PROGRESS REPORT AND OVER VIEW OF PINK BOLLWORM, PECTINOPHORA GOSSYPIELLA (SAUNDERS), ERADICATION ACTIVITIES IN CALIFORNIA

James F. Rudig
State of California Department of Food & Agriculture
Fresno, CA
Daniel F. Keaveny
State of California Department of Food & Agriculture
Shafter, CA

Abstract

The California Department of Food and Agriculture (CDFA) Pink Bollworm (PBW) Program is a unique integrated pest control (IPC) program. This IPC Program has been in continual operation since 1967. Program activities have successfully prevented incipient infestations of PBW from becoming established in the cotton growing areas of the San Joaquin Valley. In 2007 the United States Department of Agriculture (USDA) included the southern California cotton growing regions into PBW Area-wide Eradication Program. This program has the potential to:

- Reduce pest management and regulatory enforcement costs
- Improve the ability of growers to compete in the global marketplace
- Significantly reduce the use of conventional pesticides that also harm non-target insects and biological control organisms

Introduction

The pink bollworm, *Pectinophora gossypiella* (Saunders) is most destructive in the desert cotton growing regions of Arizona, southern California, and northwestern Mexico. Pink bollworm became established in southern California in the mid-1960's and soon developed into a major pest problem. Southern California cotton growers used a variety of broad spectrum conventional pesticides to combat pink bollworm infestations. This resulted in minimally effective control. The treatments were expensive with numerous secondary pest outbreaks.

The San Joaquin Valley is the state's primary cotton growing region and is approximately 175 miles from the generally infested areas of southern California. The region between the San Joaquin Valley and the southern desert cotton regions is essentially host free. Under normal conditions this mountain and desert host free zone provides a natural barrier. However, movement of pink bollworm between the two regions has been documented. This can occur during "hurricane" type conditions from storms emanating from Baja California. Adult moth captures in desert gossyplure baited trap lines, have coincided with increases in late season captures within the San Joaquin Valley.

The IPC approach was designed to keep infestations in the San Joaquin Valley below economically damaging levels. The San Joaquin Valley PBW Program has been a model for effective IPC management. Using pheromone baited detection trapping, sterile insect release, crop destruction, and occasional pheromone treatments, Program activities have successfully prevented incipient infestations of pink bollworm from becoming established in the cotton growing areas of the San Joaquin Valley for over forty (40) years.

Program personnel continue to utilize a risk-based management approach to maximize cost efficiencies without significantly sacrificing program detection and control objectives. The San Joaquin Valley was divided into bio-potential zones, based on climate data and native moth capture history. The program activities of mapping, trapping, and sterile release are then coordinated within each zone using the pink bollworm heat unit model (Huber).

The program has not used pesticides, but rather uses sterile PBW moths to overwhelm these infestations. Sterile moths are produced at the CDFA owned Pink Bollworm Sterile Insect Rearing Facility in Phoenix, Arizona. Through a cooperative agreement, the USDA manages and directs the sterile PBW moth production at the facility. Sterile adult moths are sent to California daily and released by aircraft over target areas determined by trapping results.

Southern California cotton growing areas of Riverside, San Bernardino, and Imperial Counties were added to the USDA coordinated PBW Area-wide Eradication Program in 2007. The initial objective was to reduce PBW infestation levels below economic damage. As the Program progresses the goal will be the eradication of PBW from the region. The area known as Bard/Winterhaven in Imperial County was not included into the area-wide Program at this time. It will be scheduled for further expansion when funding is obtained.

The USDA Area-wide Eradication Program strategy includes the use of the transgenic *Bt (Bacillus thuringiensis)* cotton, insect monitoring, sterile release, pheromone mating disruption, and *Bt* resistance monitoring. The USDA obtained a Section 18 Crisis Exemption from the US Environmental Protection Agency (EPA) for the use of 100% *Bt* cotton. This EPA Section 18 allowed growers to plant 100% *Bt* cotton as a part of the 2007 PBW Area-wide Eradication Program. Sterile PBW insects were applied to the *Bt* cotton plantings in lieu of refugia. CDFA PBW Program staff, in conjunction with the Arizona Cotton Research and Protection Council, monitors selected fields for *Bt* resistance.

