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PINK BOLLWORM ERADICATION PLAN IN THE U.S.

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Abstract

An areawide pink bollworm eradication program, involving growers and state and federal cooperators, has been proposed by the National Cotton Council's Pink Bollworm Action Committee, with the objective of eradicating the pink bollworm (PBW) from the southwestern portion of the U.S. Cotton Belt.

Through coordinated efforts by cotton producer communities, and federal, state, regional, county, and local entities in the U.S. and Mexico, the plan is to implement the eradication program in three incremental phases. Phase I, in 2001/2002, consists of the El Paso/Trans Pecos region of west Texas, south-central New Mexico, and northern Chihuahua, Mexico. Phase II, in 2004, consists of cotton-growing areas in southeastern and central Arizona. Phase III, in 2006, consists of western Arizona, southern California, and the Mexicali Valley of northwest Mexico.

The operational elements of the proposed program include: 1) *mapping* to identify cotton field locations, acreage, and genotypes; 2) *detection* by trapping and visual inspection; and 3) *control* using cultural practices, mating disruption with pheromone, Bt transgenic cotton, sterile moth releases, and minimal insecticide applications.

This report provides a summary of the strategic plan and the operational aspects of the proposed PBW eradication program.

Introduction

The pink bollworm (PBW), *Pectinophora gossypiella* (Saunders), was described from larvae recovered from infested cotton bolls in India in 1843 (Noble 1969). It has since become one of the most destructive pests of cotton in many of the major cotton-growing regions of the world. The first reported cotton infestation in North America occurred in 1911 in Mexico, presumably from Egyptian cotton seed shipments (Glick 1967). In the United States, PBW was detected first in Robertson County, Texas, in 1917 (Scholl, 1919). By 1926, the pest had spread from Texas through New Mexico and into eastern Arizona, and became a major economic pest of cotton in Arizona and southern California in 1965 (Burrows et al. 1982).

Conventional insecticides have not provided a long-term solution to the pink bollworm problem (Henneberry 1986).

Considerable amounts of basic biological and ecological information have been accumulated and applied in developing PBW control programs. Experience has demonstrated that no single control method is completely satisfactory. The possibility of combining a number of methods into a single control system appears the most promising approach (Henneberry et al. 1980).

Methods of PBW Control

Mating Disruption with PBW Sex Pheromone (gossyplure)

Behavioral insect control by mating disruption with sex pheromone was suggested by Knipling and McGuire (1966).

Hummel et al., (1973) identified a mixture of the Z,Z- and Z,E-isomers of 7,11-hexadecadienyl acetate as the pink bollworm sex pheromone and proposed the name "gossyplure." Shorey et al., (1976) initiated studies to evaluate the mating disruption method, in which the atmosphere of the cotton field was permeated with gossyplure, for PBW control.

Albany International Co., Needham, Massachusetts, developed NoMate-PBW®, a slow release formulation of gossyplure and hexane contained in 1.5 cm lengths of about 200µ I.D. hollow fibers, sealed near one end (Brooks et al. 1979, Brooks and Kitterman 1978). The results of extensive testing in Arizona and southern California indicated substantial reduction in boll infestations and in the need for chemical insecticides for PBW in the NoMate-PBW treated fields (Doane and Brooks 1980).

Areawide applications with PBW pheromone in the Imperial Valley of California resulted in curtailing insecticide use and significant yield increases (Staten et al. 1983). Additional evaluations of the effectiveness of control of PBW using pheromones in commercial cotton conditions were made in 1981 (Butler and Henneberry 1982, Butler et al., 1983), and in 1982 (Butler and Henneberry 1983). The gossyplure combination used in these studies included the addition of 0.004 kg of permethrin or fenvalerate (AI) per ha to the polybutene sticker, Bio-Tac, used to adhere fibers to leaves (NoMate-PBW Attact'n Kill). The addition of this small amount of insecticide was shown to enhance the effectiveness of the pheromone by killing male moths that encountered the fiber (Staten and Conlee, U.S. Patent No. 4671010). The small amount of insecticide, in sources that were attractive only to the pink bollworm and widely scattered (one per 2 m^2) through the top of the cotton canopy, did not appear to be a threat to insect predators (Butler and Las 1983).

Hercon Group of Herculite Products, Inc., New York, developed Disrupt®, a slow release system for gossyplure, consisting of three-layer plastic dispensers (0.05 cm^2) with gossyplure concentrated in the center reservoir and the outer layers regulating the release of the pheromone (Kydonieus 1978). The results of field tests of this product in Arizona indicated substantial reduction in boll infestations (Henneberry et al., 1981).

