A CASE FOR THE SUBTHRESHOLD ADVANTAGE OF BOLLGARD COTTON

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Abstract

In making a case for the subthreshold protection that Bollgard cotton provides the cotton grower, several factors require additional consideration and scrutiny based upon the numerous events that have been observed since commercialization in 1995. Though adoption of the Bollgard technology over the past five years has varied across the cotton belt, steady increases in the number of acres planted to the technology either as Bollgard or Bollgard with Roundup Ready have occurred. Bollgard use has increased in many areas that are traditionally low infestation or infrequent spray areas. The higher adoption in these areas is primarily due to enhanced yields realized in a large part due to subthreshold protection. We contend that the subtreshold protection provided by the Bollgard trait has significantly enhanced the per acre economic value (beyond chemical application replacement costs) due to the additional yields which can not be consistently matched with the use of traditional chemistries on nonBollgard cotton. It maybe debated that the sale of products generated from emerging technologies tends in part to initially stem form novel excitement; however, the sale of technologies that lack value tend to quickly decline despite the economic sector in which they occur.

Introduction

Cotton insect management has for years presented a challenge to producers and researchers due to the diversity of pest issues and the potentially greater economic incentive cotton production provides relative to other row crop commodities. Additionally, cotton remains highly vulnerable to insect injury throughout much of the season and in many areas little benefit of beneficial arthropods is permitted due to early season insecticide applications. Beltwide, Bollgard cotton has reduced the number of insecticide applications necessary for the control of the tobacco budworm, *Heliothis virescens*, and the cotton bollworm, *Helicoverpa zea*. Much of the mid-south and lower southeast cotton production areas routinely confront two and at times three generations of budworm and bollworm each year. Often there is poor generational synchrony of the two species and insecticides must be applied for the control of each species independently in non-Bollgard cotton. Infestations from the early and mid-season generations of these pests tend to remain below established treatment thresholds in the more northern cotton production areas. However, significant late season (third generation) infestations can be quite destructive across much of the cotton belt..

Pyrethroids remain the insecticides of choice by producers due to their broad spectrum activity, long residual efficacy, and price. Unfortunately the "hey day" of the pyrethroid class of insecticides has come and gone. No longer do pyrethroids provide satisfactory control of the tobacco budworm or late season plant bug infestations where multiple pyrethroid applications have been made. The crop protection industry has addressed this issue by developing many new insecticides with novel modes of action but very few if any provide the attributes that pyrethroids once offered. There is little debate that Bollgard cotton is yet another novel approach to budworm and bollworm management, however the distinction between Bollgard and foliar applied insecticides is that Bollgard provides greater efficacy (especially against budworm) and continual protection against target pests. It is this continuous protection that is in part responsible for the success of Bollgard whether due to the greater yield potential or risk management attributes recognized by the producer.

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Thresholds and Their Application

There is no question that decision levels based on economics remain the cornerstone of pest management programs. Economic damage has been defined as the amount of injury to the crop which would justify the cost of a control measure. In cotton, injury to the crop maybe defined as the number of insects observed or the number of reproductive structures lost from pest activities. Though these distinctions are often recognized in local thresholds, in practice these values are combined to establish an economic injury level and serve as the basis for treatment decisions. The dilemma is that the destructive capacity of the *Heliothine* complex can reduce profitability even under low infestation levels. Consider an economic example:

Economic Example:

- cotton field with 55,000 plants/acre (4 plants / row foot)
- mean lint / boll = 1 gram
- 1 lb. = 453.6 grams
- $0.65 / lb. lint

Consider the loss of 1 boll / plant / acre ?

55,000 grams / acre ÷ 453.6 grams / lb. = 121.25 lbs injury
121.25 lbs. x $0.65 = $ 78.81 economic loss

Now consider the loss of 0.1 boll / plant / acre ?

