An Economic Evaluation of Bollgard II Cotton in West Tennessee

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Introduction

Background of Bollgard and Bollgard II Cotton

Monsanto has commercially marketed Bollgard cotton since 1996 (Allen 1999). Bollgard cotton includes a single gene from a bacterium, Bacillus thuringiensis. This single gene is referred to as Cry1Ac. Cry1Ac has a high level of toxicity to many lepidopteron insects but it has proven to be less effective against others. Specifically Bollgard cotton has provided excellent control of Tobacco Budworms, Heliothis virescens, and the Pink Bollworm, Pectinophora gossypiella. Bollgard cotton has been less effective in controlling Bollworms, Helicoverpa zea, and Loopers, Pseudoplusia includens (Miczinski and Walther 2000) Fall Armyworms, Spodoptera frugiperda, and Beet Armyworms, Spodoptera exigua (Stewart and Knighten 2000) when compared to Budworms. The reduction of control in some worm species has led to over sprays of Bollgard cotton with pesticides to control the worm escapes.

The main reason farmers plant Bollgard cotton is to reduce insect costs per acre and increase profits per acre. Currently, in Tennessee, farmers pay about $24 an acre for planting Bollgard cotton. The actual cost will vary somewhat depending on cotton variety and seed size. Monsanto collects this as a technology fee. The grower expects to gain excellent control of Budworms and good control of Bollworms; these are the two main caterpillar pests in cotton fields in Tennessee (Stewart 2003). The primary advantage of Bollgard cotton is the continuous nature of its insect control. It can reduce the quantity of pesticides used, as farmers are purchasing insect control “up front” in the seed’s genetics. Unfortunately, Bollgard has not proven to be universally effective for all worm problems.

Bollgard has no activity on the Black Cutworm, Agrotis ipsilon or the Variegated Cutworm, Peridroma saucia (Johnson, 1995 pp.26-27). It is very effective in controlling Bollworms and Budworms prior to bloom. After first bloom the efficacy of Bollgard against Bollworms is greatly compromised. Under high pressure from Armyworms, both Fall and Yellow-striped, squares, blooms and bolls may be destroyed. The Bollgard toxin is readily expressed in the squares but less expression exists in the pollen and leaf tissue.

Because of the drawbacks from Bollgard cotton, Monsanto introduced Bollgard II commercially in 2003. Bollgard II cotton contains the same Cry1Ac gene as the Bollgard, but Bollgard II has an additional gene, Cry2Ab. Testing in prior years indicated that the combination of these two genes improves efficacy on target species as well as aids in resistance management (Akin et al.2002.) Bollgard II cotton is projected to cost an additional $8/acre over Bollgard. This translates to roughly $32/acre for caterpillar insect control paid up front. Results from previous years show that greater efficacy of Bollgard II increases retention of early boll set and may promote an earlier harvest. However, because of strict EPA guidelines, the Bollgard II varieties have never been harvested for yield under commercial conditions. The Bollgard II plots have been
studied for insect control then destroyed in the fall or harvested in small plots under strict guidelines.

Objectives of this Study

This study has four primary objectives. First, to evaluate how effective Bollgard II controls Bollworms and other lepidopteron insects. Each plot will be scouted weekly and all caterpillar insects will be recorded. The next evaluation will be in maturity between varieties. Weekly plant mapping, including square and boll retentions (Teague et al 2000), along with end of the season boll damage and maturity measurements will be made. Also each plot will be harvested and weighed for lint yield; replicated treatments will be evaluated for grade quality. The final objective of this study is to determine the economic relationship among the treatments and the probability for delivering value with these technologies to the producer in this environment.

