2003 BELTWIDE COTTON CONFERENCES, NASHVILLE, TN – JANUARY 6-10

COMPATIBLE IPM PROGRAM OF "AGREEN" AND *TRICHODERMA*" IN COTTON

Malak F. Gergis, Magda K. Megali, and Mortada A. Ali
Plant Protection Research Institute, Agricultural Research Center
Dokki-Giza, Egypt

Abstract

Cotton in Egypt is subjected to yield and quality losses by arthropod insects. The cotton leafworm (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.

The high costs of chemical control, continuing economic losses, secondary pest problems and environmental considerations suggest the need for ecologically and biologically oriented cotton pest management strategies. Extensive research on cotton in Middle Egypt has resulted in a broad array of monitoring, biological control, cultural, behavioral, genetic and bioinsecticides that can serve as a base for the formulation of biologically-based new approach of integrated management of control key pests.

In this paper, different ways for use of biological control as a reliable, environmentally safe means of pest reduction will be illustrated.

Predictive capabilities of pheromone based monitoring system, several simple degree-day models, larval age structure and egg sampling techniques for forecasting spring emergence patterns and population peaks for cotton key pests were studied and coupled to a physiologically-based cotton plant model to examine the insect-plant interactions and timing control applications. Biological control by preservation and augmentation of natural enemies as an important component of pest management practices was involved particularly for *Trichogramma* species.

Results indicated the common key pests could be significantly reduced through area-wide management approaches. In such case, estimating economic impact of a biological control program has to be used on a lot of different indicators including, among others : (1) reduction of the pest population size, (2) increase in crop yield, (3) increase in production, (4) increase in farm revenue or receipts, (5) cost saving, (6) increase in product value, and even (7) social gain (Tesdell, 1990).

In Egypt, four different aspects should be developed for successful biologically-based management program : (1) Identification of optimal species ad population for a given biological control program, (2) determine of thermal requirements for parasitoid, pest and host plant, (3) design of prediction models of the parasitoid, and (4) proper timing for release.

Integrated biologically-based pest management program was formulated of various biological components of cultural control, natural enemy preservation and augmentation and timing bio-insecticide-based control applications by using certain advanced and integrated prediction models of heat unit, pheromone trap catches, egg sampling and larval age structure. This program successfully met both of short and long tern needs of cotton pest management in Middle Egypt.

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, 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 effective 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 models for forecasting cotton bollworm spring emergence patterns have been developed (Sevacherian *et al*., 1977; Huber *et al*., 1979). Recently, Baseley and Adams (1966) 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 maximize 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 (Basley *et al*., 1977). Gutierrez *et al*. (1977) coupled a physiologically based cotton plant model to temperature-dependent PBW model to examine the impact of weather on insect-plant interactions.

Heat unit for predicting pest and crop phenology. 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 (Gutierrez *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 overwintering populations that initiate infestations in the current year's 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 bolls 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 phenology models has also enabled practitioners of biological control to anticipate the development of various life stages of pest species. This allows augmentative or inundative 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 pests 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 better 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 simulate early emergence and can be timed to increase suicidal emergence (Baseley and Adams, 1955).

Supplemental management strategies designed to exploit low-level, early-season population increase 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.

Prediction Models

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

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 x 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.

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.

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 aegypti* 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 natural class of insect control products, was introduced by Dow Agroscience for control of lepidopterous insects in cotton under the trade name of "Tracer". Spinosad is naturally occurring mixture of two active components, Spinosyn A and Spinosyn B.

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 a 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 IPM program concentrations 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 mortalities of 48-99 % (Slosser and Watson, 1972; Bariola, 1983). However, in most cases survival occurs in sufficient numbers to develop economic levels of infestation the following year. The reproductive capability of emerging moths from the overwintering generations and the survival of F_1 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 foods 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 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 :

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 phenology, cotton key pests (CLW, PBW and SBW) 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 table (3).

<u>*A- Cotton Pests*</u>. Data in tables (1, 3 & 5) indicate the presence of four peaks for CLW and SBW and also, four peaks for PBW after the emergence of diapause.

About 550, 475 and 552 degree-day were required consequently for each peak of CLW, PBW and SBW.

<u>*B- Fruiting Structures for Cotton Plants (Giza-80)*</u>. Data in table (7) 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 15-20 day gave started at 1400 degree days.

<u>*C- Bollworm Population Dynamics in Relation in Cotton Fruiting Structures*</u>. 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.

<u>Natural Enemies</u>

<u>*Maximizing the Role of Existing Natural Enemies*</u>. 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, 5). 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 exposed to high risk from predation. Later in the season, moths oviposit under the calyx of green bolls and the eggs are protected, to some extent, from predators. Some of these eggs can be reached and destroyed by predators (Irwin *et al*., 1974).

