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Bt Cotton Technology in Texas:

A Practical View

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Since their introduction in 1996, transgenic cottons expressing the Bollgard® gene technology have been evaluated by producers in large scale commercial plantings across the U.S. Cotton Belt.

Transgenic cottons are designed to be resistant to the target pests of bollworm *Helicoverpa zea* (Boddie), pink bollworm *Pectinophora gossypiella* (Sanders), and tobacco budworm *Heliothis virescens* (F.). These cottons contain *Bacillus thuringiensis* (Bt), a gene toxic to the target pests. The performance of these cottons has been highly efficacious against the tobacco budworm and the pink bollworm. They also preform well against bollworm; however, in certain situations producers may need to make supplemental insecticide treatments for this insect. Conditions that have contributed to the need for supplemental control are heavy bollworm egg laying during peak bloom, boll injury and the presence of larvae larger than 1/4 inch, high production inputs that favor rapid or rank plant growth, and fields previously treated with insecticides.

Earliest reports of bollworm damage on transgenic cotton varieties NuCOTN 33B and NuCOTN 35B surfaced in the Brazos Bottomlands and parts of the upper Coastal Bend areas of Texas in 1996. NuCOTN 33B and NuCOTN 35B have, however, provided effective bollworm control throughout much of Texas and reduced insecticide treatments for bollworm, tobacco budworm and pink bollworm compared to non-Bollgard® cotton.

Yields from Bollgard® cotton are generally equal to or slightly higher than those for standard non-Bollgard® cultivars grown under the same production scheme. The relationship between the costs and benefits of this technology is critical to its adoption (Benedict 1996, Pigg 1995).

Much has been learned about the performance of these new transgenic cottons. Producers, consultants, Extension entomologists, researchers and industry

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must work together to better understand how to manage and maximize the benefits of this technology. During 2000, the Bollgard® gene was commercially available in certain Delta and Pine Land, Paymaster, Sure Grow and Stoneville varieties. Some varieties are also offered with a stacked gene product featuring a combination of the Bollgard® gene and a herbicide tolerance gene; either the Roundup Ready gene or BXN (Buctril resistance gene). In 2001, Delta and Pine Land, Sure Grow, Paymaster and Stoneville seed companies will have new Bt cotton varieties for sale, many with Bollgard® and herbicide resistance genes.

Cotton producers and consultants have asked for more information on the use and management of Bollgard® cottons. The following information on scouting and management of Bollgard® cotton was developed from university research and Extension trials and field experiences of producers and consultants.

Requirements for Planting Bollgard® Cottons

Q. Who may plant Bollgard® cotton?

A. Any producer who does the following:

- Signs a new grower agreement or renews the past year's agreement in order to purchase and grow Bollgard® cotton.
- Pays a technology fee to Monsanto for each bag of Bollgard® planting seed.
- Plants a non-Bollgard® cotton refuge to help manage potential resistance problems by producing Bollgard® susceptible lepidopterans (tobacco budworm/bollworm and pink bollworm).
- Guarantees that seed produced on the current Bollgard® crop will not be saved for replanting next year.

Management of Bollgard® Cottons

Q. Should Bollgard® cottons be planted during an optimum planting window?

A. Ideally producers will benefit from optimum planting, which will allow them to take advantage of early season moisture and additional heat units, thereby enhancing yield potential.

However, because Bollgard® cottons effectively control tobacco budworm/bollworm and pink bollworm, late planting is not as critical a problem as with non-Bollgard® cottons. Under heavy bollworm pressure, especially during periods of peak bloom, Bollgard® cottons may require supplemental control for this species.

Q. Is it really necessary to plant a refuge (non-Bollgard® cotton) adjacent to the Bollgard® cotton field or nearby on the farm?

A. Yes, a refuge planting of non-Bollgard® cotton is a requirement for planting Bollgard® cotton. The refuge is essential to delaying insect resistance to Bollgard® cotton. There are three refuge options:

Option 1

- For every 100 acres of Bollgard® cotton, plant an additional 25 acres of non-Bollgard® cotton (20 percent refuge). All Bollgard® fields must be within 1 mile of the refuge (field border to field border).
- Absolutely no foliar Bt insecticide can be applied to the refuge.

