PINK BOLLWORM ERADICATION PLAN IN THE U.S.

Bill Grefenstette, Osama El-Lissy, and R. T. Staten (retired)
United States Department of Agriculture
Animal and Plant Health Inspection Service
Riverdale, MD
Phoenix, AZ

Updated February 2009

Abstract

An area-wide pink bollworm eradication program, involving growers and state and federal cooperators, has been proposed by the National Cotton Council's Pink Bollworm Action Committee. The program's objective is to eradicate the pink bollworm (PBW) from the infested areas of the U.S., essentially the southwestern portion of the Cotton Belt.

Through the coordinated efforts of cotton producer communities, and federal, state, and local entities in the U.S. and Mexico, the plan is to implement the eradication program in three phases. Phase I began in 2001/2002, and consists of the El Paso/Trans Pecos region of west Texas, south-central New Mexico, and northern Chihuahua, Mexico. Phase II began in 2006, and consists of cotton-growing areas in southeastern and central Arizona. Partial expansion into Phase III began in 2007, and included portions of western Arizona and southeastern California. The remaining portion of Phase III, including Yuma, Arizona, southern California, and the Mexicali Valley of northwest Mexico, began in 2008.

The operational elements of the 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 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. No single control method is completely satisfactory. The possibility of combining a number of methods into a single control system appears to be the most promising approach (Henneberry et al. 1980).

Various 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 hectare 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 that 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 Bt transgenic 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 percent 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 percent of the Upland cotton acreage was planted to Bt cotton in 1997 (Silvertooth, 1998), and 70 percent in 1998 (Patin et al. 1999).

Despite 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 this 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). Ongoing evaluations through the 2008 season have confirmed these earlier findings.

Sterile Insect Technique (SIT) –
As early as 1937, E. F. Knipling had conceived of an approach to insect control in 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 the native insects that are 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 number of native insects 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 that no PBW were present in Arkansas, Louisiana, Oklahoma, and most of Texas. PBW populations appeared to be confined to west Texas and south central New Mexico. This was confirmed through additional trapping surveys in 2002-2004. Trapping surveys conducted in Arizona by the Arizona Cotton Research and Protection Council, and in California by the Imperial Valley Commissioner of Agriculture and California Department of Food and Agriculture, indicate reduced distribution of PBW in the eastern and central portions of Arizona (as a result of eradication efforts), but wide distributions of the pest in western 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). More recently, the National Cotton Council estimated that U.S. cotton producers' annual losses to pink bollworm are about $32 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 United States and northern Mexico.

The plan includes coordinated efforts by cotton producer communities and federal, state, 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.

Following grower approval through scheduled referenda, adequate funding and PBW rearing capacity, the plan was to implement the PBW eradication program in three phases: Phase I in 2001/2002, Phase II in 2006, and Phase III in 2007/8 (Figure 1).

Phase I –
Consists of the El Paso/Trans Pecos region of West Texas, south-central New Mexico, and northern Chihuahua, Mexico. The El Paso/Trans Pecos region includes 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 includes approximately 26,000 acres of cotton in Doña Ana and Luna counties. The northern Chihuahua region includes approximately 93,000 acres in Juarez, Acension, Janos, Ojinaga and the surrounding cotton-growing areas. The plan was designed to begin the program in the El Paso/Trans Pecos region in 2001, and in south-central New Mexico and northern Chihuahua in 2002. In 1999, 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. In 2002, producers in south central New Mexico approved the PBW referendum to start the program in the same year. Also at that time, growers in the state of Chihuahua in Mexico had approved a referendum to begin the program in 2002 as well.

Phase II –
Consists of approximately 250,000 cotton acres in southeastern and central Arizona, including Cochise, Graham, Pima and Maricopa counties, and the Mexican state of Sonora. Phase II of the program began in 2006.

Phase III –
Consists of approximately 245,000 acres of cotton in western Arizona, Southern California, and Mexicali, Mexico. This includes Mohave, La Paz, and Yuma counties of Arizona, and Riverside and Imperial counties of California. Phase IIIa of the program began in 2007, with Phase IIIb starting in 2008.

Materials & Methods

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

Mapping:
Mapping is one of the first phases of field operations implemented in the 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 are mapped using the differentially corrected Global Positioning System (GPS) (El-Lissy et al. 1996). The program uses a numbering system that is designed to identify each cotton field in the eradication zone with a unique number.

