Use of pheromones and other semiochemicals in integrated production
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Use of mating disruption in cotton in North and South America

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Abstract: The pink bollworm, *Pectinophora gossypiella* (Saunders), is one of the most serious pests of cotton worldwide causing losses in both yield and quality. Control with conventional insecticides is difficult because the pest is well protected within cotton squares and bolls. Furthermore insecticide costs are high and applications of broad-spectrum materials have contributed to outbreaks of secondary pests. Mating disruption has provided a viable alternative for pink bollworm control. Development of mating disruption for the pink bollworm began 25 years ago and the first EPA registration of a pheromone formulation for mating disruption was issued for the pink bollworm in 1978. Since that time many formulations have been developed and commercialized. These materials represent various use methods and modes-of-action. The effectiveness of these formulations has been demonstrated in several areawide programs. These programs integrate IPM techniques conducive to mating disruption and avoid some of the factors detrimental to the technique.

Key words: pink bollworm, *Pectinophora gossypiella*, mating disruption, pheromone, gossyplure

Cotton pest pheromones

Insect pheromones have been identified for most of the important cotton pests in North America and commercial synthetic formulations have been developed for management of many of these pests either for monitoring or control. Economic thresholds have been established for trap and pheromone lure systems for some pests; however, except for the boll weevil (*Anthonomus grandis*) and the pink bollworm (*Pectinophora gossypiella* Saunders) trapping systems are not widely used for monitoring cotton pests chiefly due to expense and labor.

Sex pheromone formulations have also been developed for the direct control of several potential cotton pests either by classical mating disruption, attracticide or bioirritation. In the 1980's pheromone systems were developed in the USA for management of Tetranychus mites, Heliothis/Helicoverpa and the boll weevil. These products did not survive due to low efficacy and availability of cheaper insecticide alternatives. Currently the omnivorous leafroller (*Platynota stultana*), an occasional pest of cotton has several mating disruption formulations registered in the USA but

not for use in cotton. A hand-applied formulation is now registered with the US-EPA for mating disruption of the beet armyworm (*Spodoptera exigua*) in cotton but because this pest is sporadic and difficult to predict in cotton, control by mating disruption will be limited.

Pink bollworm mating disruption

The most successful development of mating disruption for cotton pests has been with the pink bollworm (PBW). Part of this success is a result of the pest's biology. PBW has only one important host – cotton, it is widely spread throughout the world, and where it occurs it is generally a serious problem. Yield reductions of 30% or higher can result from PBW infestation (1). PBW feeds within the cotton squares and bolls, cutting and staining fiber and feeding on seeds. It is well protected from traditional chemotherapy. Insecticides applications aimed at adult moths can be expensive and difficult to time. The pheromone of PBW, gossyplure, is relatively cheap to produce and stable in the environment (2). It is commercially available from a number of sources.

In 1978, the first mating-disruption product was registered with the US-EPA for PBW control (3). Development of pheromone delivery systems and application technology progressed as the use of mating disruption increased. The first innovation in mating disruption of PBW came early in 1980 when observations led to the attracticide technique for this pest. Male moths may approach and contact synthetic pheromone dispensers (4). Furthermore, male encounters with pheromone dispensers could be quantified by looking at moth scales associated with point sources. Studies showed small amounts of insecticide incorporated into the pheromone dispenser had no negative impact on beneficial insects (5) but could result in a more robust system than conventional mating disruption (6). Several commercial formulations adopted this approach.

PBW mating disruption formulations can be divided into several categories based on dispenser type and application technique (Table 1): (1) Reservoir, high rate systems that must be hand applied; (2) female equivalent, low rate sprayable systems; (3) female equivalent, low rate hand-applied systems; (3) microdispersible, low rate systems that are sprayable.

In the high rate, reservoir systems the number of dispensers per hectare is relatively low (250-1000). The advantage is long field life. Generally only a single application is needed and gaps between applications are eliminated. The disadvantage is labor cost for hand application - a negative in some markets such as the USA but an advantage in others where cheap labor is abundant.

The second and third groupings are female equivalents, low rate systems that are either sprayable with specialized equipment or hand applied. Dispenser numbers vary between hundreds and thousands per hectare. Longevity is short: 7 - 28 days

Table 1. Commercial PPW mating disruption formulations

Reservoir, high-rate, hand-applied

Producer	Product Trade Name	Dispenser Type	Points per ha	Field Life (days)	Mode of Action*
Shin-Etsu	PB-ROPE L®	Plastic tube	250 - 500	90	MD
Biosys	Frustrate Band®	Plastic band	250	90	MD
Scentry	NoMate PBW Spiral®	Plastictube	500-1000	60	MD

