticides.

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). Field observations were conducted on the Egyptian cotton (Giza-80). The experimental area consisted of 25 feddans (1 feddan = 0.42 hectares). 100 plants were inspected daily for different fruiting structures. The estimated threshold for cotton growth and development is 12°C (Gutierrez et al., 1975).

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 counting of the main predators and sucking pests was carried out through the period from early July 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.

Gossyplure-baited traps (Baseley et al., 1985; Henneberry & Steven, 1999) were used for the early-season detection and population monitoring of moth populations. Pheromone traps were used: one for CLW/5 feddans, one for PBW/30 feddans and one for SBW/25 feddans. Semi-weekly catches were recorded for each.

Bioinsecticides and chemical insecticides: *Agreen* – "Bt" compound produced by the agricultural genetic Engineering Research Institute, Agricultural Research Center, Egypt. It contains *Bacillus thuringiensis aegypti* that distributes a different profile with various combinations of genes from groups *cry 1*, *cry 2*, *cry 8*, and *cry 9*.

*Spinosad* – the first active ingredient in the natural class of insect control products, was introduced by Dow Agrosience for control of lepidopterous insects in cotton under the

trade name of "Trace". Spinosad is a naturally occurring mixture of two active components, Spinosyn A and Spinosyn B.

Insect growth regulators: *Consul* – anti-moulting compound produced by Dow Agrosience, *Cascade* – anti-moulting compound produced by American Cyanamid and *Mimic* – moulting 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.

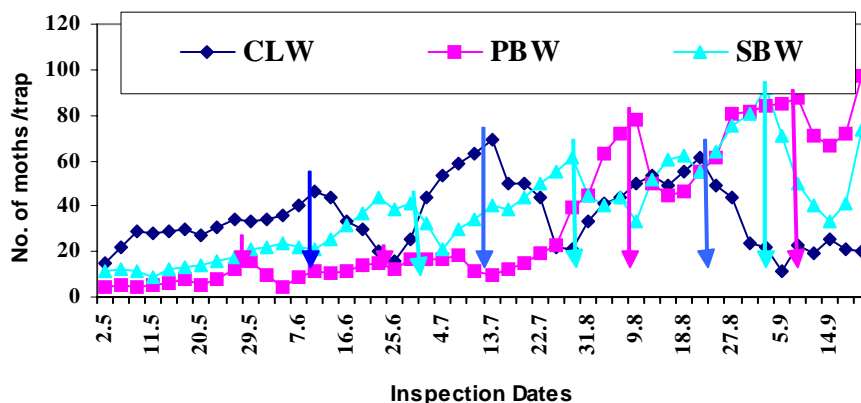
Various combinations of the tested components were formulated and applied in commercial cotton fields in two successive seasons. The percent of infestations, cotton yield and population density of both natural enemies and sucking pests were used as criteria for evaluation of various programs.

## RESULTS AND DISCUSSION

To avoid the unfavourable side effects of pesticides on beneficial insects, natural enemies and environment, and to reduce outbreaks of cotton pests, an alternative approach for integrated pest management (IPM) was initiated recently to minimize the role of chemical pesticides. Currently we are trying to develop this program for a safer and more effective modified approach, mainly depending on the biological agents. It seems clear that the key cotton 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 IPM program concentrates on formulation of compatible use of cultural and biocontrol agents of natural enemies and products, timed properly 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 mortalities of 48–99% (Slosser and Watson, 1972; Bariola, 1983). However, in most cases survival of the infestation occurs in sufficient numbers to affect economic levels the following year. The reproductive capability of emerging moths from the over-wintering generations and the survival of F1 generation eggs and larvae are adversely affected by several biological and environmental factors. Moth emergence before fruiting forms (3 day before cotton squiring) (Bariola, 1983) are available as a source of larval food is termed suicidal (Adkisson et al., 1962). Proper timing of application should be determined according to certain advanced and accurate models for prediction. Among the many timing techniques in use, 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 system. Some different approaches to forecast population peaks of pests' natural enemy complex follow.

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, PBW and SBW 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 is the confusion that can occur at the peak population, especially with high densities of females which lead to

high secretion of pheromone and, consequently, higher concentration of natural pheromone than the synthetic pheromone in trap. Ultimately that could result in lower catches and false results. The second is the false relationship between the number of male moths in traps and the expected percent of boll infestation located in the same area of the traps,, as a result of inter-field movement of females, especially during the first generation when the susceptible structures are not available in some fields.

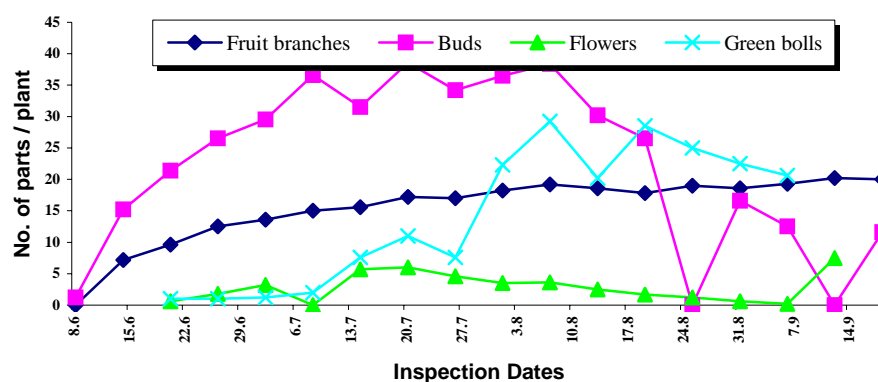


**Fig. 1.** Fluctuations in population density of main cotton pests. CLW = the cotton leaf worm, *Spodoptera littoralis*, PBW = the pink bollworm (cotton bollworm), *Pectinophora gossypiella* and SBW = spiny bollworm, *Earias insulana*.