Detection:
Trapping -- pink bollworm delta traps are used as the primary tool of detection. Traps are 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 are 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) are inspected weekly for rosetted blooms. Weekly larval surveys in bolls are conducted at the boll formation (quarter size) stage and continue through cut-out.

Control:
The control part of the eradication program consists of cultural control, 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, are highly encouraged, as they constitute 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 is 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), is 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 a high level of moth catches, as well as in fields located near sensitive sites where aerial applications are not practical. Dispensers are 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 are evenly applied at a density of 400 dispensers (28 gm/ac) per acre, and the PB-Rope* L (or equivalent) dispensers are applied at a density of 200 dispensers (28 gm/ac) per acre.

Bt Transgenic Cotton –
Planting of the Bt transgenic cotton varieties is highly encouraged as they provide an exceptional level of control for pink bollworm. The program maintains full compliance with the Environmental Protection Agency's (EPA) Refuge Requirements, designed as a strategy for insect resistance management (IRM). During the 2007 through 2009 seasons, limited areas within the program have been authorized by EPA and state agencies to use up to 100 percent Bt cotton in combination with the release of sterile moths.

Sterile Moth Releases –
Pink bollworm sterile moths produced in the PBW rearing facility in Phoenix will be aerially released at a rate of 100 moths per acre per day, or about 25 million moths per day, beginning at the four-leaf growth stage and until defoliation or harvest. Sterile moths will be released on all conventional cotton fields in the eradication region, with a reduced rate used on Bt transgenic 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 that are 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 pink bollworm eradication program utilizes a more diverse blend of control methodologies than has been used in other successful area-wide 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.

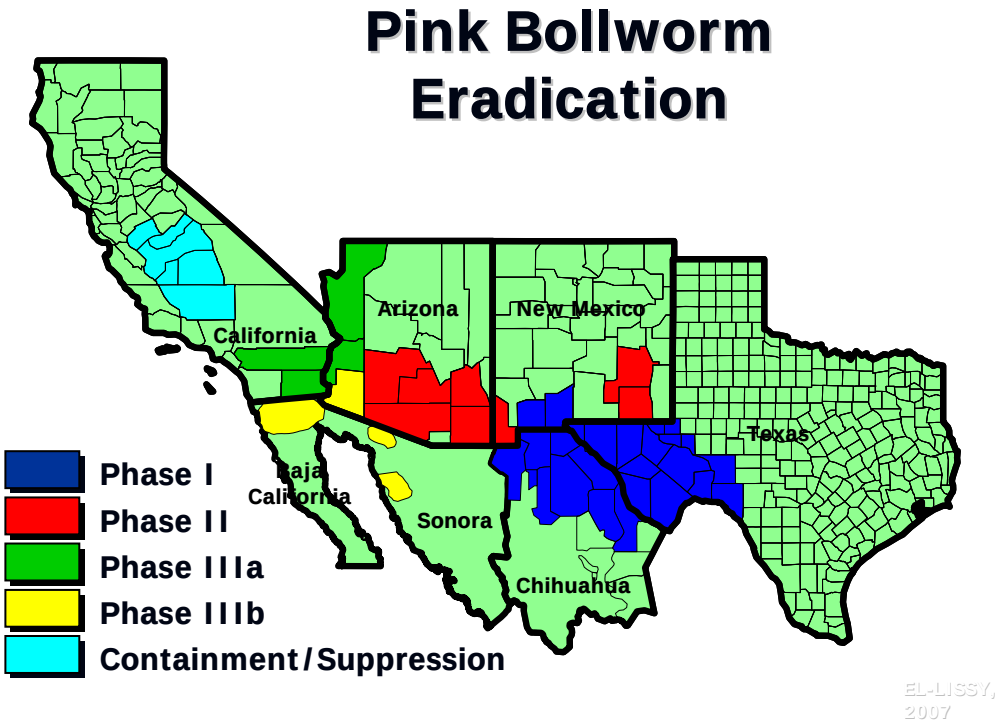

Figure 1. Incremental Phases of the Pink Bollworm Eradication Program

References

Adkisson, Perry L., L. W. Wilkes, and B. J. Cochran. 1960. Stalk shredding and plowing as methods for controlling the pink bollworm, Pectinophora gossypiella. J. Econ. Entomol. 53 (3): 436-9.

Antilla, L., M. Whitlow, R. T. Staten, O. El-Lissy, and F. Myers. 1996. An integrated approach to areawide pink bollworm management in Arizona. Proc. Beltwide Cotton Production and Research Conf., National Cotton Council of America, 1083-1085 pp.