Data presented in table (5), 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 77.7 to 95.6 %. Consequently, high values for reduction of sucking pest populations was achieved in the biologically-based program averaged from 83 to 87 %.

<u>Augmentation of *Trichogramma* for Suppression of Bollworm Population</u>

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 PBW have shown some promise for early-season control. In large scale cotton field, 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 welt adapted to the temperature conditions of Middle Egypt, and readily attacks the eggs of other pest Lepidoptera in cotton (15) and is currently available from several commercial insecticides. 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 inundative release, in order to increase the parasitization rate sufficiently to reduce crop damage.

Biology and thermal requirements of the native species of *Trichogramma* is studied. The objective is to select the best performance to be produced in the laboratory and to be used for inundative 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 host. The overall parasitism was about 24.5 % on PBW eggs, 19.66 % on SBW and 6.2 % on CLW.

A thermal constant of 166.2 degree-day and a 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) (Table 8).

<u>Developmental Times and Emergence Rates Under Various Temperature and R.H. Regimes</u>

An intensive relationship between temperature and development time was observed in the thermal studied. The range 20-32 was adequate for *T. evanescens* whereas the 16 was deleterious (Table, 7).

Similar results were obtained by many authors studying other *Trichogramma* species (Parra *et a;*., 1991 & 1994). The higher parasitization rate was observed at 32°C. There also, were a trend of longer life cycles at 70.90 % R.H. There were no statistical interaction between temperature and relative humidity (Table, 7). Relative humidity affected mainly parasitoid mortality, which was higher at 70 % R.H. Longevity was longer to some extent, at lower R.H. 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, 9).

References

Adkisson, P.I.; Robertson, O.T. and Fife, L.C. 1962. planting date as a factor involved in pink bollworm control. In D.F. Martin and R.D. Lewis (eds.), A summary of recent research basic to the cultural control of pink bollworm, pp. 16-20. Texas Agric. Exp. Sta., miscellaneous Publication, 579.

Bariola, L.A. 1983. Survival and emergence of overwintered pink bollworm moths. Environ. Entomol., 12, 1877-81.

Baseley, C.A. and Adams, C.I. 1995. Effect of irrigation, irrigation timing and cotton boll burial on extent and pattern of pink bollworm spring emergence. Southwestern Entomol., 20, 73-106.

Baseley, C.A.; Henneberry, Adams, C. and yates, L. 1985. Gossyplure-baited traps as pink bollworm survey, detection, research and management tools in southwestern desert cotton growing areas. California Agric. Exp. Stn. Bull., 1915, 15 pp.

Burrows, T.M.; Sevacherian, V.; Browning, H. and Baritelle, J. 1982. The history and cost of pest control alternatives for Imperial valley cotton. Bull. Entomol. Soc. Am., 28, 286-90.

Gutierrez, A.P.; Falcon, L.A.; Leow, W.; Leipzig, P.A. and Vadenbosch, R. 1975. An analysis of cotton production in California : A model of Acala and the effect of the defoliators on its yield. Environ. Entomol., pp. 125-136.

Gutierrez, A.B.; Butler, G.D.Jr; Wong, Y. and Westphal, D. 1977. The interaction of pink bollworm, cotton and weather : A detailed model. Can Entomol., 109, 1457-68.

Hafez, M. 1960. The effect of some new insecticides on predators of the cotton leafworm in cotton fields. Agric. Res. Rev., 30 (1), 47-79.

Henneberry, T.J. and Steven, E.N. 1998. Integrated management approaches for pink bollworm in southwestern Unites States. Integrated Pest management Review, 3, 31-52.

Huber, R.T.; Moore, L. and Hoffman, M.P. 1979. Feasibility study of area wide pheromone trapping of male pink bollworm moths in a cotton pest management program. J. Econ. Entomol., 72, 222-27.

Knipling, E.F. 1979. The basic principles of insect population suppression and management. US Dept. of Agric.

Sevacherian, V.; Stern, V.M. and Muller, A.J. 1977. Heat accumulation for timing *Lygus* control measures in sufflower cotton complex. J. Econ. Entomol., 70, 399- 402.

Slosser, J.E. and Watson, T.E. 1972. Influence of irrigation on overwinter survival of the pink bollworm. Environ. Entomol., 1, 572-6.

Table 1. Average No. of heat unit accumulation in cotton fields (Minia, Egypt).

