AREA-WIDE MANAGEMENT/MAXIMUM SUPPRESSION OF PINK BOLLWORM IN SOUTHERN CALIFORNIA

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Introduction

Sterile insect technology has been used for 25+ years to prevent establishment of the pink bollworm, *Pectinophora gossypiella* (Saunders) as an economic pest in the San Joaquin Valley, CA (Staten et al. 1993). This is an exclusion program dependent largely on sterile insects over a very large area against targeted low level adult population. Migration is heavily implicated from southern desert growing regions. In the past, this technology has not been applicable against high populations in a generally infested area. To obtain controlling ratios would simply be cost prohibitive. With the full development of cost effective pheromone technology, shifts to determinant cotton in a compressed season and now genetically engineered cotton varieties (a *Bacillus thuringensis* endotoxin producing plant defined as Bt cotton), use of sterile insect technologies may be expanded. We have an excellent potential for a management/eradication program that is expected to eliminate the pest potential of this species in the Southwest U. S.

The use of sterile insect technology is particularly valuable with Bt cotton. Sterile insects act as pseudo-refugia. In the past 5 years we have used the Imperial Valley as a large area test site to conduct exploratory programs (Staten et al., 1995, Walters et al., 1995, 1998). Although this area does not have adequate isolation for eradication, high levels of suppression are measurable. Data has been convincing enough to expand this experimental phase to the Palo Verde Valley in 1998. This paper will summarize briefly data and program activities to date. It will cover Imperial Valley activities from 1994 through 1998 and the pre-program data from the Palo Verde and its first year of organized control activity in 1998.

Methods

The Imperial Valley used pheromones and sterile insects in conjunction with a well-regulated season from 1994 through 1996. Fields were monitored biweekly with a minimum of 2 Gossyplure baited traps per field. Boll samples were collected from 10 randomly selected fields from each "treatment" category, listed below. Bolls were incubated in boll boxes as in previous studies in the Imperial Valley (Chu et al., 1996). Sterile insect management and release is detailed in Pierce et al, 1995 with variables as per Table 1.

Pheromone treatments were used in 1997 and 1998 on all treatable refugia (<=80 Bt cotton and >=20% conventional cotton). Untreatable refugia (>= 4% of the grower's total acreage) were all planted "in-field" within the Imperial Valley. 100% Bt fields also received sterile release. Thus, treatments were 1) Pheromone + sterile release, 2) Bt + sterile with untreatable, in-field refugia, or 3) 100% Bt + sterile release.

Sterile releases averaged 100 sterile insects per acre per day over all acreage. Distribution of sterile releases, however, was altered based on field type and ration of sterile to native in traps. All fields were eligible for sterile release. Sterile insecticides are not registered as an insecticide and may thus be used in "untreatable" refugia.

Three trap lines, remote from any cotton field, were set up to measure migration, particularly from the 110,000+ non-program cotton growing areas of the Mexicali Valley, Mexico. These trap lines were placed nearly perpendicular to the expected line of flight from the Mexicali Valley, within the Imperial Valley (Figure 1) and along a highway running northward from the Valley toward Central California.

The Palo Verde Valley was not used for any organized area-wide program before 1998. It was, however, monitored in a manner similar to the Imperial Valley from 1994 to 1998. Boll samples were taken from three categories of fields in the Palo Verde Valley in 1998, as described above except that in this valley growers chose to plant entire fields of untreatable refugia as opposed to in-field refugia. The preponderance of all sterile insects were used on these "untreatable refugia" with a minimum release on Bt cotton during the first half of the season. As the season progressed, sterile insects were shifted to adjacent Bt cotton fields as a hedge against resistance development (Figure 2). Only 3 fields were eligible for pheromone treatment within the Valley. Each of these fields was sampled for larval populations in bolls. Fifteen fields of Bt cotton and 12 untreatable refugia fields were also randomly selected from their respective categories for boll samples.

Results

In the Imperial Valley, populations were extremely low until the adjacent Mexicali Valley ended irrigation in its vast 110,000+ acres of cotton. Figure 3 provides insight into population development of native adult males in 1998 compared to the previous four years. Figure 4 shows

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numbers of sterile moths released vs. numbers of native males trapped in 1998.