Option 2

- For every 95 acres of Bollgard® cotton, plant an additional 5 acres of non-Bollgard® cotton (5 percent refuge).
- Do not treat the refuge with foliar Bt's or "any" insecticide active against target lepidopterans. The unsprayed refuge must be at least 150 feet wide (approximately 48 rows in conventional row width cotton) and all associated Bollgard® fields must be within 1/2 mile (field border to field border) of the unsprayed refuge. Requirements apply to all 5 percent unsprayed option users regardless of the percent of cotton acres in that county planted to Bollgard®.

Option 3

- A 5 percent embedded option, added for 2001, allows the refuge to be treated with any insecticide at the same time as the Bollgard® is treated, providing the refuge is embedded in the field or field unit. The refuge must be at least 150 feet wide regardless of field size.

Example (**large field application**): Five percent of the field would be planted to a non-Bollgard® variety, the rest with Bollgard®. If the Bollgard® cotton required treatment for bollworms or other pests, the entire field, including the refuge, could be sprayed with the same insecticide at the same time. However, the refuge could not be treated for cotton bollworms, tobacco budworms or pink bollworms independently of the associated Bollgard® field.

Example (**small field situations**): Fields could be grouped into "field units" so that one of the smaller fields, or a portion of one of the fields, would serve as the embedded non-Bollgard® refuge. The embedded refuge could be treated with the same insecticide at the same time that all of the associated Bollgard® fields were sprayed, but could not be treated for bollworms or tobacco budworms independently of the associated Bollgard® fields. **Any fields contained within a 1-mile square area can be considered a "field unit."**

Q. What are the optimum planting rates for Bollgard cotton?

A. Producers should strive for planting rates that produce between two and four plants per row foot. Based on field trials, plant growth and uniformity are more easily managed when final plant stands do not exceed four plants per row foot. Because the Bollgard® technology fee is applied to a bag of planting seed, the less seed the grower plants per acre the lower the cost of the technology per acre. The technology fee works out to $20 per acre of seed based on a planting rate of 67,500 seed per acre in central, east and south Texas. Producers who plant less than 67,500 seed per acre pay less per acre for the seed and the Bollgard® technology. For example, if a grower in east Texas planted four seeds per foot of row on 38-inch centers, which is 55, 000 seed per acre (55,000 seed on NuCOTN 33B is about 9.5 pounds per acre), the producer could reduce the cost for planting seed and Bollgard® technology by 18 percent compared to planting 4.9 seed per foot or 67,500 seed per acre. This is a savings of about $5.40 per acre.

Q. Is nitrogen management important with Bollgard® cottons?

A. Yes. As with non-Bollgard® cottons, excessive nitrogen application promotes excessive vegetative growth, delays fruiting and generally makes

the plant more attractive to insect pests. Based on field trials, optimum nitrogen fertilization for Bollgard® cottons that are expected to yield two bales per acre should be between 90 and 100 pounds of actual nitrogen per acre.

Q. How should early season insects be managed?

A. Bollgard® cottons will require effective early season insect control as will non-Bollgard® cottons. Early season insects that may require insecticidal control include thrips, aphids, cotton fleahoppers and overwintering boll weevils.

Q. How should Bollgard® cottons be managed in-season?

A. Producers should manage for earliness. Plant mapping is highly recommended to monitor the relationship between vegetative growth and fruit retention. The timely use of a plant growth regulator may aid in the overall management of plant growth.

Q. What in-season cotton insect management is needed?

A. Insecticide treatment for cotton fleahoppers, boll weevils, plant bugs, stinkbugs, aphids, whiteflies and spider mites may be required as with non-Bollgard® cottons. Thresholds for treatment of these pests are the same as for non-Bollgard® cottons. Producers are advised that under heavy bollworm pressure and during periods of peak bloom, Bollgard® cottons may require supplemental insecticidal control for bollworm. We suggest that producers consider using selective insecticides that minimize disruption of beneficial insects. Beneficials are important in controlling all insect pests.