Literature Review

Review of Integrated Pest Management (IPM)

Integrated Pest Management (IPM) uses a variety of control tactics, cultural practices, variety selection, biological control and chemical control, rather than relying solely on one method of control, such as insecticide use (Stewart and Lentz 2003 pp 2). This program seeks to increase cotton yields by using the best approach to a given situation while reducing unnecessary insecticide applications. An example would be spraying an insecticide that is less harmful to beneficial insects in hopes that the beneficials will reduce non target populations. Specifically a producer may use Trimax, imidacloprid, or Centric, thiamethoxam, for control of tarnished plant bugs, Lygus lineolaris (Greene and Capps 2003). These chemicals offer excellent control of the target pest without devastating the beneficial populations in the field. Leaving the beneficials in the field will hopefully help to prevent a flare of addition pests. So the target pest is controlled and no additional problems are created because of the implementation of IPM.

Selecting the correct chemical for the job is not the only use of IPM. Cultural practices that promote earliness, such as an early planting date or the well-calculated use of nitrogen, will help the cotton crop to mature ahead of some insect pressures (Robertson et al 2003).

Importance of Caterpillar Pests in Cotton IPM

Once an understanding of Integrated Pest Management (IPM) is achieved, the practice can target caterpillar pests specifically. In the Bollgard varieties the control of some species has been excellent, namely in controlling populations of Tobacco Budworms, Pink Bollworms and European Corn Borers. Bollgard has been less effective in controlling Bollworms, especially at high infestations after bloom, Armyworms, Fall, Yellow-Striped and Beets, as well as leaf feeders, such as Loopers and Salt Marsh
Caterpillars. Based on these limitations, the producer should have an alternative insect control action plan in place.

If there is an infestation of “fruit feeding worms” in Bollgard cotton the problem is assumed to be caused by either Bollworms or Armyworms. However, there is no one chemical that will control Bollworms and Armyworms, so proper insect identification is crucial. Luckily, differences between each of these pests are easily identified. If an overspray of Bollgard cotton becomes necessary, special attention must be given to identification of insects and proper recommendations for the insecticide.

**Economics of Bollgard/ Bollgard II Cotton in West Tennessee**

Currently in West Tennessee a grower will pay for Bollgard technology when at purchase. The technology fee is paid to Monsanto as a type of royalty fee. The net cost the farmer pays is about $24 an acre; depending on variety, seed size, and planting rate. For this price the farmer knows the Bollgard gene is working twenty four hours a day seven days a week from emergence until defoliation. In 2002 just over 75% of Tennessee cotton was planted into a Bollgard variety (Williams 2003.) The reason for such a high percentage of Bollgard, or BT, cotton in Tennessee can be seen when looking at the previous years yield losses and the reason for those losses. The Helothin complex, (Bollworm and Budworm) has comprised a large portion of Tennessee’s yield losses over the past five years (Williams 2003.) The only pest that has been close to doing as much damage in Tennessee is the boll weevil. Thanks to the Boll Weevil Eradication program, this insect is no longer of economic concern, aside from eradication fees. Since 1998 the Bollworm/Budworm complex has reduced Tennessee producer’s yield from 0.5 % to almost 6% depending on the year. For a state that has averaged 650 pounds of lint per year; that translates to a reduction of $3 to $39 per acre, not counting control costs, (assumes 60 cent cotton). Over the past five years the reduction in yield has averaged 2.6% or about $17 per acre.

With such a variation in Bollworm/Budworm pressure, many have wondered why producers in Tennessee are planting so many acres using Bollgard varieties. This is not a simple question to answer. Tennessee has not had a major outbreak of Budworms since 1995, however, many producers remember 1995 and the nightmare that pyrethroid resistant Budworms caused. In 1995 Tennessee producers averaged 2.9 applications per acre at a cost of $12/acre per application. In addition to these costs they lost about 10.8% of their yield. These costs, without application fees, add up to about $104.80 per acre. There were fields of cotton in 1995 that were never picked because the worms had left virtually no lint cotton! As a result, many producers decided that Bollgard would be effective insurance against future outbreaks.