55,000 grams / acre x 0.1 = 5,500 lost grams / acre
5,500 grams ÷ 453.6 grams / lb. = 12.13 lbs. injury
12.13 lbs x $0.65 = $7.89 economic loss

This hypothetical example demonstrates that a modest loss of 12.13 lbs of lint could result in economic damage of $7.89. It could be considered that $7.89 would justify a pyrethroid application possibly for bollworm, but an application of many newer and more costly insecticides necessary to control budworm would in theory not be warranted (Figure 1). It is this issue which presents the greatest challenge to crop consultants when thresholds for tobacco budworm are only marginally met. This in turn places even greater emphasis on thresholds due to the cost differential between pyrethroids and newer insecticides. Due to the efficacy of Bollgard against tobacco budworm, the cost differential between pyrtethroids and newer insecticides is less of a concern. Furthermore, the shorter residual and greater selectivity of many newer insecticides will drive producers to tank mix these insecticides with more broad spectrum chemistries or make follow up applications with more broad spectrum chemistries to manage other pest species.

The utility of any economic threshold depends upon the ability to estimate a pest population based on specific sampling criteria. The science providing justification to various sampling criteria are based upon a knowledge of the host / pest biology and aspects of statistics. The practical statistical parameters which influence the value of pest infestation estimates and our ability to make treatment decisions depend on sampling efficiency. Sampling efficiency in turn depends upon a samplers level of accuracy and precision per unit of time. Accuracy by definition is the extent to which a mean generated from a given set of values estimates the total population mean i.e. will the estimated mean describe the actual population. Precision describes the extent to which a given set of values agree with the estimated mean i.e. what is the variability associated with the estimated mean. In the context of sampling efficiency, accuracy and precision tend to be inversely related when the function of time is introduced. Because the amount of time permitted to enact a sampling plan is limited under practical application, field scouts must often sacrifice precision to gain a higher degree of accuracy. Accuracy maybe improved by taking a large number of samples within a field but often considerable variability will be associated with the estimated mean i.e. precision is diminished. In circumstances where pest populations are high, striving for higher accuracy or precision will not tend to produce inaccurate decisions. However to avoid having their producers make inappropriate treatment decisions when pest populations are low (at or below threshold levels), scouts must either improve accuracy by taking a greater number of samples or improve their precision by enhancing the quality of their samples.

To demonstrate these factors, consider three hypothetical fields with random 1, 5, and 10 percent pest infestation levels (Figures 2 - 4). Also, consider a specific path that a scout may follow while sampling a field. If the scout did nothing more than evaluate the presence or absence of a pest on the terminal leaf of a cotton plant, his chances to detect a pests presence would increase as the infestation level increased. As described in the three hypothetical field scenarios, the scout detected 0, 2, and 11 infested plants for the 1, 5, and 10 percent infestation levels, respectively. The problem with this model is that cotton plants are three dimensional which provides caterpillar pests numerous sites to feed and avoid detection (Figure 5). As a result, university reccommendations prescribe sampling a variety of plant parts (squares, flowers, bolls, and terminals) or taking entire plant samples. These sampling reccommendations do increase precision, but accuracy may be reduced because time limits the number of different samples that can be taken.

Heliothine Complex as Pests of Cotton

The Heliothine complex composed of the tobacco budworm and cotton bollworm routinely plague cotton fields throughout most of the traditional cotton belt. The principal host of the tobacco budworm is tobacco, however only a modest amount of tobacco is produced within the cotton belt. In these areas, the tobacco budworm tends not to inflict as serious injury to cotton as it does in the southern United States. The cotton bollworm a.k.a. corn earworm prefers corn as it's primary host. Areas with considerable corn acreage may experience less overall complications from bollworm in cotton during the first and second generations of this pest. However later in the season when corn begins to senesce, it can be considered a nursery crop producing large populations of moths which lay eggs for the third generation of larvae in cotton.