Methods And Materials

Mapping

Field mapping crews employed the use of handheld GPS (Global Positioning System) Units to validate cotton field locations. All cotton-field mapping throughout the State was digitized into computers using MapInfo® software. These digitally, computer generated maps, depicting individual cotton fields, were utilized in trapping, boll survey, sterile release, and plowdown compliance monitoring. PBW Program personnel mapped 428,725 acres of cotton in six counties of the San Joaquin Valley. The total 2007 California cotton acreage was 452,005 acres. The statewide acreage was down (~19%) from the 556,355 acres mapped in 2006. The San Joaquin Valley had a total of 428,725 acres. Pima cotton plantings in the San Joaquin Valley for 2007 amounted to 260,005 acres. This is the second consecutive year in which Pima acreage has eclipsed Upland acreage. The total 2007 cotton acreage in southern California was 18,840 acres. There were 4,440 acres of cotton planted in northern California in the Sacramento Valley region.

Trapping

Early detection trapping was done at selected San Joaquin Valley sites having native PBW moth catches in the year 2006 to detect possible over-wintering populations and monitor sterile release. The early detection trapping was conducted from April 17 through July 04. General detection trapping activities were matched to the bio-potential zones. The program also utilized different trapping ratios: 1) one trap per 60 acres, 2) one trap per 80 acres, and 3) one trap per 100 acres.

The starting dates for each bio-potential zone were staggered to align with the PBW heat unit model. The earliest general detection trapping began in the southern San Joaquin Valley on June 16. The total number of traps deployed during the peak of the season was 5,889 traps. The Program used a 2 mg Consep® lure in the pheromone baited traps. Traps and lures were changed, on the average, at four (4) week intervals. Traps were inspected weekly, (bi-weekly in Merced, Madera, and a portion of Fresno County), and were removed by October 12.

A special desert trap line ran from Highway 58 into the Mojave Desert. This trap line monitors the possible PBW moth migration from the southern desert cotton growing regions of Arizona, Mexico, Riverside and Imperial counties into the San Joaquin Valley. Zero (0) PBW moths were detected in the Mojave Desert trap line in 2007. There was one PBW moth detected in the Mojave Desert trap line in 2003. This was most likely a “blow-in moth”, resulting from hurricane “Marty”.

Southern California trapping was performed at protocol levels. Two-hundred seventy-seven (277) traps were placed in Riverside County, 32 traps in Imperial County, and San Bernardino County had 8 traps. There were three research plots (less than one (1) acre each) of non-*Bt* cotton plantings (conventional cotton). These fields were also trapped. All traps were serviced weekly.

Control

The primary control technique used in the San Joaquin Valley was the Sterile Insect Technique (SIT). The sterile moth receipts from the PBW Rearing Facility in Phoenix, AZ were consistent throughout the entire release period. There was an average of 2 million sterile moths released per day, six days per week. Sterile release began on May 2

and concluded September 23, 2007. Moth quality is confirmed by running a battery of quality control tests including: mortality on arrival and again seven days after arrival and mating on arrival and forty-eight hours after arrival. The results of these tests over the last five years demonstrate that the sterile moths received are in excellent condition, will live long enough in the field to be effective, and have the capacity to mate frequently. (See Table 1)

Table 1

STERILE MOTH QUALITY CONTROL					
	MORTALITY			MATING	
YEAR	*0 HOUR*	*7 DAY*	*14 DAY*	*0 HOUR*	*48 HOURS*
2003	3.19%	6.35%	42.06%	2.14%	86.79%
2004	2.34%	7.02%	38.59%	2.49%	86.93%
2005	0.20%	6.39%		1.59%	84.88%
2006	5.77%	13.33%		4.15%	82.00%
2007	0.52%	16.03%		2.92%	86.16%
Average	2.40%	9.82%	40.33%	2.66%	85.35%

