Pectinophora gossypiella

Scientific Name
Pectinophora gossypiella Saunders

Synonyms:
Depressaria gossypiella Saunders
Ephestia gossypiella Saunders
Gelechia gossypiella Saunders
Gelechiella gossypiella Saunders
Platyedra gossypiella Saunders

Common Name(s)
Pink bollworm

Type of Pest
Moth

Figure 1. *P. gossypiella* larvae. Image courtesy of Peggy Greb, USDA Agricultural Research Service, www.bugwood.org.

Taxonomic Position
Class: Insecta, **Order**: Lepidoptera, **Family**: Gelechiidae

Reason for Inclusion In Manual
PPQ Program Pest

Pest Description
Eggs: Elongate oval, flattened; about 1 mm long and 0.5 mm broad (0.04 by 0.02 in.); the shell is pearly white, with a finely wrinkled surface. When newly laid, the egg has a slightly greenish tint. At maturity it turns reddish (Busck, 1917).

Larvae: The larvae (Fig. 1) are initially white with a dark head. The full grown larvae are 10 to 12 mm (0.39 to 0.47 in.) long and are white with a double red band on the upper portion of each segment (Mukuka et al., 2002).

Figure 2. *P. gossypiella* adult. Image courtesy of Mississippi State University Archive, Mississippi State University, www.bugwood.org.

Pupae: The pupa is 8 to 10 mm (0.31 to 0.39 in.) long, rather plump, reddish brown; posterior end pointed and terminating in a short, stout, upwardly turned hooklike cremaster; entire surface finely pubescent; no long setae, spines or hooks, except on last joint. When mature, the pupa becomes much darker; the imago's eyes can be seen prominently under the gena of the pupal skin, and the segmentation of the adult antennae and legs becomes discernible (Busck, 1917).

Adults: Moths (Fig. 2) are brown with a wingspan of 15 to 20 mm (0.59 to 0.79 in) (Mukuka et al., 2002).

P. gossypiella adults are small, dark-brown moths measuring about 12 to 20 mm (0.47 to 0.79 in) across the wings (USDA, 1948). The head is reddish brown in color with pale, iridescent scales. Antennae are brown and the basal segment bears a pecten of five or six long, stiff, hair-like scales. The labial palpi are long and curved upwards: the second segment bears a slightly furrowed hairy brush on the underside that becomes smooth distally and the terminal segment is shorter than the second. The proboscis is scaled.

Forewings are elongated-oval, pointed at the tips and bearing a wide fringe. The ground color of the forewings is brown and they have fine dark scales that form vague patches in the region of the medial cells and at the wing base. The apical portion of the wing is dark brown with a transverse, light-colored band. Sometimes the wing bears a round medial spot.

The hind wings are broader than the fore wings, trapezoidal in form and silvery gray with a darker, iridescent hind margin. The wing fringe is ochreous and darker at the base and apex.

Legs are brownish black with transverse, ochreous bands in the form of rings. The abdomen is ochreous toward the upper side, dark brown laterally and covered with ochreous-brown scales on the underside.

In the genitalia, the male uncus is broad at the base, tapering to a point and the aedeagus has a hooked tip. The female ovipositor is weakly sclerotized (CABI, 2010).

Biology and Ecology

This species is adapted for areas with low rainfall and a long growing season (Noble, 1969).

Eggs are laid singly or in small batches on the green cotton boll, the calyx, or the flower; they are more commonly found on the apex of the green boll on the longitudinal depressions (Busck, 1917). Before bolls are present, eggs are laid singly on squares, stems, and terminal buds; bolls are preferred when present (Noble, 1969). One to four eggs per boll are commonly seen although as many as 20 can be found on one boll (Busck, 1917). Hatching occurs in four to six days (Mukuka et al., 2002). Females can lay approximately 300 eggs (Mukuka et al., 2002).

After hatching, the larva tunnels into the boll and begins feeding on the soft inner wall or the partitions of the boll (Busck, 1917). The larva will usually bore close to the apex and tunnel downward towards the bottom seeds (Busck, 1917). From here it begins partially feeding on seeds while moving back up towards the tip of the boll where it ends as a full grown larva (Busck, 1917). Feeding lasts 10 to 15 days (Noble, 1969). Development is completed in a single square or boll; larvae do not move between structures (Noble, 1969). If buds are less than 10 days old, larvae will die (Ingram, 1994).