Another reason for large scale adoption of BT cotton is associated with yield among varieties. When looking at Tennessee’s variety trials (Gwathmey et al 2003), seven of the top ten yields were from Bollgard or Bollgard/ Roundup Ready varieties. Thus producers feel that in order to achieve high yields they need the plant genetics found in the Bollgard varieties. Tennessee producers believe the insect control of Bollgard and the higher average yields of the Bollgard varieties result in higher profits versus conventional, non-Bollgard, varieties.
Bollgard II varieties are under licensing agreements in much the same manner as Bollgard. The technology fee is paid to Monsanto at seed purchase. The Bollgard II seed currently sell for a net price of about $32 per acre or about $8 per acre more than traditional Bollgard. How can producers justify spending an additional $8 an acre? Bollgard II has the same gene as Bollgard, Cry1Ac, plus an additional gene, Cry2Ab. The addition of the second Bt gene helps in reducing the frequency of oversprays. In Bollgard cotton a typical overspray will consists of a synthetic pyrethroid (Massey 2002.) According to Tennessee yield loss estimates from 2002, 331,000 acres of Bt cotton were treated with at least one over spray application. The typical synthetic pyrethroid application cost $5 per acre for the pesticide, not counting the cost to apply. That translates to about 300,000 acres of the total 480,000 acres of Bt planted or about 62% received an over spray treatment. Additionally, the Bt crop as a whole lost 2.07% of its yield due to the Budworm/Bollworm complex. In 2002 producers harvested an average of 729 pounds of cotton per acre (Kenerson 2003.) If we reduce the 729 pound yield by 2%, at 60 cent cotton the farmer lost just over $22.50 an acre on Bt cotton due to worms. So by looking at 2002 data, it would appear that the purchase of Bollgard II would justify its’ additional cost for worm control.

Insect Resistance Management and Refuge Requirements

The Environmental Protection Agency (EPA) granted conditional registration of the Cry1Ac delta endotoxins from Bacillus thuringiensis subspecies kurstaki and the genetic material necessary for its production in cotton on October 31, 1995 (USEPA 2000.) Because the EPA granted only a conditional registration the Bt gene; it has to be reviewed periodically. Also the EPA required Monsanto (the registrant) to implement an Insect Resistance Management (IRM) program to mitigate the possibility that pest resistance might occur (Matten 2002.) The EPA has enacted these strict requirements on Monsanto due to fears of the public, the government and producers of all crops that insects might eventually mutate and become resistant to the Bt toxin. Should that occur it would not only mean the loss of an effective worm fighting material, it could potentially lead to a widespread crop failure. The objective of a refuge is to maintain a Bt susceptible insect population. In the event, a Bt resistant moth survives and emerges from Bollgard cotton, the adjacent refuge supports a susceptible moth population that can mate with the resistant moth reducing the potential development of a Bt resistant population (Gable et al 2003.)

The EPA has used models developed to predict the estimated time that resistance would develop to compare IRM strategies for Bt crops. Because these predictive models cannot be validated without actual field resistance trials, they have limitations. The information gained from models can only be used as part of the evidence determination conducted by the EPA to assess risks of resistance developing in target pest populations (Matten 2002.)

Before purchasing Bollgard technology cottonseed, a grower must first sign a grower licensing agreement. Among other items, this agreement states that the producer will actively participate in an insect resistance management program (Monsanto 2003a). Monsanto and the EPA have agreed on several different programs that producers may
use. There are three different choices that an individual producer may choose or they could opt for a community refuge program.