Shin-Etsu Chemical Co., Ltd, Tokyo, Japan, developed the PB-Rope®, a high rate, slow release system consisting of a wire-based, sealed polyethylene tube (8") filled with gossyplure (Flint et al. 1985). Extensive field trials conducted in the Imperial Valley of California and the Mexicali Valley of Mexico indicated a substantial reduction in boll infestations and insecticide applications in the PB-Rope treated fields, compared with that in conventional insecticide-treated fields (Staten et al. 1987). Community-wide application of the PB-Rope in the Coachella Valley of California, at the pinhead square growth stage, provided a highly effective level of control of PBW for approximately sixty days, and insecticide usage was drastically reduced or even eliminated in some fields (Staten et al. 1988).

Area-wide, timely application of commercial formulations of gossyplure in the Parker Valley of Arizona, demonstrated the feasibility of suppressing PBW infestations to a near zero level in four years, and conceptualized the prospect of eradication (El-Lissy et al. 1993, Staten et al. 1995, and Antilla et al. 1996).

Bt Transgenic Cotton

Genes from the bacterium *Bacillus thuringiensis* (Bt) that produce the Cry1Ab or CrylAc proteins which are toxic specifically to lepidopterous insect species were inserted into cotton plants by Perlak et al., (1990). Several field tests of Bt transgenic cotton indicated a high degree of efficacy against lepidopterous insect pests (Wilson et al. 1992, Mahaffey et al. 1994, and Benedict et al. 1996). In particular, Bt cotton provided an exceptionally high level of season-long control of pink bollworm (Flint et al. 1995, Watson 1995, and Flint and Parks 1999). Bollgard® Cotton (Monsanto Technology LLC, St. Louis, Missouri), was the first transgenic Bt cotton, commercially released in the U.S. and other cotton-growing countries in 1996. In the first growing season of commercial Bt cotton, U.S. growers planted approximately 1.6 million acres, which represented 14% of the total cotton acreage (USDA, 1999). In 1997, about 25 percent of U.S. cotton acreage, approximately 3.4 million acres, was planted to Bt cotton (USDA, 1999). In Arizona, where PBW is a key pest, approximately 60 to 70% of the Upland cotton acreage was planted to Bt cotton in 1997 (Silvertooth, 1998), and 70% in 1998 (Patin et al. 1999).

In spite of early concerns regarding potential development of PBW resistance to Bt cotton (Bartlett 1995, Watson 1995, and Patin et al. 1999), evaluations of Bt cotton in 1995 through 2000 indicated that Bt cotton continues to provide a high degree of season- long efficacy against PBW, irrespective of the suggested reduction in the amount of toxic protein in fruit tissues late in the season (Henneberry et al. 2001).

Sterile Insect Technique (SIT)

As early as 1937, E. F. Knipling had conceived of an approach to insect control by which the natural reproductive processes of the screwworm fly are disrupted by chemical or physical mechanisms, thus rendering the insects sterile (Knipling 1985). Sterile insects are released into the environment in very large numbers (10 to 100 times the number of native insects) in order to mate with native insects present in the environment. A native female that mates with a sterile male will produce infertile eggs. Since there are 10 to 100 times more sterile insects in the population than native insects, most of the crosses become sterile. As the process is repeated, the native population decreases and the ratio of sterile to native insects increases, thus driving the native population to extinction (Knipling, 1979). This unique insect control method is known as the sterile insect technique (SIT), or the sterile insect release method (SIRM).

One of the most successful SIT programs involves the pink bollworm in the San Joaquin Valley of California (Staten et al., 1993). This cooperative grower-state-federal effort began in 1968. Sterile pink bollworm adults, produced at the PBW rearing facility in Phoenix, Arizona, have been released each day of the cotton-growing season on approximately one million acres of cotton. This program has proven successful in preventing the high populations of PBW occurring in the adjacent regions of southern California, Arizona, and northern Mexico, from becoming established in the San Joaquin Valley (Staten et al., 1993).

Cultural Control

Cultural practices affecting the survival of pink bollworm have been extensively investigated and found to have an important role in reducing overwintering populations. Adkisson et al. (1960) reported more than 80 percent reduction in moth emergence from fields that had been shredded and plowed. Diapausing larvae overwinter in immature cotton bolls, trash, and soil (Bariola 1984). The removal of late-season immature cotton bolls is a viable option to reduce the overwintering population (Kittock et al. 1973). Cultural control techniques that include shredding stalks, disking, plowing, and winter irrigation have been shown to result in high levels of mortality of diapausing larvae in bolls, trash, and soil (Watson 1980).