There are four instars total; only the last instar has the pink tint referred to in its common name (Busck, 1917). The larval period lasts 20 to 30 days during the summer and much longer during colder months (Busck, 1917). Overwintering occurs in the larval stage within the seeds (Busck, 1917), old bolls, leaf litter, or at gins or seed-storage facilities (Noble, 1969).

Pupation occurs in a spun cocoon (Noble, 1969) within the seeds although larvae may pupate in the soil if disturbed (Busck, 1917). The pupal period lasts 10 to 20 days (Busck, 1917).

The adult is small and sluggish, hiding during the day mainly in ground cover (Busck, 1917). Flight occurs at dusk, with adults flying to the nearest cotton boll to mate and lay eggs (Busck, 1917). Mating can occur on the first night after emergence and can occur more than once (Noble, 1969). Although adults have the capability for strong flight, they usually only infest nearby or adjoining fields (Busck, 1917). Adults are too sluggish for sustained flight (Busck, 1917). Pre-oviposition is about two days (Matthews, 1989). After oviposition, the moths live from 1.5 to 2 weeks (Noble, 1969). Under favorable conditions, an entire life cycle can be completed in as little as 35 days. There may be four to six overlapping generations per year (Busck, 1917).

Symptoms/Signs

Entry holes made by *P. gossypiella* larvae are difficult to see. If opened, the caterpillars are easy to find (Fig. 3). Bolls damaged by the larvae fail to open completely (Mukuka et al., 2002). Other signs include fruit shedding, lint damage, seed loss (CABI, 2010), rotted bolls, and discolored lint or seed (Leigh et al., 1996). Flowers may also be damaged (Ingram, 1994).

Figure 3. *P. gossypiella* larva on a section of a cotton boll with attendant damage. Image courtesy of David Pierce, USDA-APHIS-PPQ-WR.

Larvae may be hard to see at the early larval stages, but close examination may reveal the small entrance hole. The entrance hole may have a small amount of reddish frass, empty egg shells, or small larvae mining within the boll wall when dissected (Busck, 1917). Larval mines on the inner carpel wall can be seen from the outside (Noble, 1969). Also, a round exit hole about 2 mm (0.08 in.) in diameter can be found in the carpel (Noble, 1969; Matthews, 1989).

The shell of the infested bolls will eventually become discolored taking on a reddish or black color (Busck, 1917). It should be noted that this discoloration may also occur from other injuries besides *P. gossypiella* and should not be used for definitive diagnosis (Busck, 1917).

In square infestations, the bloom is usually prevented from opening due to the larval webspinning (Noble, 1969). In boll infestations, older bolls (20+ days) are usually attacked; younger bolls will be attacked if older bolls are scarce or the *P. gossypiella* population is high (Noble, 1969). Younger bolls will have the greatest damage (Noble, 1969).

Larvae do not attack cotton leaves or shoots (Busck, 1917). Bud and flower damage only occurs early in the season (Ingram, 1994).

Pest Importance

P. *gossypiella* is currently found in almost all cotton growing countries of the world (Naranjo et al., 2001) and is considered one of the most important economic pests in the world (Raulston et al., 1996). In the United States, it attacks two cultivated crops, cotton and okra (Wagner et al., 1996). Damage can reduce the lint yield by 50% and can lead to a decrease in seed oil (Busck, 1917).

As the larvae eat, they tunnel and soil the lint, which causes slowed growth of the cotton plant (Busck, 1917). The boll may then either rot or open prematurely and imperfectly (Busck, 1917). Un-infested parts of the boll will have slowed growth and the cotton lint will depreciate in value (Busck, 1917).

Boll feeding leads to reduction of quality of lint (discoloration, reduced fiber length, and strength) and seed (Noble, 1969). If damaged lint fibers are mixed with undamaged lint, it will reduce the average grade of the crop (Parencia, 1978). It can also lead to reduced yield in weight in high infestations (Noble, 1969). Quantity of seed cotton can be reduced as well (Noble, 1969). Severe infestations can lead to crop loss (Matthews, 1989).

Known Hosts

The major host of *P. gossypiella* is *Gossypium hirsutum* (cotton). Other hosts include *Abelmoschus esculentus* (okra), other *Gossypium* spp. (cotton), *Gossypium tomentosum*, and *Hibiscus* spp. (Busck, 1917; EPPO, 2007). Incidental hosts include species in the family Malvaceae (EPPO, 2007).