Q. How is irrigation managed?

A. Over irrigation and excessive rainfall, particularly in mid and late season, promote excessive plant growth, boll rot and may increase plant susceptibility to Bollgard® target pests. Over irrigation should be avoided.

Q. How should Bollgard® cottons be managed with regard to crop termination?

A. As with non-Bollgard® cotton cultivars, early uniform cutout is important to maximize the benefits of harvest aid chemicals. Early crop termination should allow for harvest during periods when weather is most favorable. Immediate postharvest

stalk destruction is critical for minimizing late-season insect infestations and reducing the number of boll weevils and pink bollworms that successfully overwinter.

Q. Are there any restrictions on insecticides that can be used on Bollgard® cotton?

A. According to Monsanto, there are no restrictions, with the exception of foliar Bt's.

Q. What insect pests does the Bollgard® cotton control?

A. The target insect pests are tobacco budworm/bollworm and pink bollworm.

Q. Does Bollgard® cotton control lepidopterans?

A. According to research entomologists, varying degrees of control may be realized depending on the insect species. Preliminary information indicated the following levels of control in research plots.

Species	% Control*
Bollworm prebloom	90
Bollworm blooming	70
Tobacco budworm	95
Pink bollworm	99
Cabbage looper	95
Beet armyworm	25
Fall armyworm	20 or less
Saltmarsh caterpillar	85 or more
Cotton leaf perforator	85 or more
European corn borer	85 or more

*Measured as percent mortality of larvae

Source: Benedict et al. (1991, 1999), Bradley (1995), Wilson et al, (1992, 1994)

Control of all insect pests may be higher in Bollgard® cotton fields where insecticide treatments are NOT being applied for other insects, such as boll weevil, and beneficial insects are adequate to enhance pest mortality.

Q. How will producers scout Bollgard® cottons?

A. Whole plant inspections should be made just as for non-Bollgard® cottons (for further information see the cotton insect guides, 1204, 1209 and 1210, Texas Agricultural Extension Service) or *http://insects.tamu.edu.* A proper sample includes

squares, white blooms, pink blooms, bloom tags and bolls. It is very important to know which lepidopteran species is present (bollworm and/or tobacco budworm and/or beet armyworm and/or fall armyworm and/or cabbage loopers). The choice of scouting method, treatment threshold and insecticide are dependent upon the lepidopteran species. Consultants and producers are advised to collect and identify larvae from the field. It is also useful to monitor pheromone traps, flush moths from fields or observe moth flights to determine species. The Ag Dia test kit may be used to determine bollworm/budworm species composition based on presence of eggs and small larvae. Scouting intervals should be reduced to 3 to 4 days during periods of increasing bollworm egg laying, especially during peak bloom.

In scouting for pink bollworm, monitor pheromone traps for presence of moths, and bolls for larvae 1/4 inch or larger. Entrance warts, mines in carpal walls, and small larvae less than 1/4 inch long may be observed on Bollgard® cotton, but lint feeding and seed injury will be minimal. The presence of rosette blooms, third instar larvae (1/4 inch or more long), and exit holes would indicate potential loss of control for pink bollworm in Bollgard® cotton.

With all three target insects, economic injury should be low on Bollgard® cotton compared to nearby non-Bollgard® cotton unless resistance to the toxin arises. However, many new Bollgard® varieties are available and it is possible that one or more of these new Bollgard® varieties may not perform well in some production environments (Sachs et al. 1998).

Q. What type of insect injury can be expected in Bollgard® cotton?

A. Little terminal injury and very few large larvae of tobacco budworm will be observed as long as the Bt toxin remains effective. Slight feeding (grazing) on the bracts and calyx of terminal squares by tobacco budworm/bollworm may occur. However, such feeding is not economic injury to the square and often the square remains on the plant and produces a boll. Obviously, early instar larvae must do some feeding, usually on leaves, square bracts and the calyx of the square, to ingest a lethal dose of the Bt toxin. They must eat

the Bt toxin to die. In prebloom, expect to see some large larvae (usually bollworm) and damage, since not all plants will have a Bollgard® gene (usually less than 1 percent of plants in a field will be non-Bollgard®) and larvae may migrate from unsprayed weed hosts.