PBW Distributions in the United States

A two-year PBW adult detection survey was conducted in Arkansas, Louisiana, Oklahoma, Texas, and New Mexico in 2000 and 2001. PBW delta traps baited with 4.0 mg of gossyplure, were placed around cotton fields at a density of one trap per 640 acres, in the first week of August (first week of July in South Texas), and inspected weekly through the month of October. Preliminary analysis indicated no PBW present in Arkansas, Louisiana, Oklahoma, and most of Texas. PBW populations appear to be confined to far-west Texas and south central New Mexico (Figure 1). Ongoing trapping surveys conducted in Arizona by the Arizona Cotton Research and Protection Council, and in California by Imperial Valley Commissioner of Agriculture and California Department of Food and Agriculture, continue to indicate wide distributions of PBW in the entire state of Arizona and Southern California.

Economic Importance of PBW in the United States

Control costs for PBW in Southern California and Arizona were estimated to exceed $1.2 billion over the past thirty years (Roberson et al. 1998, Antilla et al. 1999). Yield losses caused by PBW ranged from $85-$170 per acre (Antilla et al. 1999). Most recently, the National Cotton Council estimated that U.S. cotton producers' annual losses to pink bollworm are about $21 million due to prevention, control costs and lower yields due to plant damage (NCC, 2001).

The Bilateral PBW Eradication Plan

In its annual meeting on October 9-10, 2000, in El Paso, Texas, the National Cotton Council's Pink Bollworm Action Committee recommended launching a "bilateral" PBW eradication program in the Unites States and northern Mexico. The plan includes coordinated efforts by cotton producer communities and federal, state, regional, county, and local entities in the U.S. and Mexico to combat and eliminate the PBW from cotton-producing regions of West Texas, New Mexico, Arizona, California, and northern Mexico.

Pending grower approval through scheduled referendums, adequate funding and PBW rearing capacity, the plan is to implement the PBW eradication program in three incremental phases: Phase I in 2001/2002, Phase II in 2004, and Phase III in 2006 (Figure 2).

Phase I

Consisting of the El Paso/Trans Pecos region of West Texas, south-central New Mexico, and northern Chihuahua, Mexico. The El Paso/Trans Pecos region consists of approximately 55,000 acres of cotton in Brewster, Crane, Crockett, Culberson, El Paso, Hudspeth, Jeff Davis, Loving, Pecos, Presidio, Reeves, Terrell, Ward, Winkler, and Val Verde counties. The south-central New Mexico region consists of approximately 26,000 acres of cotton in Doña Ana and Luna counties. The northern Chihuahua region consists of approximately 80,000 acres in Juarez, Acension, Janos, Ojinaga and the surrounding cotton-growing areas. The plan is to begin the implementation of the program in the El Paso/Trans Pecos region in 2001, and the south-central New Mexico and northern Chihuahua in 2002. Cotton growers in the El Paso/Trans Pecos region had approved the initiation of a combined boll weevil and pink bollworm eradication program. Boll weevil eradication began in 1999, and pink bollworm operations in 2001. As of this writing, producers in south central New Mexico are in the process of conducting a PBW referendum, in an effort to begin the eradication program in 2002. Growers in the state of Chihuahua of Mexico are in the process of finalizing budgets and operational plans to begin the program in 2002 as well.

Phase II

Consists of approximately 220,000 cotton acres in southeastern and central Arizona, including Cochise, Graham, Pima and Maricopa counties. The plan is to begin Phase II of program operation in 2004.

Phase III

Consists of approximately 120,000 acres of cotton in western Arizona and Southern California. This includes Mohave, La Paz, and Yuma counties of Arizona, and Riverside and Imperial counties of California. The plan is to begin Phase III in 2006.

Materials & Methods

Embracing the integrated pest management (IPM) concept, the operational success of the areawide PBW eradication program hinges on three separate, yet interdependent, components including: *mapping, detection*, and *control*.

Mapping

Mapping is one of the first operational components to be implemented in the proposed eradication program. In addition to identifying the exact location and the surrounding environment of each cotton field, another important purpose of mapping is to record and verify the cotton varieties, including Bt, non-Bt, and long-staple planted in each field. All cotton fields will be mapped using the differentially corrected Global Positioning System (GPS) (El-Lissy et al. 1996). The program will utilize a numbering system that identifies each cotton field in the eradication zone with a unique number.

Detection

Trapping -- pink bollworm delta traps will be utilized as the primary tool of detection. Traps will be baited with rubber septa impregnated with 4 mg of gossyplure and attached with brass fasteners to a wooden stake placed around the perimeter of each cotton field. Traps will be placed at planting, or shortly thereafter, at a rate of one trap per ten acres and inspected weekly until defoliation and harvest or a killing freeze (Leggett et al. 1994).