CABI (2010) also list the following species as host plants of *P. gossypiella*: *Abutilon* spp. (Indian mallow), *A. indica* (country mallow), *Althaea* spp. (hollyhocks), *Gossypium arboretum*, *Hibiscus* spp. (rosemallows), *H. cannabinus* (kenaf), *H. sabdariffa* (Jamaica sorrel), and *Medicago sativa* (alfalfa, lucerne).

Noble (1969) lists the following as alternative hosts of *P. gossypiella*:

Malvaceae (mallow family):
Abutilon amplum, *A. hirtum*, *A. hypoleucum*, *A. incanum**, *A. indicum*, *A. lignosum**, *A. otocarpum*, *A. trisulcatum*, *Althaea rosea* (hollyhock), *Callirhoe involucrata* var. *lineariloba* (poppy-mallow), *Fugosia australis*, *Hibiscadelphus hualalaiensis*, *Hibiscus abelmoschus**, *H. aculeatus**, *H. bifurcatus*, *H. brasiliensis**, *H. cannabinus**, *H. cardiophyllus**, *H. coccineus** (scarlet-rosemallow), *H. coulteri* (desert-rosemallow), *H. dasycalyx**, *H. denudatus* (paleface-rosemallow), *H. divaricatus*, *H. drummondii*, *H. esculentus** (okra), *H. furcellatus* var. *youngianus*, *H. heterophyllus*, *H. incanus**, *H. lambertianus**, *H. lasiocarpus* (woolly-rosemallow)*, *H. leucophyllus**, *H. ludwigii*, *H. militaris** (rosemallow), *H. mutabilis** (cotton-rosemallow), *H. panduraeformis*, *H. rosa-sinensis* (rose of China), *H. sabdariffa* (roselle), *H. syriacus* (shrubby althea), *H. tiliaceus*, *H. trilobus*, *H. tubiflorus*, *H. vitifolius*, *Kosteletzkya althaeifolia*, *K. virginica*, *Malachra capitata**, *Malva parviflora*, *M. sylvestris* (high-mallow), *Malvastrum coromandelianum*, *Malvaviscus arboreus* (false-mallow), *M. drummondii** (waxmallow), *Pseudabutilon lozani** (false-abutilon), *Sida cordifolia**, *S. corrugata*, *S. spinosa** (prickly-sida), *S. virgata*, *Thespesia danis*, *T. grandiflora*, *T. lampas*, and *T. populnea** (tulip tree).

Euphorbiaceae (spurge family):
*Croton capitatus** (croton), *C. texensis** (croton), and *Ricinus communis** (castorbean).

Leguminosae (pea family):
Acacia wrightii (tree cat's-claw), *Daubentonia punicea** (coffeebean), *Gleditsia triacanthos** (honeylocust), and *Prosopis juliflora* var. *glandulosa* (mesquite).

Convolvulaceae (morning-glory family):
Ipomoea crassicaulis (Texas brush morning-glory).

Tiliaceae (linden family):
Corchorus olitorius (jute).

Bombacaceae (bombax family):
Bombax munguba.

Cochlospermaceae (cochlospermum family):
Cochlospermum regium.

*Diapausing larvae were found to survive the winter in seed pods (Noble, 1969).

Pathogens or Associated Organisms Vectored

This pest is not currently known to vector any pathogens or other associated organisms. However, feeding by *P. gossypiella* larvae can lead to secondary rot on the host plant (Mukuka et al., 2002). Exit holes can predispose the bolls to *Aspergillus flavus* infections (Henneberry et al., 1978; Ingram, 1994).

Known Distribution

This pest has a large distribution throughout the world. It is thought to have originated in India.

Areas of distribution include: **Africa:** Algeria, Angola, Benin, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Cote d'Ivoire, Egypt, Ethiopia, Ghana, Kenya, Libya, Madagascar, Malawi, Mali, Mauritius, Morocco, Mozambique, Niger, Nigeria, Rwanda, Senegal, Seychelles, Sierra Leone, Somalia, Sudan, Tanzania, Togo, Tunisia, Uganda, Zaire, Zambia, and Zimbabwe. **Asia:** Afghanistan, Bangladesh, Cambodia, China, India, Indonesia, Iran, Iraq, Israel, Japan, Jordan, Korea, Laos, Malaysia, Myanmar (Burma), Pakistan, Philippines, Saudi Arabia, Syria, Taiwan, Sri Lanka, Thailand, Turkey, Vietnam, and Yemen. **Caribbean:** Antigua and Barbuda, Bahamas, Barbados, Cuba, Dominica, Dominican Republic, Grenada, Guadeloupe, Haiti, Jamaica, Martinique, Montserrat, Puerto Rico, Saint Lucia, Saint Kitts-Nevis, Saint Vincent and the Grenadines, Trinidad and Tobago, and Virgin Islands (British). **Europe:** Cyprus, Greece, Macedonia, Montenegro, Romania, and Spain. **North America:** Mexico and United States. **Oceania:** Australia, Fiji, French Polynesia, New Caledonia, Northern Mariana Islands, Papua New Guinea, Samoa, and Vanuatu. **South America:** Argentina, Bolivia, Brazil, Colombia, Guyana, Paraguay, Peru, Uruguay, and Venezuela (Mukuka et al., 2002; EPPO, 2007).