During bloom, few large bollworm larvae should be observed except when newly hatched larvae can feed on pollen in white and pink blooms and bloom tags. This allows first instar larvae to reach third instar. Because expression of the Bt toxin is low in pollen, bollworm larvae survival is highest in flowers. When egg-laying is high, this can lead to bollworm numbers, and square and boll injury in excess of the economic threshold.

Pink bollworm entrance warts and mines in carpal walls may be observed in bolls, as in non-Bollgard® cotton, but very few larvae and no economic injury should occur.

Many new Bollgard® varieties are becoming available to cotton producers. In certain production environments some of these varieties may show different agronomic or insect control performance than current Bollgard® varieties. Consultants and producers should carefully observe new Bollgard® varieties in their production systems to ensure that the new varieties are performing as expected.

Q. Are economic thresholds for tobacco budworms/bollworms different for Bollgard® cotton?

A. No. Treatment with foliar insecticides for tobacco budworm or bollworm should be considered when: A) there are 4,000 to 8,000 larvae per acre larger than 1/4 inch (based on a population of 40,000 to 60,000 plants per acre) or B) there are eight to 12 larvae larger than 1/4 inch per 100 plants and 5 to 15 percent of the squares or bolls are worm damaged. Many factors influence where in this range the treatment is made. (i.e., 5 to 15 percent injury and 4,000 and 8,000 larvae per acre). Some of these factors are: presence or absence of beneficial insects; value of the crop (yield per acre multiplied by price per pound of lint); duration of infestation; stage of crop growth at infestation; percent fruit set on the plant; cost of insecticide treatment; and type of production system (high yield/high input or low yield/low

input). These factors may influence the actual thresholds used to trigger foliar spray as follows:

- If cotton has been recently sprayed with a broad spectrum insecticide and few beneficials are present, then the lower thresholds may be used, (i.e., 4,000 larvae per acre and 5 percent injured squares and bolls), especially if the market value of the crop is greater than $600 per acre.
- If a broad spectrum insecticide has not been used, beneficial insects are abundant, and market value is less than $500, then the higher threshold may be used.
- If weather has caused fruit set to be less than 50 percent, then yield can be expected to be below average and the higher thresholds may be used.

Note that the use of these thresholds is justified only if injury is expected to stay at this level or to increase over the following 3 weeks, if untreated. These thresholds are not recommended for use later than 20 days after cutout. The boll crop at 20 days after cutout is quite resistant to injury from first and second instar larvae, and higher numbers of young larvae can be tolerated. At this time, larval parasitism also is high and most young larvae will die; therefore, little injury to large bolls is likely to occur. Also, egg parasitism and mortality are usually high at 20 days after cutout.

Q. Will economic thresholds for pink bollworms change for Bollgard® cotton?

A. No. Insecticide treatment should be based on percent infestation as assessed by boll sampling. If boll sampling determines that 10 to 15 percent of Bollgard® bolls are infested with medium to large larvae (1/4 inch or more in length), and seed and lint are being damaged, then treatment is warranted. However, this should not occur unless the Bollgard® cotton field is contaminated with some non-Bollgard® cotton plants, or pink bollworms have become resistant to the Bt toxin.

Both Bt and non-Bt cotton should be treated the same as far as cultural control is concerned. Cultural control is still one of the most desirable, satisfactory and economical methods of controlling pink bollworms. Production practices that promote an early crop and permit crop termina-

tion by mid-September is encouraged. Cotton should be harvested as early as possible. Stalks should be shredded and plowed (preferably with a moldboard) to a depth of at least 6 inches. Plowing should be completed as early as possible. Timely termination of the crop and immediate post-harvest stalk destruction are important practices in resistance management for pink bollworm.