Female equivalent, low rate

Producer	Product Trade Name	Dispenser Type	Points per ha	Field Life (days)	Mode of Action*
		Sprayable (special equipment)			
Scentry	NoMate PBW Fiber®	Hollow fiber	5000-12,500	7-21	MD, A&K
Hercon	Disrupt PBW®	Laminate flake	12,000-32,000	7-21	MD, A&K
		Hand-applied			
Troy	Last Flight®	Liquid polymer	750	28	MD, A&K
Novarits	Last Call®	Viscous paste	5,500	28	MD, A&K

Microdispersible, low rate, sprayable

Producer	Product Trade Name	Dispenser Type	Points per ha	Field Life (days)	Mode of Action*
ICI	Pectone®	microcap	fog	10-30	MD, BI
Fermone	Stirrup-PBW®	na	fog	na	MD, BI
Agrisense	Decoy Beads®	macrocap	fog	10-28	MD, BI
Scentry	NoMate PBW MEC®	microcap	fog	7-21	MD, BI
Consep	Checkmate PBW®	macrocap	50,000	14-28	MD, BI
Consep	Checkmate PBW-F	microcap	fog	7-21	MD, BI

* MD – classical mating disruption (false trail following, camouflage, habituation, etc.)

* A&K – attract and Kill (attracticide)

* BI – bioirritation

depending on temperatures. Mode-of-action is either mating disruption or attracticide. Most Female Equivalent formulations can be used as attracticides and some actually have insecticides premixed into the formulation.

The last category is microdispersible, low rate, sprayables. These formulations have the advantage of application via conventional equipment. Many can be tank mixed with insecticides and applied simultaneously in attempt to achieve bioirritation. Most of these materials are shorter-lived and rain wash-off is a concern. There are tens-of thousands of points sources or, in the case of the microcaps, a fog rather than a distinct point site.

PBW areawide management

PBW has been used in several areawide programs in North and South America (1, 7, 8, 9). One of the more successful examples of PBW mating disruption was the Parker Valley Program (10). This effort first began as a boll weevil eradication program and grew to include PBW and whitefly management on as many as 700 fields and more than 10,000 hectares. This areawide program was supervised by the Arizona Cotton Research and Protection Council and incorporated many of the factors that contribute to the efficacy of mating disruption: early application (at pinsquare), economic thresholds (1 moth/trap/day), careful monitoring (weekly readings, 1 trap/ha), reduction of immigration from outside sources. This program had excellent results through 5 years with a gradual reduction in control costs (Table 2). However, in 1996, PBW infestations increased significantly, as a result of mild winter and because a late harvest of neighboring wheat fields left a source of PBW infestation that grew undetected until midseason. The result was higher than normal infestation and increase control cost (11). This unfortunately led to the demise of the project in 1997 as growers switched to Bt-cotton.

Table 2. PBW infestation and control cost -Parker Valley Project, AZ

Year	Bolls inspected	infested (%)	Cost per ha ($ USD)
1989	26,879	23.35	-
1990	34,726	9.91	107.50
1991	35,477	1.42	107.50
1992	30,064	0.86	137.50
1993	25,200	0.00	56.25
1994	16,109	0.02	72.00
1995	16,520	0.38	81.90
1996	45,597	2.63	127.28

Conclusion

Management of PBW by mating disruption has been one of the most successful examples of pheromone use in the USA, and in the world. Since the first commercial formulation entered the marketplace more than 20 years ago, millions of hectares of cotton have been treated with several distinct formulations. However, the use of this technique for PBW control began to decrease in the mid-90's as cotton acreage decreased in the desert southwest of North America and the use of transgenic Bt-cotton increased. An estimated 21,300 hectares of cotton were treated PBW mating disruption products during 1999, down from 46,800 in 1997 (Table 3).

Table 3. Estimated area treated with PBW mating disruption (ha)

Country	1997	1998	1999
USA	41,600	20,500	18,000
Mexico	5,200	4000	3,200
Total	46,800	24,500	21,200

Mating disruption has not been widely adopted in cotton in South America. Poor economies and decreasing cotton acres have limited market development. Currently only Peru has significant use of mating disruption with approximately 5,000 hectares treated for PBW. Still, this represents only approximately 10% of the total cotton acres.

Bt-cotton is very effective in controlling PBW. It is easier to use and cost competitive. Approximately 20% of cotton in Arizona was transgenic in 1996, 50% in 1997, 60% in 1998, and 42% in 1999 (L. Antilla, personal communication). Mating disruption has been relegated to decreasing areas of non-Bt cotton such as Pima cotton or to refugia zones.

There are now several powerful weapons to combat the PBW including transgenic cotton, mating disruption and sterile moth technique. Utilization of these techniques can provide a strong, diversified integrated management program for PBW. The USDA and CDFA tested this approach in the Imperial Valley of California during the late 1990's with good results. A larger program is now planned for the El Paso/trans-Pecos area of Texas. If successful, this program could spread to New Mexico, Arizona and the Mexican states of Chihuahua and Baja California Norte. The goal is eradication of PBW from the desert southwest.

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