Pheromone traps have provided researchers the ability to detect increases in adult activity. Substantial increases in trap catches tend to correlate well with later populations of Heliotine eggs and/or larvae detected in cotton fields. However, moth flights are not temporally discrete events no matter how significant the flight maybe. Northeast Arkansas like much of the northern cotton belt may average annually 1.5 to 2.0 insecticide applications each season solely targeting the Heliothine complex. Extensive mothflights are generally followed by insecticide applications once thresholds have been exceeded. The dilemma occurs when low to moderate adult activity is observed (Figure 6) and immature populations remain below treatment levels for several days causing accumulated crop injury. This problem maybe exacerbated if previous insecticide applications have disrupted the beneficial arthropod communities that tend to control low level caterpillar pest infestations.

Seasonal insect pest injury evaluations tend to concur with the premise that the subthreshold protection afforded by Bollgard cotton does reduce the level of injury from caterpillar pests. North Carolina pest injury surveys conducted in commercial fields have indicated that Bollgard cotton has annually sustained 50% less injury from the *Heliothine* complex and fall armyworms when compared to conventional fields (Batcheler et al. 1999). Additionally, Layton et al. (1999) indicated that *Bt* cotton fields sustained significantly less caterpillar induced boll damage than non-*Bt* fields (2.55% -vs- 4.81%) and received significantly fewer foliar insecticide treatments for the control of bollworm and tobacco budworm (1.22 -vs- 5.18 applications) in Mississippi. Producers in South Alabama have recognized the reductions in risk and number of insecticide applications (Figure 7) resulting in greater than 75% of the cotton acreage being planted to Bollgard.

Fruit Retention and Yield

Plant mapping has become a valuable research tool for evaluating various management aspects of cotton production. In 2000, Monsanto conducted several 'systems trials' which compared Delta and Pineland 50, 50B, and 50BGII (cryIAc & cryIIAb). These large scale trials were conducted in producer fields from North Carolina to California. Each variety was scouted and managed for caterpillar pests independently. A total of 5460 plants were mapped in these trials, an average of 1820 plants per variety. Insecticides were applied as needed to each variety based on local thresholds. A greater percentage of first position harvestable bolls was observed for both DPL 50B and 50BGII when compared to DPL 50 (Figure 8). Similar trends were observed for second position bolls through sympodia 14 after which DPL 50 attempted to compensate (Figure 9). Additional compensation by DPL 50 was observed on third positions (Figure 10). These data tend to be in agreement with the majority of other data which indicate that Bollgard cotton protects a higher percentage of bolls compared to conventional cotton managed with foliar insecticides.

Economic Comparison Studies

Economic comparison studies comparing Bollgard use measured against conventional cotton managed with traditional or newer chemistries have been extensively reported in the literature (Oppenhuizen et al. 2000). The problem with *proving* subthreshold value in these studies is that no isolines with and without the Bollgard trait exist. Therefore there remains a possibility that yield differentials are due to inherent agronomic differences between the Bollgard variety and the conventional variety. The 5 year averages of the enhanced yields of cotton varieties that contain the Bollgard trait in either Monsanto reported trials or third party trials support the contention that subthreshold protection adds significantly to yield in Bollgard. Lint yield increases with Bollgard cotton averaged from 17 to 129 lbs. across the cotton belt, with an overall average of 40 lbs. more lint across all sites tested. In some years/locations there was a negative return on insect control costs with Bollgard, but enhanced yields in almost every case resulted in an overall net gain with Bollgard use. The yield advantage becomes more consistent when the Bollgard variety is compared with its nearest nonBollgard relative managed with conventional chemistries.