Antilla, L., M. Whitlow, J. White, C. Youngker, T. J. Dennehy, and R. T. Staten. 1999. Alternative infield refuge strategies for control of pink bollworm in Bt transgenic cotton. Proc. Beltwide Cotton Production and Research Conf., National Cotton Council of America, 1241-1242 pp.

Bariola, L. A. 1984. Pink bollworm: factors affecting survival of diapause larvae and emergence of overwintered moths in the spring in central Arizona. USDA, Agric. Res. Serv. ARS-6.

Bartlett, A. C. 1995. Resistance of the pink bollworm to Bt transgenic cotton. Proc. Beltwide Cotton Production and Research Conf., National Cotton Council of America, 766-768 pp.

Brooks, T. W., and R. L. Kitterman. 1977. Gossyplure H. F. - pink bollworm population suppression with male sex attractant pheromone released from hollow fibers, 1976 experiments. Proc. 1977 Beltwide Cotton Production-Mechanization Conf. National Cotton Council of America, 79-82 pp.

Burrows, T. M., V. Sevacherian, H. Browning, and J. Baritelle. 1982. The history and cost of the pink bollworm in the Imperial Valley. Bull. Entomol. Soc. Amer. 28:286-290.

El-Lissy, O., R.T. Staten, and L. Antilla. 1993. Control of pink bollworm, Pectinophora gossypiella (Saunders) (Lepidoptera: Gelechiidae) in Parker Valley, Arizona, by mating disruption using commercial formulations of gossyplure. Proceedings of the International Cotton Pest Work Committee, California Department of Food and Agriculture, Sacramento, CA., 114-117 pp.

Doane, C. C., and T. W. Brooks. 1980. Research and development of pheromone for insect control with emphasis on the pink bollworm, p. 285-303. *In* E. Mitchell (edit.), Management of insect pests with semiochemicals. Plenum Press, New York and London. 514 p.

Flint, H.M., T. J. Henneberry, and F.D. Wilson. 1995. The effects of transgenic cotton, Gossypium hirsutum L., containing Bacillus thuringiensis toxin genes for the control of the pink bollworm (Saunders) and other arthropods. Southwestern Entomol. 20 (3): 281–292.

Glick, P. A. 1967. Aerial dispersal of the pink bollworm in the Unites States and Mexico. U.S. Dept. Agric. Agric. Prod. Res. Rep. 96.

Henneberry, T. J., T. J. Bariola, L. A. and D. L. Kittock. 1980. Integrating methods for control of the pink bollworm and other cotton insects in the southwestern United States. USDA, Tech. Bull. No. 1610. 45 pp.

Henneberry, T. J., J. M. Gillespie, and L. A. Bariola. 1981. Gossyplure in laminated plastic formulations for mating disruption and pink bollworm control. J. Econ. Entomol. 74:376-380.

Henneberry, T. J. 1986. Pink bollworm management in cotton in the southwestern United States. U.S. Dep. Agric. Agric. Res. Serv. ARS-51.

Henneberry, T. J., L. Forlow Jech, T. de la Torre. 2001. Larval mortality of pink bollworm and other lepidopterous pests on NuCotton 33B and Daltapine 5415 cottons. Proc. Beltwide Cotton Production and Research Conf., National Cotton Council of America, 866-868 pp.

Hummel, H. E., Gaston, L. K., Shorey, H. H., Kaae, R. S., Byrne, K. J., and Silverstein, R. M. 1973. Clarification of the chemical status of the pink bollworm sex pheromone. Science 181:873-875.

Kittock, D. L., J. R. Mauney, H. F. Arle, and L. A. Bariola. 1973. Termination of late season cotton fruiting with growth regulators as an insect-control technique. J. Environ. Qual. 2:405-408.

Knipling, E. F. 1979. The Basic Principles of Insect Population Suppression and Management. U. S. Dept. of Agriculture. Agriculture Handbook No. 512. Washington, DC

Knipling, E. F. 1985. Sterile insect technique as a screwworm control measure: The concept and its development, pp. 4-7. In O. H. Graham [ed.], Symposium on Eradication of the Screwworm from the United States and Mexico. Misc. Publ. Entomol. Soc.America 62, College Park, MD.

Leggett, J. E., Osama El-Lissy, and Larry Antilla. 1994. Pink bollworm moth catches with perimeter and in-field gossyplure baited traps. Southwestern Entomologist. Vol. 19, No. 2:147-155 pp.