Visual Inspection (scouting) -- beginning at the bloom stage, ten randomly selected conventional cotton (non-Bt) fields per work unit (12,000 -15,000 acres) will be inspected weekly for rosetted blooms. Weekly larval surveys in bolls will be conducted at the boll formation (quarter size) stage and continue through cut-out.

Control

The control part of the proposed eradication program consists of cultural, mating disruption, Bt transgenic cotton, sterile moth releases, and chemical control.

Cultural Control

Uniform cotton planting and harvesting, done during timeframes recommended by the local Agricultural Extension Service, will be highly encouraged, as it constitutes an important strategy in providing a host-free period. Other cultural practices, including timely defoliation and stalk destruction, off-season irrigation, and burial of crop residues through normal tillage practices will continue to play an important role in reducing diapausing populations during the off-season months.

Mating Disruption (pheromone)

Aerial, ground, or hand application of pheromone will be made only to conventional cotton fields (non-transgenic), or to Bt transgenic cotton fields imbedded with conventional cotton (95:5 embedded refuge), that meet the predetermined treatment threshold.

A single application of NoMate-PBW®, at a rate of 15 gm/ac (1.05 gm [AI]/ac of gossyplure), mixed with polybutene sticker (Bio-Tac) at a rate of 5.3 oz/ac and the insecticide permethrin at a rate of 0.5 fl oz/ac (0.08 lb. [AI]/ac), will be made by air each time a field meets the treatment criteria (treatment threshold). Fields meet the treatment threshold beginning at the six-node (prior to pinhead square) growth stage and when trap captures average more than zero and less than one moth per trap per night.

The insecticide chlorpyrifos, at a rate of 24 fl oz/ac (0.75 lb. [AI]/ac), may be added to the pheromone application as an over-spray (doubleton application), only if the average trap capture equals or exceeds one moth per trap per night.

The PB-Rope or PB-Rope* L, or equivalent formulations, may be used in the earliest planted cotton fields, in fields with high level of moth catches, as well as in fields located near sensitive sites where aerial applications are not practical. Dispensers will be hand twist-tied around the main stem of the cotton plant near the bottom at or near six true leaf growth before the pinhead square. The PB-Rope (or equivalent) dispensers will be evenly applied at a density of 400 dispensers (28 gm/ac) per acre, and the PB-Rope* L (or equivalent) dispensers will be applied at a density of 200 dispensers (28 gm/ac) per acre.

Bt Transgenic Cotton

Planting of the Bt transgenic cotton varieties will be highly encouraged as they provide an exceptional level of control for pink bollworm. The program will maintain full compliance with the Environmental Protection Agency's (EPA) Refuge Requirements, designed as a strategy for insect resistance management (IRM).

Sterile Moth Releases
Pink bollworm sterile moths produced in the PBW rearing facility in Phoenix will be aerially released at a rate of 200 moths per acre per day, beginning at the four-leaf growth stage and until defoliation or harvest. Sterile moths will be released on all cotton fields in the eradication region including Bt transgenic and conventional cotton. This component is particularly important as a final control measure to achieve eradication.

Chemical Control
Aerial or ground applications of the insecticide chlorpyrifos at a rate of 24 fl oz/ac (0.75 lb. [AI]/ac), may only be made to prevent economic loss in fields that exhibit larval infestations of 5 percent or higher.

Discussion

The pink bollworm continues to seriously affect western cotton-growing regions critical for the export of fiber, and production of seed for the entire U.S. Cotton Belt. The eradication of the pink bollworm will provide significant economic gains for cotton producers through lower production costs, higher yields, and better quality of fiber. An additional benefit of eradication will be its positive effect on the environment through significant reductions in pesticide usage.

The proposed pink bollworm eradication program utilizes a more diverse blend of control methodologies than has been used in other successful areawide eradication programs. The incorporation of an unprecedented number of highly effective control methods, simultaneously implemented within a harmonized system, maximizes the opportunity to achieve the goal of eradicating one of the oldest and most destructive cotton pests in the world.