Native moth capture levels were lower in 1998 than any year but 1994. In 1994 there was no significant migrational influence from cotton in Mexico. Mexicali cotton was at an all-time low of less than 1,000 acres in 1993 and less than 10,000 acres in 1994. Early season populations in Imperial in 1994 and 1998 were comparable. Late season populations were also low longer than in any year but 1994. In addition, sterile to native ratios held longer than any year but 1994. We maintained ratio well with only minor shifts in release patterns through mid-August. Only after August 24 were there major ratio losses. Sterile insects where then shifted to Bt cotton as a resistance management strategy until mid-September.

Boll data in the Imperial Valley is extremely important (Table 2). As expected there were essentially no larval populations in Bt cotton. Pheromone treated fields had extremely low populations until the end of the first boll set period when cotton is normally largely open. There was some late cotton set but no appreciable populations developed, even after migrational influences. Boll samples from untreatable, in-field refugia are of the most interest. The distribution of these refugia is most favorable to maximum suppression systems, if refugia continue to be required. Larvae were not found in bolls sampled on or before 8/16/98. Levels remained low throughout the season. Even with low native populations, because these refugia were infield they were well dispersed over the Valley within blocks of Bt cotton.

Movement of native adults was first detected in non-cotton traps along the Mexican border at the end of the first week of August. Numbers escalated most sharply in the 2 trap lines closest to Mexico on 8/9/98 (Figure 5). These lines generally maintained highest captures season long. The moth capture in the trap line leaving the valley did not escalate until after 8/30/98 even though it is closer to Imperial cotton fields than the most southern line.

The Palo Verde Valley provides several interesting contrasts. In 1998, adult populations were the lowest in our monitoring history. Even in 1997 with similar levels of Bt cotton, populations from 4/21/98 through early July 1998, were lower (Figure 6).

By mid-July however, untreatable refugia fields began to develop significant populations of native moths. Ratios were not maintainable by late July in an ever-increasing number of untreatable refugia fields. By the first of August, ratios were not maintainable in 1/3 of the 30 fields in this category. By mid-August, only 1/3 of these fields had acceptable ratios. All sterile releases were shifted to Bt cotton for resistance management.

Boll data is of major interest for untreatable refugia fields. Larval populations developed early, and after July were high in a few problematic fields. This is a stark contrast to the untreatable, infield refugia of the Imperial Valley. The three pheromone-treatable refugia fields in Palo Verde maintained non-detectable larval populations until the end of the season. Larval populations in Bt cotton were near or below detectable levels season-long with larvae collected only on 8/23 and 8/30.

Conclusions

Populations are again below the economic threshold in the Imperial Valley even though chemical treatments and plowdown have each been extended by 1 month. In addition, the legal planting window has been pushed back to the 10th of February. Seasons are now significantly longer than in the first year of regulation reported by Chu et al, in 1996. Each year the most important influence on populations has been the influence of the Mexicali Valley. The untreatable refugia are of particular interest in Imperial. It appears that this type of refugia would not block an eradication effort, even over a massive area of 250,000+ acres, if they were remote enough from migrational influences.

In the Palo Verde Valley, the 281 Bt fields produced extremely low native populations. Untreatable refugia produced native moths that distributed over much of the valley (see Walters et al in following paper). These moths were produced in abundance. Only pheromone treatable, full-field refugia blocks were maintained at levels low enough for any expected maximum-suppression/eradication effort.

The comparison of populations between untreatable, full-field refugia in the Palo Verde Valley and untreatable, in-field refugia in the Imperial Valley is of major importance. If untreatable refugia are required within a maximum suppression/eradication program, it is important that it follows the in-field refugia model of the Imperial Valley. Full fields of non-pheromone treatable cotton are not desirable on an area-wide basis if eradication if the desired outcome.

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Table 1. Imperial Valley 1994 – 1998 Program Review

Year	1994	1995	1996	1997	1998
Sterile Release	250	175	350	100	100
Pheromone Treatment	Rope + MEC	Rope + Fiber	Rope + Fiber	Rope	Rope

Notes: Sterile Release = average number of moths per acre per day, calculated on a 7 days per week basis. Delivery was on a 6 day a week basis for 1994-1996 and on a 3-day per week basis for 1997-1998.