Distribution within the United States

Infestations first occurred in the United States in 1917 on cotton in Texas (Naranjo et al., 2001). This population was apparently eradicated only to have the same area reinfested in the 1930s through suspected moth migration from Mexico (Raulston et al., 1996). Since its original introduction, it has spread to other states including Arizona, Arkansas, California, Florida, Georgia, Louisiana, New Mexico, and Oklahoma (Naranjo et al., 2001). Several eradications and re-infestations have occurred over the years. *P. gossypiella* is actively being eradicated from Arizona, New Mexico, and Texas and managed/suppressed in California (Schoenholz, 2011). This species has been present in Hawaii since the early 1900s (Ingram, 1994).

Pathway

This species has been introduced into many new areas through infested cottonseed, including Brazil, Mexico, the West Indies, the Philippines, the United States, and possibly Australia (Naranjo et al., 2001).

This pest can also move through infested okra as well as any material that has been contaminated with infested cottonseed including baled lint, mechanical cotton pickers, transport vehicles, and oil mill products (Noble, 1969).

Adults can also fly long distances (Noble, 1969), although they are usually considered too sluggish for sustained flight (Busck, 1917). Adult dispersal may be aided by wind (Raulston et al., 1996).

Several items are regulated to prevent the spread and reintroduction of pink bollworm, including all parts of cotton, seed cotton, cotton waste, used cotton-harvesting equipment, and okra. A list of these can be found here: http://www.aphis.usda.gov/plant_health/plant_pest_info/cotton_pests/downloads/bollw.pdf or in the Code of Federal Regulations, 301.52.

Survey

CAPS-Approved Method*:

Trap with lure. The CAPS-Approved Method will follow the PPQ Pink Bollworm Program recommendations. The trap is the pink bollworm delta trap (Fig. 4). This trap is orange in color and has each of the three interior surfaces coated in adhesive.

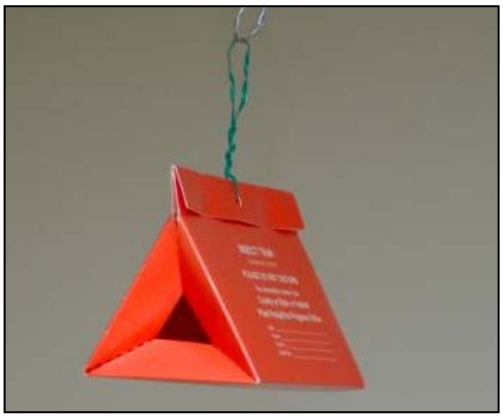

Figure 4. Delta trap used for *P. gossypiella*. Image courtesy of John Crowe, USDA-APHIS.

Lures should be changed every 2 weeks. The PPQ Cotton Program changes the lures on a weekly basis; however, every 2 weeks is acceptable for CAPS (Schoenholz, 2011). In excessively dusty conditions, lures should be changed weekly as moth specimens may be too dusty to properly identify (Schoenholz, 2011).

IPHIS Survey Supply Ordering System Product Names:

1) Paper Delta Trap, 3 sticky sides, Orange
2) Pink Bollworm Lure

IMPORTANT:
Before planning a pink bollworm survey it is IMPERATIVE that you contact your PPQ Regional Cotton Program Manager to determine if your state should survey for this pest. CAPS surveys should NOT be conducted in states that are part of the PPQ Pink Bollworm eradication program (AZ, CA, NM, and TX). In addition, some cotton-producing states have wet climates that are not conducive to pink bollworm development.

IMPORTANT: Do not place lures for two or more target species in a trap unless otherwise recommended.

Trap spacing: When trapping for more than one species of moth, separate traps for different moth species by at least 20 meters (65 feet).