Date	HU	Date	HU	Date	HU
2/5	628	19/6	1288	6/8	2047
5/5	671	22/6	1332	9/8	2095
8/5	712	25/6	1378	12/8	2142
11/5	747	28/6	1420	15/8	2188
14/5	781	1/7	1462	18/8	2234
17/5	820	4/7	1506	21/8	2279
20/5	863	7/7	1552	24/8	2323
23/5	907	10/7	1596	27/8	2369
26/5	954	13/7	1640	30/8	2413
29/5	996	16/7	1685	2/9	2454
1/6	1036	19/7	1726	5/9	2495
4/6	1058	22/7	1770	8/9	2535
7/6	1117	25/7	1815	11/9	2578
10/6	1160	28/7	1858	14/9	2648
13/6	1200	31/8	1903	17/9	2655
16/6	1242	3/8	1951	20/9	2697

Table 2. Percent of bollworm infestation in cotton green boll and larval age-structure.

	PBW			SBW		
Dates	Small	Medium	Large	Small	Medium	Large
10/7	1					1
16/7		1	1	2		
22/7		1	1	1	1	
28/7		1	2		1	
3/8			4		1	1
9/8	2	1	1		1	2
15/8	8	3			1	2
21/8	2	5	6	1	1	3
27/8	3	4	10	6	1	
2/9	4	3	1	7	4	1
8/9	6	6	7	4	5	4
14/9	10	8	2	2	4	9
20/9	4	8	9	1	1	10
26/9	1	7	13	2	2	11

Table 3. CBW population peaks (Minia, Egypt).

	CLW	
Peaks	Date	HU
1	11-17/4	473
2	10-19/6	1160
3	10-13/7	1685
4	24-27/8	2234

Table 4. CBW population peaks (Minia, Egypt).

	PBW		SBW	
Peaks	Date	HU	Date	HU
1	10-30/5	800	15-30/6	1330
2	26/6-8/7	1400	18-30/7	1850
3	1-10/8	1875	26/8-6/9	2380
4	9-15/9	2350	10-20/10	2920
5	9-20/10	2825		

Table 5. Mean number/plant of certain natural enemies in biologically-based and insecticide-based cotton pest management programs (Minia).

Natural enemies	Mean number/plant 2001 B	I	2002 B	I	% reduc.
C. undecimpunctata	6.5	0.6	5.4	0.8	88.3
Orius spp.	14.5	0.6	8.2	0.4	85.6
Scymnus spp.	8.5	0.6	7.6	1.2	88.8
P. alfierii	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

B : Biologically
I : Insecticidal

Table 6. Mean number of certain sucking pests/leaf in biologically-based and insecticide-based cotton pest management programs.

Sucking pests	Mean number/plant 2001 B	I	2002 B	I	% reduc.
Aphid	5	36.5	5.5	44.2	-87.4
Jassid	6	40.2	6.3	33.6	-83.0
Whitefly	4	22.6	4.5	25.5	-85.8
Mite	4	25.3	6.0	32.0	-83.3
Average	4.6	31.2	5.6	33.8	-84.9

Table 7. Egg to adult development and emergence rate of *T. evanescens* on cotton bollworm eggs at different temperatures and R.H. %.

Temp. (°C)	50	70	90 %
	Developmental times in days		
16	30.2±0.07	29.7±0.06	29.5±0.06
20	19.6±0.05	19.4±0.50	19.3±0.40
24	13.0±0.03	12.8±0.04	19.1±0.30
28	10.2±0.01	10.1±0.01	10.0±0.02
32	7.40±0.02	7.30±0.02	7.30±0.01
	Emergence rate %		
20	59.6±1.3	77.5±2.2	92.0±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

Table 8. Thermal requirements for the egg parasitoid *Trichogramma evanescens*.

Natural enemy / pest	To	Tu	Degree-day
Trichogramma evanescens	11.4	34.5	166.2
Spodoptera littoralis (CLW)	12.1	36.5	334.5
Pectinophora gossypiella (PBW)	12.66	35.0	478.5
Earias insulana (SBW)	11.65	36.5	367.6
Aphis gossypii (Aphid)	9.3	37.4	133.0
Bemisia tabaci (Whitefly)	10.3	36.0	184.8
Tetranychus urticae (Mite)	12.2	35.5	164.8

Table 9. Comparative efficacy of certain bio compounds and conventional insecticides against cotton key pests (Minia, Egypt).

	% Reduction in CLW and CBW infestation						
	No. sprays				CBW		
Pesticides	**O**	**A**	**T**	**CLW**	**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	91.0	60.4	69.5	65.0
	0	2	3	78.5	56.3	60.2	58.3
		2	2	69.6	52.3	55.5	54.0
Trichogramma sp.	0	0	3	6.2	24.5	19.6	22.1
Spinosad	1	0	0		44.5	89.5	67.0
	1	0	2		56.3	91.5	73.9
	1	1	1	66.9	61.2	93.0	77.1
Conventional program		3		71.5	66.3	60.5	63.4