Conclusion

Although a theoretical concept, the case for subtreshold protection adding yield value in Bollgard cotton relative to comparisons with traditional/newer chemical sprays on nonBollgard cotton is supported by the following evidence:

1. Low levels of damage (due to low pest population levels) can accrueover the season to result in significant yield reductions compared to the consistent protection provided by the Bollgard trait.
2. Recognized difficulties in the accuracy/precision of insect sampling under low population conditions resulting in inefficient treatment decisions.
3. Higher treatment costs with newer chemistries that could necessitate higher injury levels to justify treatment.
4. Boll damage surveys that consistently demonstrate fewer damaged bolls with Bollgard compared to conventional cottons managed with traditional/new chemistries.
5. Fruit retention indices that demonstrate higher fruit retention in the primary and secondary fruiting positions in Bollgard cotton (further enhanced with the Bollgard II traits) compared to chemical use on nonBt varieties.

6. Five years of economic comparison studies that show a predominantly positive effect of the Bollgard trait on yields and resulting economics.

Choosing varieties with the appropriate agronomic traits and high yield potential is paramount to the success of any cotton producer. Producers who are considering the use of Bollgard must consider many factors before choosing cotton varieties that contain the Bollgard trait. Although factors such as environmental benefits (less insecticide use), risk avoidance (budworm cost control), and ease of management (peace of mind) weigh in favor of the Bollgard technology, the per acre economic potential must be considered to fully justify the technology fee. We contend that the per acre economic value of Bollgard extends beyond the simple replacement costs of insecticide use but must also include the consideration that the subthreshold control advantage will contribute to higher yields and better overall economics with Bollgard cottons.

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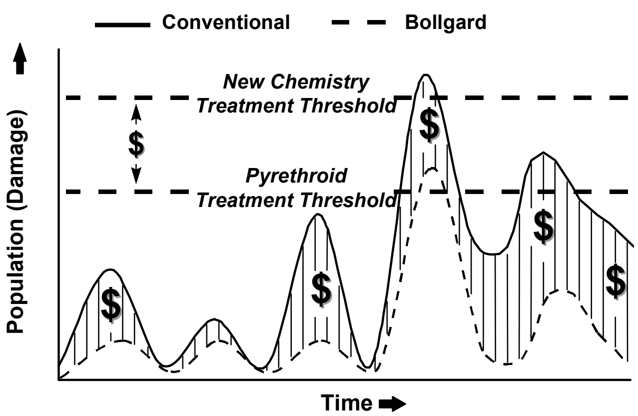

Figure 1. Example of cost differential between pyrethroid and new insecticide chemistries for use in cotton and the subtreshold advantage provided by Bollgard cotton relative to conventional cotton.

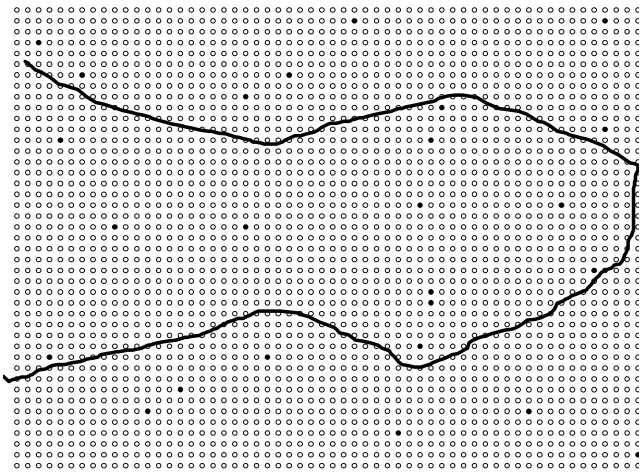

Figure 2. Hypothetical field (n= 2494 plants) where sampling path fails to discover an infested plant with field at a 1% infestation level ●= infested o = uninfested.