Time of year to survey:
Traps are set out shortly after crop planting and remain until either defoliation or harvest or a killing freeze occurs (Leggett et al., 1994; Grefenstette et al., 2009).

Trap placement:

Traps should be placed level with the crop canopy.

*For the most up-to-date methods for survey and identification, see Approved Methods on the CAPS Resource and Collaboration Site, at http://caps.ceris.purdue.edu/.

Key Diagnostics/Identification

CAPS-Approved Method*: Morphological. Samples are screened for the presence of pink bollworm. Level 1 screening for this pest requires experience working with Lepidoptera in sticky traps. Initial screening should be performed using the following characters:

1. Labial palpi long and curved upward, their second joint with two black horizontal bands.

2. Hind wing dusky, with apex pointed, margin fringed.

3. Forewing narrow, mottled brown or grayish-brown with poorly defined black spots, with apex pointed and fringed.

4. Forewing approximately 6.3 to 8.7 mm (0.25 to 0.34 inches) in length in males, 6.9 to 10 mm (0.27 to 0.39 inches) in length in females.

Suspect pink bollworm specimens should then be forwarded to the designated identifier:

Areas EAST of the Mississippi River:

Dr. Julieta Brambila
USDA, APHIS, PPQ
1911 SW 34th Street
Gainesville, FL 32608
Tel.: (352) 372-3505, ext. 438
E-mail: julieta.brambila@aphis.usda.gov

Areas WEST of the Mississippi River:

Kira Metz
USDA APHIS PPQ
412 Minnie Belle Heep Center,
TAMU 2475
College Station, TX 77843-2475
Phone: (979) 862-3052 ; Cell: (979) 450-5492
E-mail: kira.metz@aphis.usda.gov

Please include form 391 “Specimens for Determination” with each sample. Please follow the CAPS-approved sticky trap sample submission guidelines at http://caps.ceris.purdue.edu/guidelines/2011/apdx_e2.

The ***Pectinophora gossypiella*** **Pink Boll Worm Field Screening Aid and Diagnostic Aid** is available at the following link: http://caps.ceris.purdue.edu/screening/pectinophora_gossypiiella.

*For the most up-to-date methods for survey and identification, see Approved Methods on the CAPS Resource and Collaboration Site, at http://caps.ceris.purdue.edu/.

Literature-Based Methods:
A thorough description of the moth and larvae can be found in Busck (1917). A description of all stages can be found in Noble (1969) and Matthews (1989).

An online key for *P. gossypiella* was recently released and can be found here: http://itp.lucidcentral.org/id/pbw/ (Hughes and Moore, 2011). This key offers ID support for field surveys and includes an adult and larval key with similar pests that may be found when surveying for *P. gossypiella* and many detailed images.

Easily Confused Pests

P. gossypiella is similar to both *P. scutigera* and *P. endema* in markings, venation, and morphology (Hodges, 1984). Descriptions to tell the males and females of each species apart can be found in Hodges (1984). A key to differentiate *P. gossypiella* and *P. scutigera* larvae (second to fourth instar) can also be found in Hodges (1984).

Busck (1917) states that several caterpillar species found in the United States in cotton bolls have been previously mistaken for *P. gossypiella*. These include (*Platynota*) *Sparganothis idaeusalis* and *Sparganothis rostrana* (Busck, 1917). These species are usually leaf-rollers but may enter open cotton bolls (Busck, 1917). *Pyroderces rileyi* may also be found in open cotton bolls, their color resembling the color of older instar *P. gossypiella* (Busck, 1917). Hughes and Moore (2011) state that the larvae of *Crocidosema plebejana*, *Dicymolomia julianalis*, and *Pyroderces rileyi* are similar to larvae of *P. gossypiella,* all of which are found in the United States. Distinguishing characteristics are found in Hughes and Moore (2011).

Matthews (1989) states that *P. gossypiella* may also be confused with *Mometa zemiodes* and *Pyroderces simplex*. Both species look similar, but *M. zemiodes* tends to feed on mature seeds and *P. simplex* is found in damaged open bolls (Matthews, 1989).

Hughes and Moore (2011) list similar adult species that are found in the United States including *Epilechia catalinella*, *Gelechia* sp., *Ofatulena duodecemstriata*, *Platyedra subcinerea*, and *Pyroderces rileyi*.

Commonly Encountered Non-targets

Both males and females of *Gelechia* sp. are attracted to the pink bollworm delta traps. Other moths that have been found in pink bollworm delta traps include *Epilechia catalinella* and *Ofatulena duodecemstriata* (Hughes and Moore, 2011).