Southern California cotton growing regions were added to the USDA Pink Bollworm Area-wide Eradication Program. The strategy for this program includes insect monitoring, *Bt* cotton plantings, sterile insect release, and pheromone treatments in non-*Bt* cotton. Growers in the Blythe/Palo Verde and Imperial Valleys chose to plant 100% *Bt* cotton. Of the three research plots, two were treated with pheromone rope to induce mating disruption and also received aerial SIT releases. The third plot received twice weekly ground releases of sterile PBW moths.
No pheromone mating disruption treatments were required in the San Joaquin Valley.

Mass aerial dispersal of sterile PBW moths was performed on cotton plantings in Imperial, Riverside, and San Bernardino counties under a contract with the USDA. Over 32 million sterile moths were released during the cotton-growing season in southern California as a component of the PBW Area-wide Eradication Program.

The GPS MapInfo®-based guidance and flight recording system was again utilized in release aircraft. This GPS guidance/flight recording system greatly improves sterile moth delivery to the target sections and provides post flight analysis.

Monitoring

California monitoring was preformed using pheromone baited traps. Trap data was collected and compared to previous years. This included both sterile recapture data and native (non-sterile) moths trapped. Sterile moth recapture numbers provided an indication of SIT effectiveness, sterile to native over-flooding ratios, and general distribution and concentration of sterile insects. Trappers inspected their traps and submitted suspect specimens to the ID Lab for determination. Moths produced at the CDFA Pink Bollworm Phoenix Sterile Insect Rearing Facility were raised on a larval diet that contains a marker dye. ID Lab personnel identified and counted PBW moths, distinguishing steriles from non-sterile moths by examining specimens for the red dye.

In the San Joaquin Valley trap monitoring was used to determine additional SIT release sections resulting from new native moth finds. When a native was trapped in a section not currently under SIT release, the section was immediately added to the SIT release schedule. The southern California cotton plantings received a consistent release rate on all cotton fields throughout the entirety of the SIT release period.

