Chapter 4:

Effects of Insect-Plant Interactions on Crop Development

B. Roger Leonard, Tina Gray Teague, Randy G. Luttrell, and S. Aubrey Harris

Cotton Insect and Mite Pest Occurrence

Cotton is a long-season crop, which is attacked by a diverse group of insect and mite pests throughout plant development and maturity. Numerous insect and mite pests are capable of reducing cotton yields across the United States (Leigh et al., 1996). The most common pest problems in the southern region are cutworms, *Agrotis* spp.; thrips, Thysanoptera; cotton aphid, *Aphis gossypii* Glover; tarnished plant bugs, *Lygus lineolari*s (Palisot de Beauvois); cotton fleahoppers, *Pseudatomoscelis seriatus* (Reuter); stink bugs, Pentatomidae; boll weevil, *Anthonomus grandis grandis* Boheman; spider mites, Acari; bollworm, *Helicoverpa zea* (Boddie); tobacco budworm, *Heliothis virescens* (F.); fall armyworm, *Spodoptera frugiperda* (J. E. Smith); beet armyworm *Spodoptera exigua* (Hübner); and soybean looper, *Pseudoplusia includens* (Walker).

In 2005, cotton producers across the United States spent $816.4 million to control these pests on over 14 million planted acres (Williams, 2006). The range of insect and mite pests change as the cotton crop develops during the season (Fig. 1). In addition, pest density and their potential to injure the harvestable crop usually increase during the season. The number of pests and the relatively high crop value per acre cause insect pest management to be a significant annual variable production cost for cotton. During some years of intense insect and mite pest pressure, annual insect control costs can exceed $100/acre.

During the seedling stage, thrips and cotton aphids are usually the most common insect pests. As cotton plants initiate squaring (flower bud formation), a complex of boll weevil, tarnished plant bug, cotton fleahopper, spider mite, and caterpillar pests is capable of reducing yields. During the flowering stage, square-feeding insects can persist as problems, but additional caterpillar pests such as armyworms, stink bugs, loopers, and clouded plant bugs can become important yield-limiting pests. The evolving status and sporadic occurrence of multiple pests during the crop production season add to the difficulty of scouting and making the correct decision on pesticide application timing.

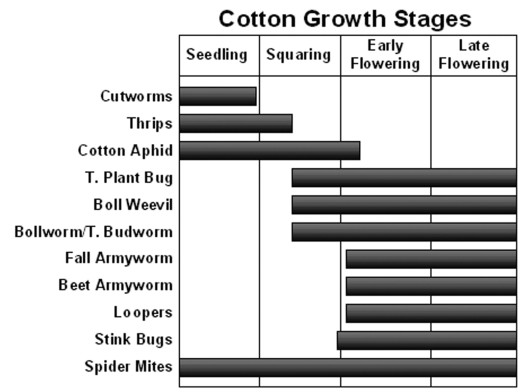

Fig. 1. Major cotton insect pests attacking selected stages of cotton across the Mid-South cotton region.

Cotton Plant Development and Plant Response to Pest Injury

The indeterminate growth pattern of cotton plants also complicates cotton pest management practices. Cotton plants generally produce more fruiting structures than can be retained during the entire growing season. Excess fruiting structures are abscised from the plant in response to several factors including environmental stresses (weather), biotic injury (pests), or competition among fruiting sites (Guinn, 1982; Mauney, 1986). The abscission of reproductive structures, regardless of the reasons, is a natural process that a plant utilizes to maintain optimal numbers of fruiting forms. The concurrent development of vegetative growth (leaves and stems) and reproductive forms (squares, flowers, and bolls) can allow up to 50% of the total fruit load to be abscised during the season and still produce optimal yields (Bourland et al., 1990; Kennedy et al., 1991). This is an important consideration because insect and mite pests can be allowed to injure the crop at low levels without producing measurable yield losses. As the production season progresses, fruiting forms reach a peak value, and plants lose the ability to fully compensate for their loss during the remainder of the season (Gore et al., 2000).

During the pre-flowering phase of cotton development, losing up to 20% of first-position cotton squares usually will not decrease yields if environmental conditions are favorable for plant development during the production season (Holman, 1996). The cotton plant naturally sheds relatively high numbers of the fruiting forms after anthesis. The rate of boll abscission directly affects final cotton yield and the actual timing of boll loss has an equally important influence on final yield. Considerable (>50%) injury to flowers and bolls during the initial weeks of flowering may not influence yields, but low levels (<15%) can contribute to significant yield losses during peak flowering (Gore et al., 2000). The cost of losing fruiting forms during the pre-flowering and flowering interval is usually a delay in crop maturity if the crop is allowed to produce optimal yields.