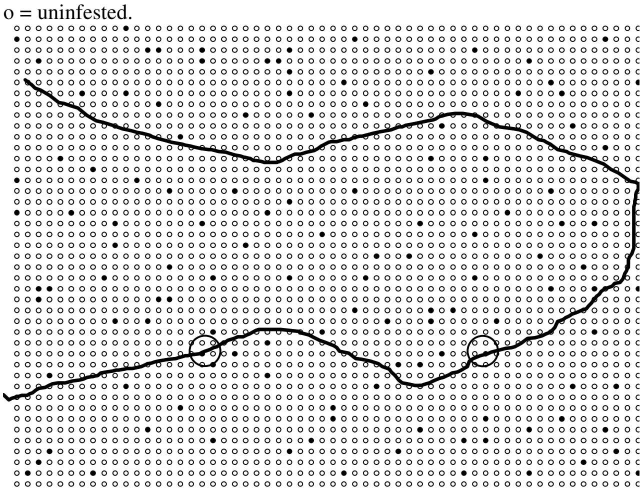

Figure 3. Hypothetical field (n= 2494 plants) where sampling discovers 2 infested plants with field at a 5% infestation level ●= infested o = uninfested.

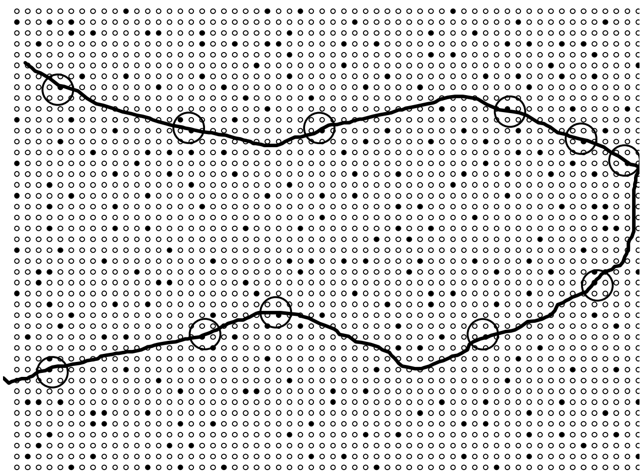

Figure 4. Hypothetical field (n= 2494 plants) where sampling discovers 11 infested plants with field at a 10% infestation level ●= infested o = uninfested.

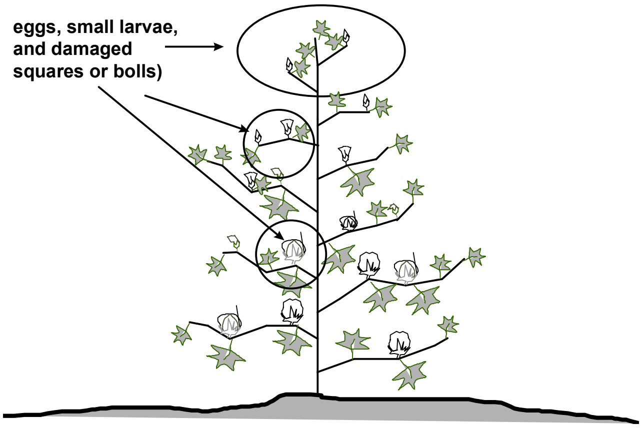

Figure 5. The cotton plant is 3 dimensional with numerous sites for pests to feed and avoid detection.

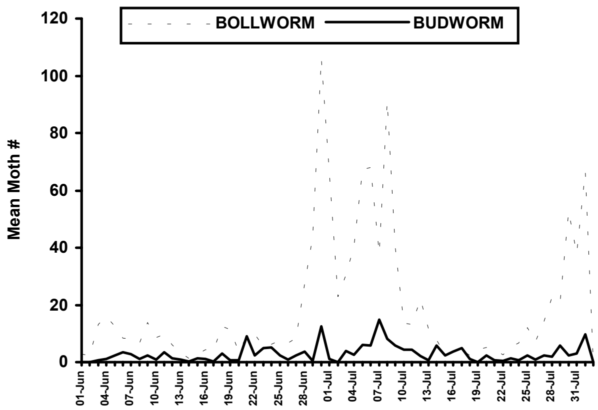

Figure 6. 1999 Northeast Arkansas pheromone moth trap data for cotton bollworm and tobacco budworm.