The first choice that an individual grower may choose is a 95: 5 external non-sprayed refuge (for every 95 acres of Bollgard cotton 5 acres of non-Bollgard cotton must be planted.) This refuge must be at least 150 feet wide, but preferably 300 feet wide, and cannot be treated with any insecticide recommended for heliothines (Gable at al 2003.) If a grower chooses the 95: 5 option, they must plant the refuge within one-half mile (preferably one-quarter mile or closer) of the Bollgard field (Monsanto 2003b.) A second option could be to plant a 5% embedded refuge. This option allows a grower to plant 95 acres of Bollgard and 5 acres of non-Bollgard in the same field. The non-Bollgard cotton may be sprayed for caterpillar insects as long as the entire field of Bollgard cotton is sprayed at the same time with the same insecticide (Monsanto 2003b.) The major difference between these two options is that with the embedded option the grower will be allowed to treat for worms. With the 5% non-sprayed option that portion of his crop could be lost should caterpillar insects infest the field. The third option is the 80: 20 external spray refuge. This option states that for every 80 acres of Bollgard cotton 20 acres of non-Bollgard cotton must be planted. This refuge plan requires the non-Bt field to be within one mile, preferably one-half mile, of the Bollgard field (Matten 2002.)

The final option is a community refuge plan. This plan allows for multiple growers to manage for external sprayed or unsprayed options or both. It does not allow for the 5% embedded/infield option (Matten 2002.) Under this plan a group of growers could set up a system of planting Bollgard and non-Bollgard fields in such a manner that one grower’s non-Bollgard would serve as another grower’s refuge. The community refuge requirements are quite lengthy in details and for further insight one should refer to 2003 IRM (Insect Resistance Management) Guide published by Monsanto (Monsanto 2003b.) Regardless of which refuge type a grower chooses, they must maintain the refuge site as a viable crop. For example; date planted, use of fertilizer, weed control, irrigation, management of other pests and termination should be the same as with Bollgard cotton. This is to ensure the refuge will produce an adequate number of susceptible insects at the same time as potential resistant insects are being produced in the associated Bollgard cotton (Monsanto 2003b.)

**Worm Species Identification**

Before implementation of an Integrated Pest Management (IPM) program, the farmer must first consider exactly which pests are problematic. Proper insect identification is essential. Although there are numerous insect pests in a cotton field, this study is concerned only with the major caterpillar insects. One particular caterpillar that will not be addressed is the Pink Bollworm, *Pectinophora gossypiella*. This insect is not of economic concern in Tennessee (Bradley 1996.)

The lepidopteran insects that historically infest cotton fields in Tennessee are the Cotton Bollworm, *Helicoverpa zea*, and the Tobacco Budworm, *Heliothis virescens* (Stewart Per. Comm. 2003.) For simplicity, these two pests are often referred to as the heliothine complex (Hopkins et al 2002.) The reasons these two caterpillar pests are referred to as one unit are many. The adults of each species are similar in size, shape, flight patterns and their general coloration. Additionally the eggs and young larva are
very hard to distinguish from each other. Adults of each pest may have similar color phases, but the Budworm has a distinctive tooth on the inside of the mandible. Often a microscope is needed to identify the tooth on the inside of the mandible. A distinctive characteristic of the Budworm moth is the color of her wings. The adult will be green to brown in color and has three dark green and off white bars located diagonally across the front wings (Johnson 1995. pp 24-26.) The Bollworm, a.k.a Corn Ear Worm, moth will have an overall tan appearance, but this species will have a very distinct black dot in the center of the front wing. Each adult lays single eggs that are usually found in the plant terminals, stems or top of leaves, but may be deposited any place on the cotton plant (Johnson 1995. pp 24-26.) The larvae of each pest range in color form light greenish-yellow to reddish-brown.

In order to determine which species is in a given area there are several methods utilized. The farmer or consultant should make visual identification of moths when walking through the cotton field. Although the moths may be similar, they are easily distinguished by the trained eye. Additionally, many states offer a newsletter that gives moth trapping information in specific areas. This trapping data may be used in order to determine if further professional help is needed before making a spray decision. Also one may chose to collect eggs during a “moth flight” and have the eggs tested using a HelioD kit (Sutula et al 1999.) Once the eggs have hatched and small larva are found in a cotton field, the small worms may be collected and taken to a trained entomologist for identification.