Table 2. 1998 Imperial Valley Boll Data

Week Of	Bt Cotton Bolls Sampled	Bt Cotton Larvae/ 100 Bolls	Conventional, no pheromone Bolls Sampled	Conventional, no pheromone Larvae/ 100 Bolls	In-field Refugia Bolls Sampled	In-field Refugia Larvae/ 100 Bolls
7/5/98	800	0.00	720	0.14	640	0.00
7/12/98	800	0.00	720	0.00	880	0.00
7/19/98	800	0.00	720	0.00	880	0.00
7/26/98	800	0.00	720	0.28	880	0.00
8/2/98	800	0.00	720	0.00	880	0.00
8/9/98	800	0.00	720	0.14	880	0.00
8/16/98	800	0.00	720	0.14	880	0.00
8/23/98	800	0.00	720	8.75	880	0.11
8/30/98	800	0.00	720	0.00	880	0.34
9/6/98	800	0.00	720	7.92	880	0.57

Note: 1998 Imperial Valley Boll Data. Total acreage consisted of 47.7% Bt cotton fields (2256 acres), 21.2% conventional cotton fields with pheromone rope (1003 acres), and 31.1% Bt cotton fields with in-field refugia. The in-field refugia consisted of a cumulative 59 acres of conventional cotton planted within 1415 acres of Bt cotton, for example, 4 rows of conventional cotton planted in the middle of a Bt cotton field.

Table 3. 1998 Palo Verde Boll Data

Week Of	Bt-Cotton Bolls Sampled	Bt-Cotton Larvae/ 100 Bolls	Conventional with pheromone Bolls Sampled	Conventional with pheromone Larvae/ 100 Bolls	Conventional no pheromone Bolls Sampled	Conventional no pheromone Larvae/ 100 Bolls
7/5/98	160	0.00	0	0.00	160	1.25
7/12/98	480	0.00	0	0.00	800	3.25
7/19/98	1040	0.00	160	0.00	960	3.13
7/26/98	1520	0.00	240	0.00	1320	1.21
8/2/98	1580	0.00	240	0.00	1360	3.24
8/9/98	1600	0.00	240	0.00	1280	6.56
8/16/98	1320	0.00	240	0.00	1360	9.85
8/23/98	1440	0.14	240	0.00	1200	25.17
8/30/98	1280	0.08	240	1.25	960	47.08
9/6/98	240	0.00	240	0.00	80	208.75

Note: Acreage consisted of 91.9% Bt-cotton fields, 1.5% conventional cotton fields treated with pheromone rope and 6.6% conventional cotton fields, no pheromone treatment, refugia.