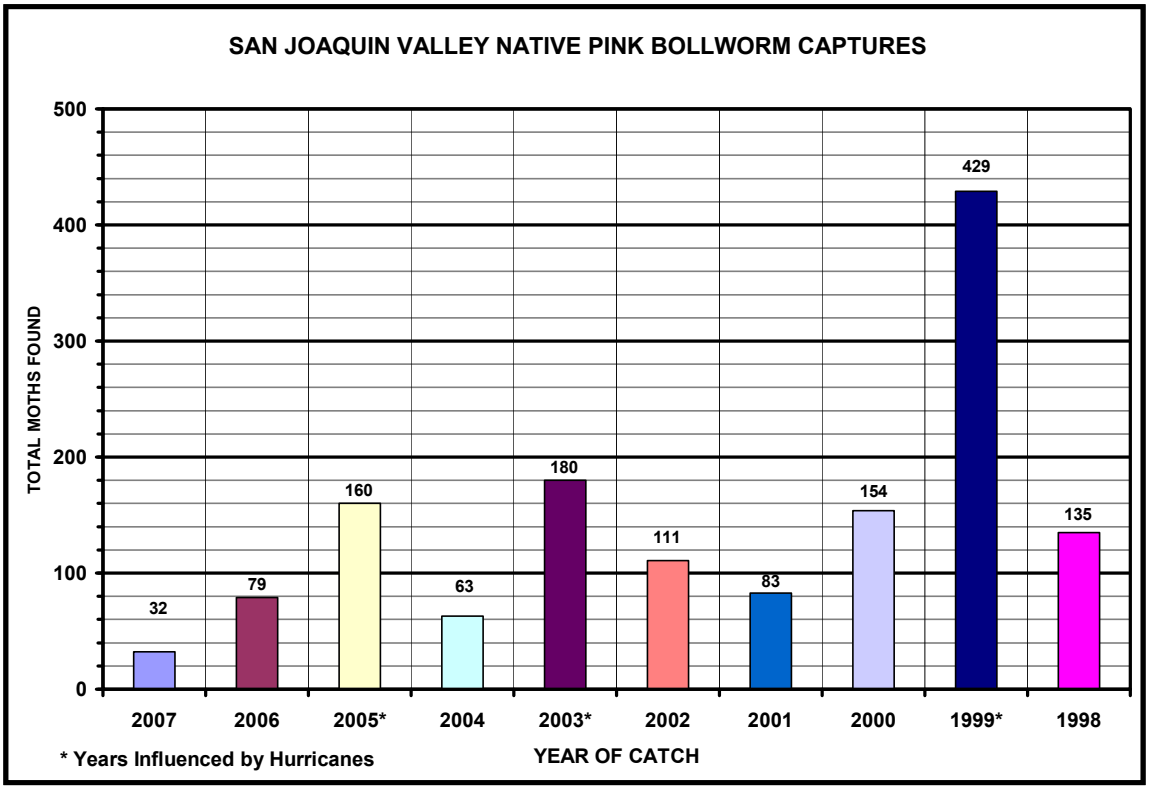
_Bt_ Resistance Monitoring

Cooperating with the USDA, the Arizona Cotton Research and Protection Council, and the University of Arizona, PBW Program staff conducted trapping and boll survey designed to evaluate PBW resistance to *Bt* cotton. Monitoring was done in the southern California counties. A total of ten (10) sites (fields) were selected for resistance monitoring. 1,000 bolls were collected from each *Bt* field and 200 bolls from each non-*Bt* field. A total of 10,400 bolls were collected and examined.