Boll and Yield Susceptibility to Insect Pests

The indeterminate growth pattern of cotton also allows bolls to develop on the plant over an interval of several weeks. Natural boll abscission peaks at five to six days after anthesis and decreases to 0% on bolls retained at 12 to 15 days after anthesis. Direct insect injury to young bolls usually results in abscission. For older bolls (12 to 15 d-old), insect injury can reduce yield in one or more locules, but the boll may not abscise from the plant. Considerable research has examined the interactions between boll age [heat units (HU) beyond anthesis] and yield loss from insect injury. Numerous cotton insect pests injure cotton during the production season, and it is unlikely that one threshold for boll susceptibility could be used for all pests. Initial studies during the previous decade found heat unit accumulation to be a consistent method of aging the susceptibility of bolls to pests (Bagwell and Tugwell, 1992).

Bolls appear to be relatively safe from direct feeding injury by boll weevil, bollworm, beet armyworm, tarnished plant bug, brown stink bug, southern green stink bug, and western tarnished plant bug, *Lygus hesperus* Knight, at 299 to 559 HU after anthesis (Fig. 2). For foliage-feeding insects, yield losses were not observed until defoliation occurred on plants that had accumulated 550 HU after setting the last effective boll. However, in similar studies, late-instar fall armyworm larvae successfully penetrated >60% of non-*Bt* cotton bolls that had accumulated 852 HU, but <10% of transgenic *Bt* bolls that had accumulated 864 HU. In addition, studies are currently underway to evaluate the interactions between boll age, insect-induced boll injury, and fiber quality.

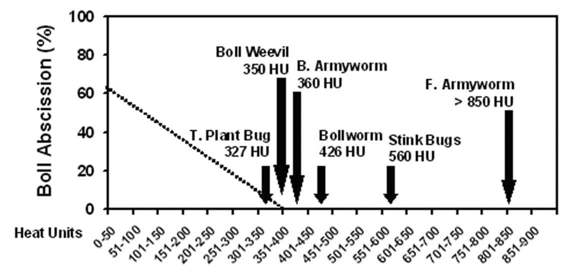

Fig. 2. The effects of boll maturity on insect pest-induced boll abscission.

Cotton Plant Development and Pest Management Decisions

Pest management decisions must rely on information about the pest as well as crop health and development patterns. Plant monitoring techniques were originally developed to document the effects of environmental stresses on plant growth (Hake et al., 1990; Bourland et al., 1992) but now are used as decision aids in the application of production inputs including pest management treatments (Cochran et al., 1994; Bourland et al., 1998).

The most widely accepted plant monitoring tool is the COTMAN™ program, which can provide information on plant development during the entire season. COTMAN data give a reference and seasonal perspective of crop fruiting patterns that can be coupled with insect and mite infestation counts to make a well-informed decision. Extension recommendations for most of the Mid-South cotton production states rely upon square retention levels as well as insect numbers to determine the needs for pesticide applications. The sub-program routine SQUAREMAN of COTMAN is an effective tool for collecting and processing data on square retention.

Late-Season Pest Management

The decision of when to terminate late-season insect pest management strategies has been a persistent problem for the cotton industry. Returns through increased yields and improved fiber quality must exceed the cost of these control strategies to justify late-season insecticide treatments. Another COTMAN component, BOLLMAN, has been used to estimate the critical time to terminate insect-pest management strategies at the end of the growing season. This program uses *cutout* [main stem *nodes above white flower* (NAWF) ≤5], as the endpoint for the last effective boll population set on the plant (Oosterhuis, 1990; Bourland et al., 1992). Many bolls produced by the plant after cutout do not have enough time remaining in the season to produce mature cotton fibers (Bernhardt et al., 1986). As a general rule, after cutout has occurred and the crop has accumulated 350 to 550 HU, harvestable bolls are considered safe from attack by most fruit-feeding insect pests (Oosterhuis and Kim, 2004). If the definition of cutout is reduced to NAWF≤4 for some regions, then the heat unit accumulation rules remain the same. Physiological cutout is a key factor that must be defined accurately for each situation to eliminate late-season treatments used to protect cotton bolls that normally abscise or will not produce mature fiber.