One may ask why a producer would go to such extremes to identify which caterpillar pest has infested a field. It must be remembered that insecticides, which are effective in controlling one pest, have often failed at controlling the other. So if a producer knows that the majority of his worm population is Bollworms they may chose to spray a synthetic pyrethroid. If, on the other hand, they have a population of Budworms they will have to chose a different compound. Typically a farmer can control Bollworms for around $5 per acre. Budworm control can cost from $9 to $14 per acre, depending on the chemical and the rate needed for control. If a farmer knows a mixed population of Bollworms and Budworms exists, then they can make the appropriate spray decisions. For the purpose of this research project, all methods of identification were utilized.

When trying to identify other caterpillar pests in Tennessee, one must consider that the Heliothine complex devastates far more acres than all other pests combined. From examination of the Crop Loss Estimates from 1998 through 2002 (Williams 2003), one notes that the Bollworm/Budworm Complex accounted for over 124,000 bales of cotton lost during that time span. All other caterpillar pest combined, during the same time period, account for only 12,000 bales lost. From this information one could deduce that the Bollworm/Budworm Complex accounts for about 10 times the damage of all other caterpillar pests combined.

When looking at other caterpillar insect’s impact on Tennessee cotton production the European Corn Borer (ECB) is third in line, when using the last five years Cotton Insect Loss Estimates (Williams 2003.) Most individuals would consider the ECB to be a corn pest. But this insect has the potential to reduce yields in cotton as well. It should be noted that in 1998, the ECB infestations resulted in an estimated loss of 9,324 bales of cotton in Tennessee. Eliminating the 1998 data gives the ECB an average of only 1.6 bales lost in Tennessee per year. The adult, moth, of the ECB is a pal yellowish brown
Materials and Methods

Plot Design and Variety Placement

For this study a randomized complete block (RCB) design was used. There were three varieties evaluated; DPL 521rr non-Bollgard, DPL 215 BR and DPL 424 Bollgard II. In order to evaluate the efficacy of the Bollgard II two treatments were evaluated. The first treatment would be Bollgard II with no overspray. The second treatment would have an automatic overspray of a synthetic pyrethroid prior to boll maturation. The RCB was initiated assuming four varieties replicated three times across the plot. Once the design was in place the varieties were planted with manual cleanout of the planter between each new variety. One row was skipped between each variety trail in order to eliminate worm movement between plots. All border rows were planted in DPL 451BR. The final plot design, without 451 BR, was as follows; 521,424 sprayed, 215, 424, 215, 424, 424 sprayed, 521, 424 sprayed, 521, 424 and 215. The field in which the plot was planted contained a Grenada Silt Loam soil and all varieties were measured in order to determine each plot’s size in acres. All varieties were planted in a no-till environment on May 26, 2003. Stand counts were taken on June 24, 2003. Each plot had a final stand scout of 2.91 plants per foot of row.

Scouting Procedures

Each plot was scouted weekly after emergence and all plots were scouted separately. Scouting procedures followed guidelines set by the University of Tennessee Extension Service (Stewart and Lentz 2003.) During weekly scouting, all insects were recorded including harmful and beneficial insects. Careful attention was given to identification of lepidopteron pests, including visual sightings of moths, egg lay and larvae.

Spraying Restrictions

After performance of scouting procedures decisions were made each week in order to determine if insects were at threshold levels. If insects were above economic threshold then a spray was administered to the entire research area. Careful attention was given to restrict pesticide chemistry to those that had no effect on lepidopteron insects. The exception to this rule was the overspray of the three Bollgard II plots as discussed earlier.

Yield and Grade Evaluations

Each research plot was harvested on November 4, 2003. Each plot’s weight was recorder in pounds of seed cotton per acre, Monsanto furnished a boll buggy with weigh scales. Plots of like varieties were put into the same cotton trailer to be evaluated for grade. Treatments were compared using a macro for converting mean separation output to letter groupings in Proc Mixed SAS V8.2 (Saxton 1998.)