Results

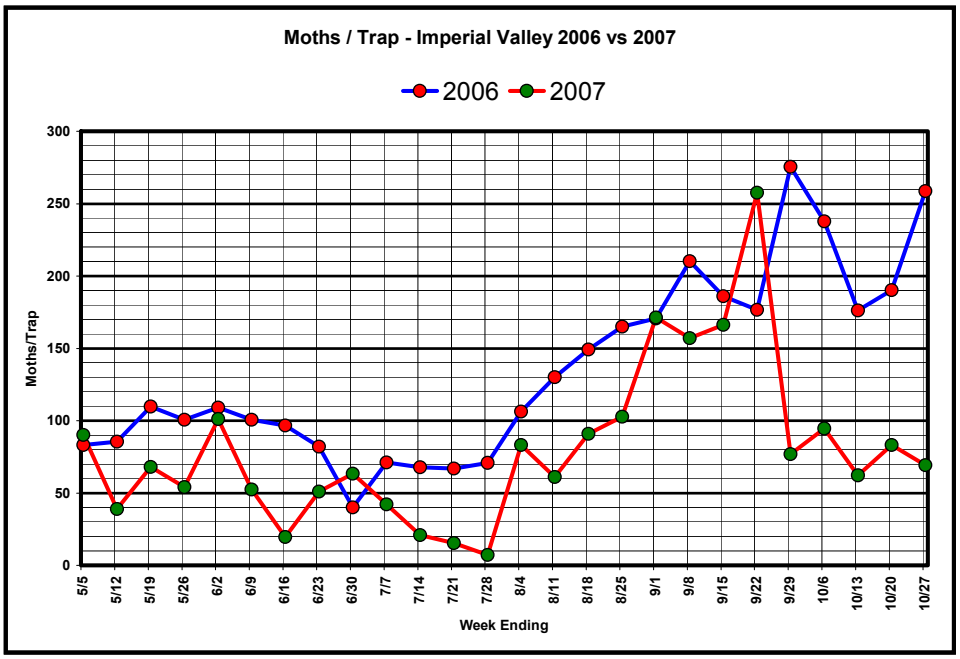
Trap Data

In year 2007, the Identification (ID) Lab examined 9,588 traps from the San Joaquin Valley containing suspect moths submitted by trappers. A total of 235,870 sterile moths and 32 native moths were identified in the San Joaquin Valley traps in 2007. This is the lowest native PBW count since 1973. There were 79 native moths trapped in 2006 and 160 native moths caught in 2005. The breakdown of native moths trapped per county in 2007 was sixteen (16) native moths trapped in Kern County, zero (0) in Kings County, zero (0) in Fresno County, nine (9) in Tulare County, one (1) in Merced County, and zero (0) in Madera County. A history of PBW moth captures in the San Joaquin Valley is illustrated in Graphic 1

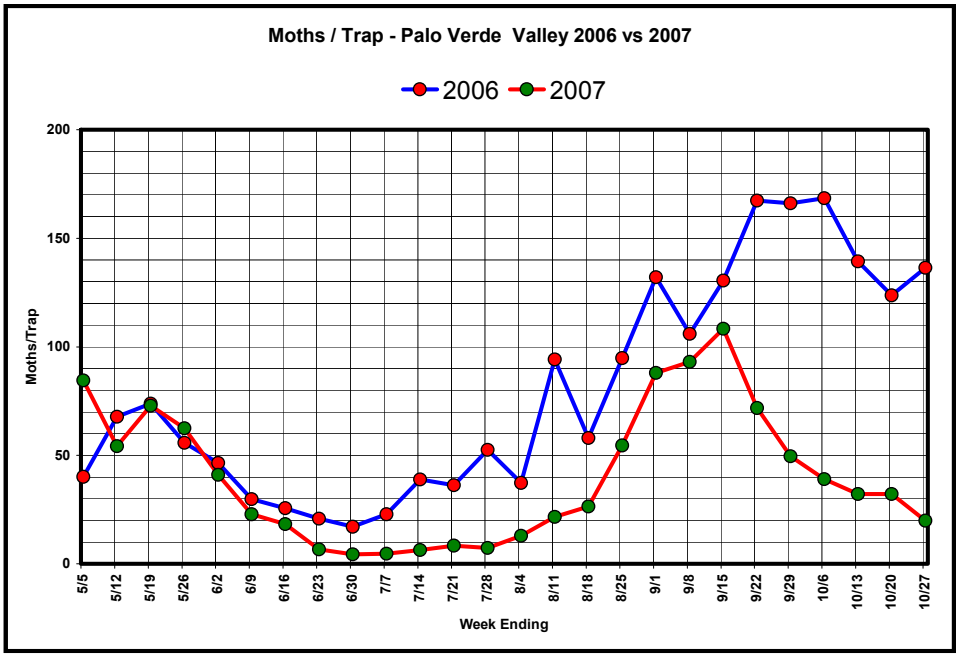


Graphic 1

In Southern California early summer PBW populations were predictably high due to overwintering emergence. There was a spike in native captures from mid-August into September due to migration from the adjoining areas of Yuma, AZ and Mexico. After September, there was a significant decline in natives trapped compared to the 2006 capture levels. (See Graphics 2 & 3).



Graphic 2



Graphic 3

Sterile moth releases were very consistent throughout the 2007 release period. Approximately 254,401,949 sterile moths were released in the San Joaquin Valley, approximately six (6) million per week. Releases started over the 2006 native find sections at a release rate of 133 moths per acre per day. Reduction in 2007 cotton acres and the

addition of new 2007 native find sections resulted in a release rate of 149 moths per acre per day at the end of the season. Southern California SIT releases were maintained at a consistent rate of nearly two (2) million sterile moths per week, averaging 15 moths per acre per day over the 100% *Bt* cotton acreage. Total PBW sterile moths released were 32,021,280 sterile moths. Southern California native captures totaled 416,765 moths, and 80,598 sterile PBW moths were recaptured.

Boll Sampling Data

Boll sampling triggers were never reached in the San Joaquin Valley due to the low number of native moth catches and lack of sufficient numbers of multiple native finds per cotton field.