Mahaffey, J. S., J. S. Bacheler, J. R. Bradley, Jr., and J. W. Van Duyn. 1994. Performance of Monsanto's transgenic B.t. cotton against high populations of lepidopterous pests in North Carolina. Proc. Beltwide Cotton Production and Research Conf., National Cotton Council of America, 1061-1063 pp.

National Cotton Council of America. 2001. Pink Bollworm Eradication: A Window of Opportunity, 1-6 pp.

Noble, L. W. 1969. Fifty years of research on the pink bollworm in the Unites States. U.S. Dept. Agric., Agric. Res. Serv. Handb. 357.

Patin, A. L., T. J. Dennehy, M. A. Sims, B. E. Tabashink, Y-B Liu, L. Antilla, D. Gouge, T. J. Henneberry, and R. T. Staten. 1999. Status of pink bollworm susceptibility to Bt in Arizona. Proc. Beltwide Cotton Production and Research Conf., National Cotton Council of America, 999-996 pp.

Perlak, F. J., R. W. Deaton, T. A. Armstrong, R. L. Fuchs, S. R. Sims, T. J. Greenplate, and D. A. Fischoff. 1990. Insect resistance cotton plants. BioTechnology 8:939-943 pp.

Roberson, R., L. Antilla, T. J. Dennehy, R. T. Staten. 1998. Pink bollworm areawide suppression-eradication action plan. National Cotton Council of America, Pink Bollworm Action Committee report.

Scholl, E. E. 1919. Report of pink bollworm of cotton (*Pectinophora gossypiella* Saunders), Texas Dept. of Agric. Bull.65, 4 pp.

Shorey, H. H., Gaston, L. K., and Kaae, R. S. 1976. Air-permeation with gossyplure for control of the pink bollworm. In Pest Management with Insect Sex Attractants. Beroza, M. (ed.) ACS Symposium Series 23, American Chemical Society, Washington, DC, 67-74 pp.

Silvertooth, J. C. 1998. Cotton report. University of Arizona.
Smith, Kirk, Tom Walgenbach, and Jeff Springer. 1996. Development of a novel sprayable pheromone product for pink bollworm control. Proc. Beltwide Cotton Production and Research Conf., National Cotton Council of America, 1085-1086 pp.

Staten R. T., Finnel, C., and L. Jensen. 1983. Monitoring of the Imperial Valley pheromone program. Imperial County Agricultural Commissioner's Office, 14 pp.

Staten, R. T., H. M. Flint, R. C. Weddle, E. Quintero, R. E. Zariti, C. M. Finnel, M. Hernandez, and A. Yamamoto. 1987. Pink bollworm (Lepidoptera: Gelechiidae): Large scale field tests with a high rate gossyplure formulation. J. Econ. Entomol. 80: 1267-1271.

Staten, R. T., Miller, E., Grunnet, M., and Andress, E. 1988. The use of pheromones for pink bollworm management in western cotton. Proc. Beltwide Cotton Production and Research Conf., National Cotton Council of America, 206-209 pp.

Staten, R. T., Rosander, R. W., and Keaveny, D. F. 1993. Genetic control of cotton insects, pp. 269-283. *In* Management of Insect Pests: Nuclear and Related Molecular and Genetic Techniques. (Proc. Symp. Vienna, 1992), International Atomic Energy Agency, Vienna.

Staten, R. T., L. Antilla, and M. Walters. 1995. Pink bollworm management: prospects for the future. Proc. Beltwide Cotton Production and Research Conf., National Cotton Council of America, 153-156 pp.

USDA, National Agricultural Statistics Service, 1999.

Watson, T. F. 1980. Methods for reducing winter survival of the pink bollworm, Pink bollworm control in the western United States. USDA. Sci. and Ed. Agric. Rev. and Manuals, Oakland, CA. 24-34 pp.

Watson, T. F. 1995. Impact of transgenic cotton on pink bollworm and other lepidopteron pests. Proc. Beltwide Cotton Production and Research Conf., National Cotton Council of America, 759-760 pp.

Wilson, F. D., H. M. Flint, W. R. Deaton, D. A. Fischoff, F. J. Perlak, T. A. Armstrong, R. L. Fuchs, S. A. Berberich, N. J. Parks, and B. R. Stapp. 1992. Resistance of cotton lines containing a Bacillus thuringiensis toxin to pink bollworm (Lepidoptera: Gelechiidae) and other insects. J. Econ. Entomol. 85: 1516-1521.