Q. What is the expression pattern of Bt toxin in the plant?

A. According to Monsanto, expression of the Bt protein toxin is highest in the terminal and, although effective, decreases as you move down the plant. The Bt toxin is relatively high in component parts of the plant with the exception of the pollen in flowers where expression is thought to be significantly lower than elsewhere in the plant.

Q. Is there any yield advantage from planting Bollgard® cotton?

A. Under ideal management, assuming optimum planting, proper fertility and effective weed control with moderate to heavy tobacco budworm pressure, or with light to moderate bollworm infestation, Bollgard® cotton producers should realize increased yield compared to non-Bollgard® cotton with no insecticide control or with conventional foliar insecticide sprays. Heavy bollworm pressure combined with foliar sprays on Bollgard® cotton can also result in increased yields compared to non-Bollgard® cotton.

Production Situations that Favor Bollgard® Cotton Planting

Q. Where should Bollgard® cotton be planted?

A. 1. Plant it where you know it is needed.

- In areas where you are making two or more foliar insecticide applications and spending $20 or more per acre for tobacco budworm/bollworm or pink bollworm control.
- In river bottom areas where tobacco budworm/bollworm pressure has been historically heavy.
- In the first and second year of the Boll Weevil Eradication programs where outbreaks of lepidopteran pests may be expected.

- Near waterways, schools, hospitals, homes and other sensitive sites, where restricted use insecticides cannot be sprayed.
- In chronic pink bollworm infested areas of West Texas.

2. Plant it where you want to minimize the use of conventional broad spectrum insecticides to achieve maximum effectiveness of beneficial insects for biological control of all insect pests. The objective here is to reduce the use of conventional insecticides that kill beneficial insects, and thus avoid potential outbreaks of all cotton pests. Pests of particular importance are aphids, whiteflies and armyworms.

- In areas where the boll weevil has been eradicated and conventional insecticide sprays are no longer required for this insect.
- In areas with chronic pink bollworm infestations that in the past have required foliar sprays of conventional insecticides. Use of Bollgard® cotton should eliminate these applications.
- In areas with chronic tobacco budworm infestations that in the past have required foliar sprays of conventional insecticides. Use of Bollgard® cotton should eliminate these applications.

Conclusion

In summary, Bollgard® cotton technology is clearly impressive, and based on previous research, producers will likely experience some yield advantage over non-Bollgard® cottons in areas infested with tobacco budworm/bollworm or pink bollworm. Estimating the economic value of Bollgard® cotton versus new or conventional insecticides is paramount! This is a question that each producer must consider for specific production situations. Consultants, producers, Extension personnel and industry representatives will need to work together to best use the Bollgard® cotton technology in conjunction with new selective and traditional broad spectrum insecticides. For further information on Bollgard® cotton, we recommend that you contact your county Extension agent or local Monsanto representative.

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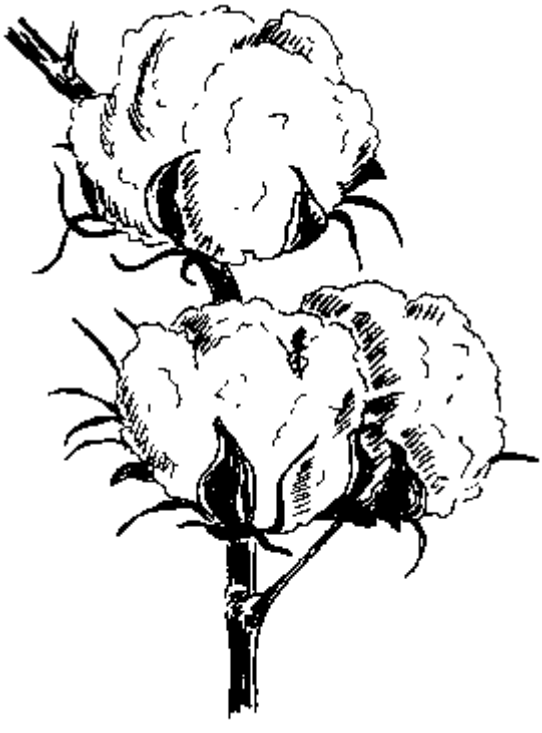

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