Southern California boll survey in *Bt* cotton was consistent with previous years. During the past six (6) years the maximum level of larvae per boll in *Bt* cotton was 0.01 larva per boll. This is below expected levels for 2% non-expression of the *Bt* endotoxin. During the same period, adjacent non-*Bt* cotton had a maximum level of 1.74 larvae per boll. (See Table 2)

Table 2

	No. Sites		No. Bolls		No. Pbw		Pbw / Boll	
	Imperial Valley	Palo Verde Valley	Imperial Valley	Palo Verde Valley	Imperial Valley	Palo Verde Valley	Imperial Valley	Palo Verde Valley
Total							Average	
Non Bt	21	27	5,400	6,900	1,149	5,053	0.213	0.732
Bt	21	27	19,000	24,050	110	76	0.006	0.003
Maximum								
Non Bt	4	6	1,100	1,800	515	1,569	0.572	1.743
Bt	4	6	4,000	6,000	48	32	0.012	0.005
Minimum								
Non Bt	3	3	800	900	5	311	0.006	0.285
Bt	3	3	2,000	3,000	0	4	0.000	0.001

Conclusions

The San Joaquin Valley suppression program was extremely successful in 2007 having the lowest number of native moth captures since 1973. Sterile insect releases were consistent throughout the entire SIT release period and there were no interruptions in the daily release schedule. All phases of the Program were conducted per established protocols.

Southern California entered the first year of PBW Area-wide Eradication Program under the direction of the USDA. No significant conclusions regarding native populations can be drawn due the migration of natives from adjoining areas not under area-wide PBW management. However, there was a 17.3% reduction in total natives caught from the previous year. This reduction is very promising. Growers did not have to apply any treatments to control PBW populations.

Migration of PBW moths from neighboring areas not under area-wide PBW eradication continues. These areas will need to be added to the PBW Area-wide Eradication Program in order to prevent the re-infestation of zones currently under suppression.

Acknowledgements

The authors wish to thank the California cotton growers, the California Cotton Growers and Ginners Association, and the California Cotton Pest Control Board for supporting the PBW Program throughout its 41 year history.

Through their foresight, the development and implementation of SIT for PBW has proven to be an effective tool in the control and eradication of PBW infestations.

Additionally, payment of assessments by California cotton growers provided the funding for the purchase and construction of the current Pink Bollworm Sterile Insect Rearing Facility in Phoenix, Arizona. This facility was built in 1993 with the intention of having the ability to produce enough sterile insects to allow area-wide PBW control to the major cotton producing states.

We thank the USDA-APHIS for their technical support and facilitation of an aerial sterile release program for southern California. Our appreciation goes to Mr. Ernie Miller and his many USDA workers for directing and managing the production and shipment of sterile PBW moths at the Phoenix Rearing facility.

The authors also wish to thank Mr. Larry Antilla and Mr. Leighton Liesner of the Arizona Cotton Research and Protection Council and their many staff members for their assistance in the area-wide eradication program.

We wish to thank Susan O'Toole and her USDA colleagues for their successful efforts in obtaining an EPA Section 18 Crisis Exemption to allow the use of 100% *Bt* cotton plantings in southern California.

We especially wish to thank Dr. Bob Staten for his work on the Pink Bollworm Area-wide Eradication Program in the US and Mexico.

We wish to thank Dr. Tim Dennehy and his co-workers at the University of Arizona for their continued work in assisting California for the past five years in the assessment of PBW resistance to *Bt* cotton.

Lastly, a special thanks to all the CDFA Pink Bollworm Program employees who have steadfastly contributed to the overall success of the California Program through years of dedicated service.

References

Staten, R. T., Rosander, R. W., Keaveny, D. F., Genetic Control of Cotton Insects. IAEA-SM-327/28. Pages 269-283.

Grefenstette, W., El-Lissy, O., Staten, R.T., Pink Bollworm Eradication Plan in the US. 9pp.