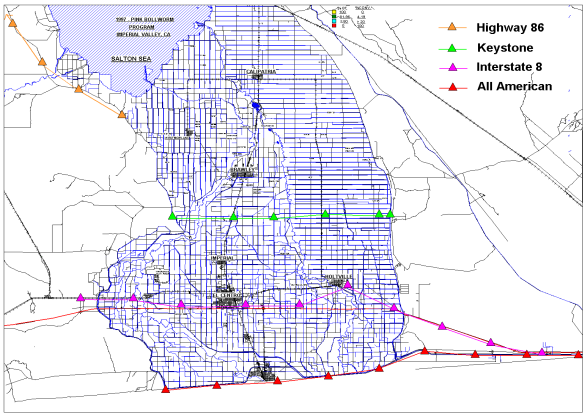

Figure 1. Migratory trap lines, Imperial Valley, CA

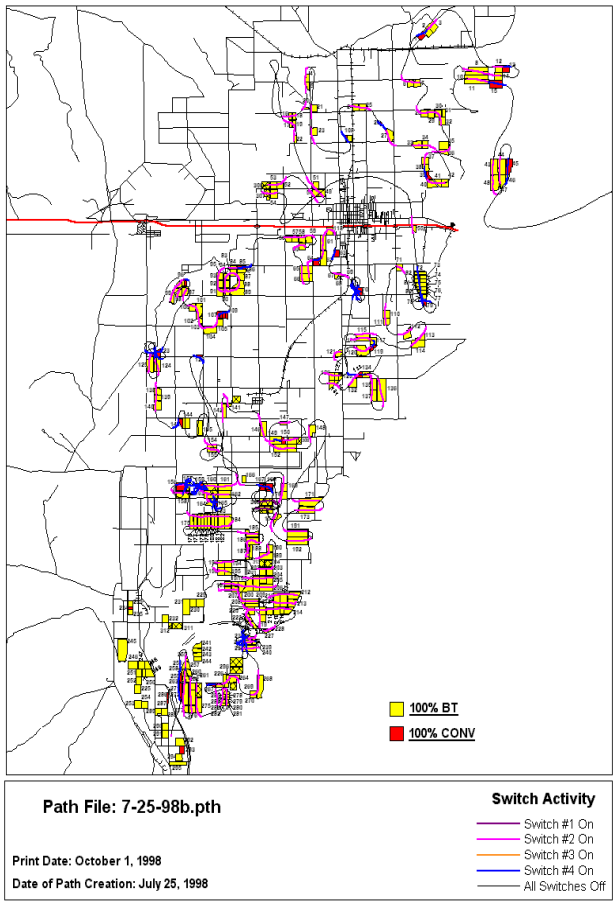

Figure 2. 1998 Palo Verde Calley, CA, showing cotton field type and locations, overlaid with the sterile release flight path and color-coded release rates.

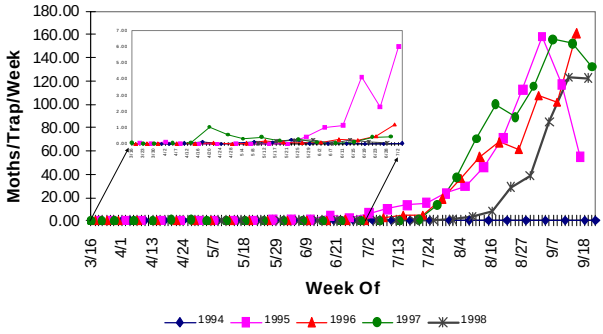

Figure 3. Comparison of Native Moths Captured per Week, 1994-1998 Imperial Valley, CA, PBW Sterile Release Project

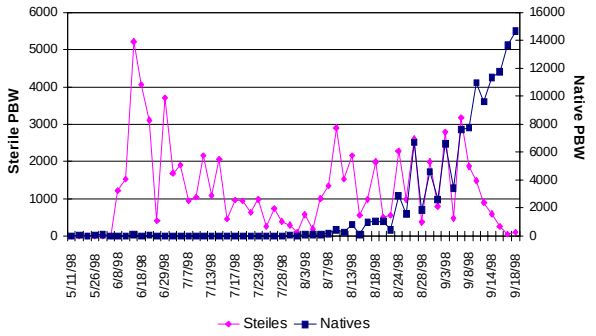

Figure 4. Total Sterile vs. Native PBW Trapped - Imperial Valley, CA, 1998

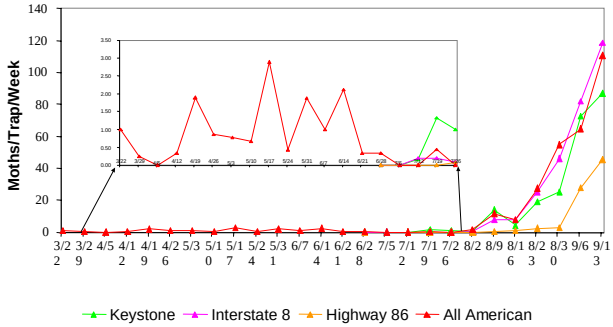

Figure 5. Comparison of Native Moths Captured per Week, 1994 - 1998, Imperial Valley, CA.

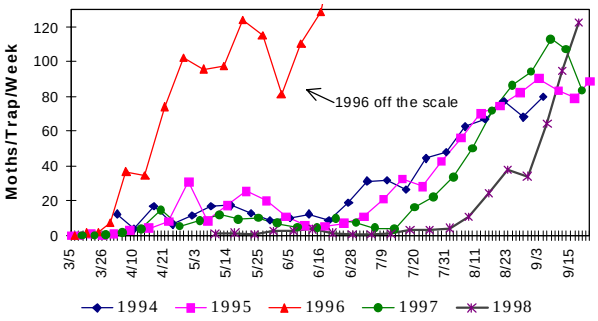

Figure 6. Comparison of Native Moths Captured per Week, 1994 - 1998, Palo Verde Valley, CA.