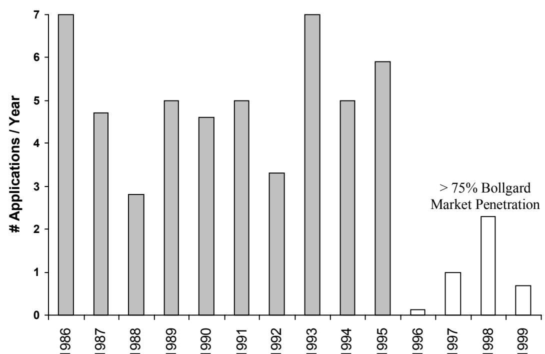

Figure 7. Number of tobacco budworm and cotton bollworm insecticide applications in south Alabama 1986-1999.

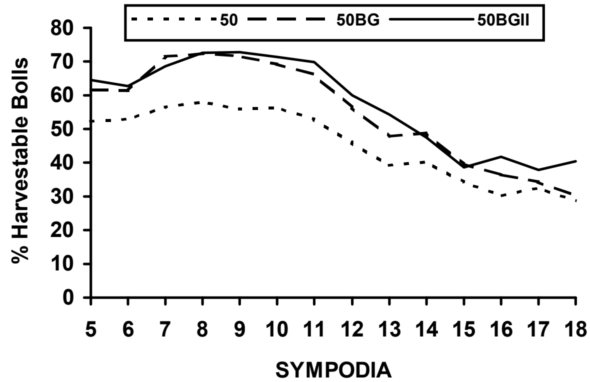

Figure 8. Comparison of Delta and Pineland 50, 50B, and 50BGII percent harvestable first position bolls among 32 field trials conducted across the cotton belt. Each variety managed independently for caterpillar pests according to local recommendations.

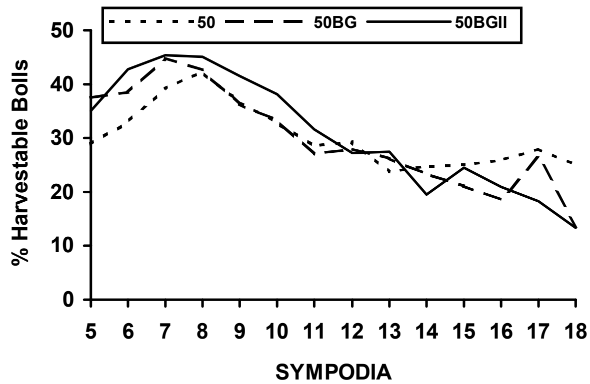

Figure 9. Comparison of Delta and Pineland 50, 50B, and 50BGII percent harvestable second position bolls among 32 field trials conducted across the cotton belt. Each variety managed independently for caterpillar pests according to local recommendations.

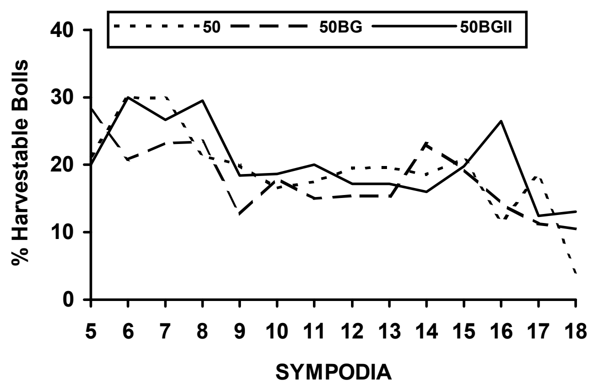

Figure 10. Comparison of Delta and Pineland 50, 50B, and 50BGII percent harvestable third position bolls among 32 field trials conducted across the cotton belt. Each variety managed independently for caterpillar pests according to local recommendations.