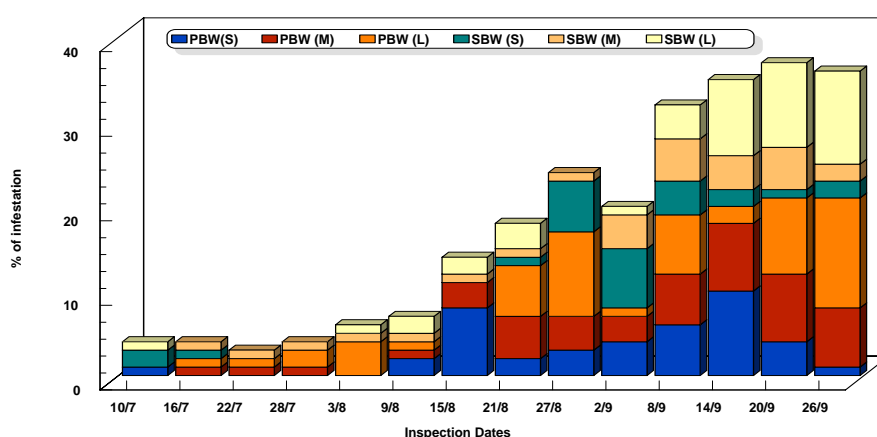
Data in Fig. 1 indicate the presence of four peaks for CLW, SBW and PBW after the emergence of diapause. Consequently, about 550, 475 and 552 degree-days were required for each peak of CLW, PBW and SBW. Cotton plants (Giza-80) under those weather conditions need 1225 degree-days for flowering and setting of green bolls. Susceptible green bolls of 15–30 day age started at 1400 degree-days.

The fruit survivorship and age structure of the fruiting population influence the dynamics of cotton growth and development and directly influence the population dynamics of bollworms (Fig. 2). The seasonal distribution of ovipositional sites shows that squares are not particularly attractive for the bollworm oviposition in comparison to the bolls.

Distribution of different categories of larval age (small, medium and large) was 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 stage of the generation period, most of the larvae are in the prepupal stage and most infested bolls have emerging bolls. This method enables the detection of the generation's starting point, which is considered to be the proper timing for control initiation.



**Fig. 2.** Fruiting structure of cotton Giza-80 in Minia (average of two seasons).



**Fig. 3.** Distribution of different categories of larval age (S – small, M – medium, L – large).

Numerous arthropod predator species are found in cotton fields in Middle Egypt and many are capable of feeding on one or more stages of the pest. The egg and first-instar larvae are most vulnerable to predation. The later stage larvae developing within fruiting forms are protected. Oviposition occurs on vegetative cotton plant parts until mid-July. During this period, the egg and young larvae searching for suitable fruiting forms are at high risk of predation. Later in the season, moths oviposit under the calyx of green bolls and the eggs are protected, to some extent, from predators, although some of these eggs can be reached and destroyed (Irwin et al., 1974). Data indicate that the biologically-based program enhanced population density of natural enemies whereas the insecticide-based program resulted in high reduction of the natural enemy populations, ranging from 77.8–95.6%. Consequently, high values for reduction of sucking pest populations were achieved in the biologically-based program, averaging from 83–87%.

During the last two decades, egg parasitoids have been widely used against several pests infesting several economic crops. Augmentative release of laboratory-reared *Trichogramma* spp., an egg parasitoid of PBW, has shown some promise for early-season control. In large-scale cotton fields, bi-weekly release of this parasitoid significantly reduced boll infestations during July in comparison with the control plot. Parasitoid release 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, readily attacks the eggs of other lepidopterous pests in cotton, and is currently available from several commercial ancestries. The potential for PBW control by *T. bactrae* is best early in the season when PBW eggs are deposited mainly on vegetative plant surfaces. 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.

Egg parasitoids, however, are almost exclusively used through inundatory releases, in order to increase the parasitization rate sufficiently to reduce crop damage. Biological and thermal requirements of the native species of *Trichogramma* are being studied. The objective is to select the best performance to be produced in the laboratory and then used for inundatory release. *T. evanescens* was mass-reared and released from 0-3 times in different treatments of cotton fields. It was very successful in finding and parasitizing the eggs of hosts. Overall parasitism was about 24.5% on PBW eggs, 19.6% on SBW and 6.2% on CLW. A thermal constant of 166.2 degree-days and developmental thresholds of 11.4 (developmental zero) and 34.5 (upper threshold) was determined for *T. evanescens*. These results are very close to those obtained by Erra *et al.* (1991, 1994).

An intensive relationship between temperature and development time was observed in the thermal range studied. The range of 20–32 was adequate for *T. evanescens* whereas 16°C was deleterious. Many authors studying other *Trichogramma* species obtained similar results. The higher parasitization rate was observed at 32°C. There was also a trend of longer life cycles at 70–90% RH. There was no statistical interaction between temperature and relative humidity. Relative humidity mainly affected parasitoid mortality, which was higher at 70% RH. Longevity was greater at lower RH levels, to some extent.

According to the reduction percentages of CLW or PBW infestations in different programs, it is evident that the program employing 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. The program using only one application of *Mimic*, *Agreen* and *Trichogramma* was inferior.

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