References

Busck, A. 1917. The pink bollworm, *Pectinophora gossypiella*. Journal of Agricultural Research 9(10): 343-370.

CABI. 2010. Crop protection compendium: global module. Commonwealth Agricultural Bureau International, Wallingford, UK. http://www.cabi.org/compendia/cpc/.

EPPO. 2007. EPPO Plant Quarantine Information Retrieval System (PQR), version 4.6. European and Mediterranean Plant Protection Organization.

Grefenstette, B., El-Lissy, O., and Staten, R.T. 2009. Pink Bollworm Eradication Plan in the U.S. USDA-APHIS. 9 pp.

Henneberry, T.J., Bariola, L.A., and Russell, T. 1978. Pink bollworm: chemical control in Arizona and relationship to infestations, lint yield, seed damage, and afatoxin in cottonseed. Journal of Economic Entomology 71: 440-442.

Hodges, R.W. 1984. Pests not known to occur in the United States or of limited distribution, No. 46: Pink-spotted bollworm. USDA-APHIS-PPQ.

Hughes, G.B. and Moore, W. 2011**.** Identification Tool to the Pink Bollworm and its Look-Alikes*.* Identification Technology Program, USDA-APHIS-PPQ-CPHST; Fort Collins, CO. http://itp.lucidcentral.org/id/pbw/Welcome.html.

Ingram, W.R. 1994. *Pectinophora* (Lepidoptera: Gelechiidae). In G. A. Matthews and J. P. Tunstall (eds.). Insect Pests of Cotton. CAB International. University Press, Cambridge. pp. 107-149.

Leggett, J.E., El-Lissy, O. and Antilla, L. 1994. Pink bollworm moth catches with perimeter and in-field gossyplure baited delta traps. Southwestern Entomologist 19(2): 147-155.

Leigh, T.F., Roach, S.F., and Watson, T.F. 1996. Biology and ecology of important insect and mite pests of cotton. In E. G. King, J. R. Phillips, and R. J. Coleman (eds.). Cotton Insects and Mites: Characterization and Management, Number Three, The Cotton Foundation Reference Book Series. The Cotton Foundation Publisher. Memphis, Tennessee. pp. 17-85.

Matthews, G.A. 1989. Cotton Insect Pests and Their Management. Longman Scientific and Technical, New York. 199 pp.

Mukuka, J., Sumani, A.J., and Chalabesa, A. 2002. Agricultural Field Insect Pests of Zambia and their Management. Ministry of Agriculture and Co-operatives, Republic of Zambia. 1st edition. 59 pp.

Noble, L.W. 1969. Fifty Years of Research on the Pink Bollworm in the United States. Agriculture Handbook No. 357. USDA-Agricultural Research Service. 62 pp.

Naranjo, S.E., Butler, Jr., G.D., and Henneberry, T.J. 2001. A Bibliography of the Pink Bollworm, *Pectinophora gossypiella* (Saunders). USDA-ARS-Bibliographies and Literature of Agriculture, Number 136. 160 pp.

Parencia, Jr., C.R. 1978. One Hundred Twenty Years of Research on Cotton Insects in the United States. Agriculture Handbook No. 515. USDA-Agricultural Research Service 75 pp.

Raulston, J.R., Henneberry, T.J., Leggett, J.E., Byrne, D.N., Grafton-Cardwell, E., and Leigh, T.F. 1996. Short- and long-range movement of insects and mites. *In:* E. G. King, J. R. Phillips, and R. J. Coleman (eds.). Cotton Insects and Mites: Characterization and Management, Number Three, The

Cotton Foundation Reference Book Series. The Cotton Foundation Publisher. Memphis, Tennessee. pp. 143-162.

Schoenholz, J.A. 2011. Pink bollworm survey protocol. Personal communication to L.D. Jackson on November 10, 2011 from J. Schoenholz (National Cotton Program Manager, USDA-APHIS-PPQ).

USDA. 1948. Pink Bollworm. Picture Sheet No. 21. Bureau of Entomology and Plant Quarantine. Agricultural Research Administration, U.S. Department of Agriculture.

Wagner, T.L., Olson, R.L., and Willers, J.L. 1996. Modeling and computerized decision aids. *In:* E. G. King, J. R. Phillips, and R. J. Coleman (eds.). Cotton Insects and Mites: Characterization and Management, Number Three, The Cotton Foundation Reference Book Series. The Cotton Foundation Publisher. Memphis, Tennessee. pp. 205-249.