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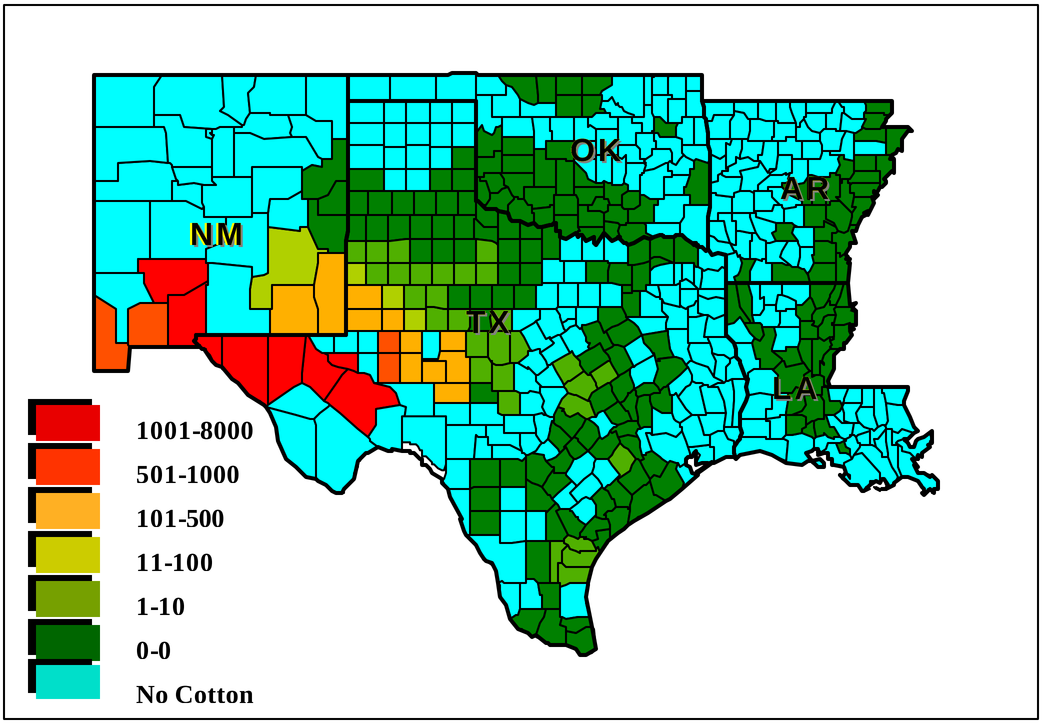

Figure 1. Mean Number of PBW Moths Captured Per Trap, August 15-October 15, 2001.

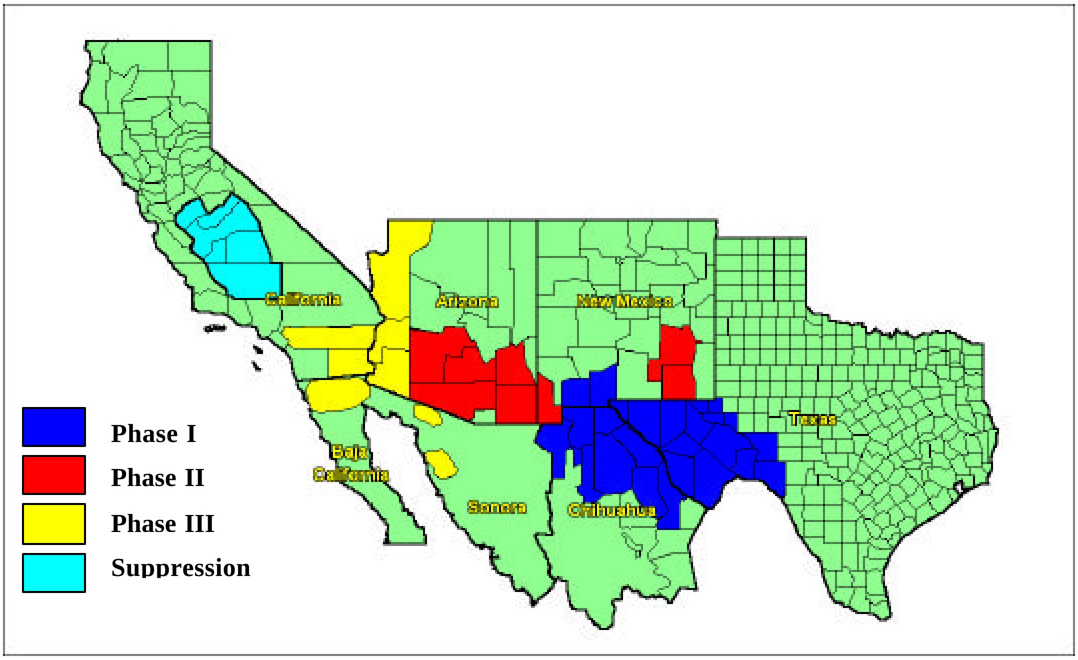

Figure 2. Incremental Phases of the Proposed Pink Bollworm Eradication Program.