Unfortunately, there are situations in which the crop develops in such a manner that the NAWF never progresses to within 5 main stem nodes of the plant terminal. Under these conditions, an alternative to using a physiological basis for cutout is to estimate the latest possible cutout date using a calendar day. This endpoint of crop development uses long-term weather data for a specific location and represents the last day in which a white flower has a 50% chance of receiving enough HU to mature into a boll of sufficient size and quality.

References

Bagwell, R.D. and N.P. Tugwell. 1992. Defining the period of boll susceptibility to insect damage in heat-units from flower, pp. 767-768. *In:* Proc. Beltwide Cotton Conferences, Nashville, Tenn. 6-10 Jan. 1992. National Cotton Council, Memphis, Tenn.

Bernhardt, J.L., J.R. Phillips, and N.P. Tugwell. 1986. Position of the uppermost white bloom defined by node counts as an indicator for termination of insecticide treatments in cotton. J. Econ. Entomol. 79:1430-1438.

Bourland, F.M., N.P. Tugwell, D.M. Oosterhuis, S.J. Stringer, J.R. Phillips, and M.J. Cochran. 1990. Reading the cotton plant for efficient management. *In:* D.M. Oosterhuis (ed.). Proc. 1990 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Staation Special Report 144:45-49. Fayetteville.

Bourland, F.M., D.M. Oosterhuis, and N.P. Tugwell. 1992. Concept for monitoring cotton plant growth and development using main-stem node counts. J. Prod. Agric. 5:532-538.

Bourland, F.M., N.P. Tugwell, D.M. Oosterhuis, M.J. Cochran, and D.M. Danforth. 1998. Establishment of SQUAREMAN decision rules for managing early-season cotton. pp. 1737-1739. *In* Proc. Beltwide Cotton Conferences, San Diego, Calif. 5-9 Jan. 1998. National Cotton Council, Memphis, Tenn.

Cochran, M.J., N.P. Tugwell, D.M. Danforth, C.D. Klein, and J.P. Zhang. 1994. The economic potential of plant monitoring to guide the termination of late-season insect control in Arkansas. pp. 914-915. *In:* Proc. Beltwide Cotton Conferences, San Diego, Calif., 5-8 Jan. 1994. National Cotton Council of America. Memphis, Tenn.

Gore, J., B.R. Leonard, E. Burris, D.R. Cook, and J.H. Fife. 2000. Maturity and yield responses of non-transgenic (cv. Stoneville 474) and transgenic Bt cotton (cv. NuCOTenn 33B) to simulated bollworm (Lepidoptera: Noctuidae) injury. J. Cotton Sci. 4:152-160. http:/www.jcotsci.org/2000/issue03/html/.

Guinn, G. 1982. Causes of square and boll shedding in cotton. U.S. Dept. of Agric. Tech. Bull. No. 1672, 21 pp.

Hake, K., T.A. Kerby, F.M. Bourland, and J. Jenkins. 1990. Plant mapping as a management tool. Physiology Today. National Cotton Council. Jan. 1990.

Holman. E.M. 1996. Effect of early-season square loss on cotton (*Gossypium hirsutum* L.) plant development. Ph.D. dissertation. 140 pp. University of Arkansas, Fayetteville.

Kennedy, C.W., W.C. Smith, Jr., and J.E. Jones. 1991. Chemical efficacy of early square removal and subsequent productivity of superokra-leaf cotton. Crop Sci. 31: 791-796.

Leigh, T.F., S.H. Roach, and T.F. Watson. 1996. Biology and ecology of important insect and mite pests of cotton. pp. 17-69. *In:* E. King, J. Phillips and R. Coleman (ed.). Cotton Insects and Mites: Characterization and Management. Cotton Foundation, Memphis, Tenn.

Mauney, J.R. 1986. Vegetative growth and development of fruiting sites. pp. 11-28. *In:* J.R. Mauney and J.M. Stewart (eds.). Cotton Physiology. Cotton Foundation, Memphis, Tenn.

Oosterhuis, D.M. 1990. Growth and development of a cotton plant. Ark. Coop. Ext. Serv. MP 332, 24 pp.

Oosterhuis, D.M. and M. Kim. 2004. Structural and biochemical changes in the boll wall in support of the NAWF5+350 heat units rule for insecticide termination. pp. 258-295. *In:* Proc. Beltwide Cotton Conferences. San Antonio, Texas, 5-9 Jan. 2004. National Cotton Council, Memphis, Tenn.

Williams, M.R. 2006. Cotton Insect Losses 2005. pp. 1151-1204. *In:* 2006 Proc. Beltwide Cotton Conferences, San Antonio, Texas, 5-9 Jan. 2005. National Cotton Council, Memphis, Tenn.