Dynamic Stink Bug Thresholds in the Southeast: Conception to Delivery

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Proceedings, 2007 Beltwide Cotton Beltwide Cotton Conferences

Abstract

In 2004, 2005 and 2006, a series of 14 total replicated "progressive spray" tests was conducted in NC, SC and GA, eight in NC, 2 in SC and 4 in GA. The purpose these small plot tests was to obtain information about the relationship between a range of spray protection levels for sucking bugs (primarily stink bugs), and its influence on boll damage, cotton yields and fiber quality. To minimize the possible confounding effect of caterpillar damage, all tests were planted to a Bollgard II cotton variety. Each test consisted of 6 to 12 rows by 50 to 100 ft with four replicates, with initial sprays beginning just after at anthesis. This "most protected" treatment was sprayed weekly until the season's end, and most often received seven applications of a high rate of dicrotophos (Bidrin 8E @ 0.5 lb. ai/acre) plus the highest rate of a pyrethroid (usually Baythroid 2E @ 0.04 lb. ai/acre). The next treatment was started one week later and protected for the remainder of the season, the third a week later, and so on. In most tests, weekly data were taken on square retention, percentage of dirty blooms, ground cloth sampling for all bug species and stages, internal damage to quarter-sized bolls, damage to bolls just prior to harvest, various measurements of boll diameters (an index of overall crop/boll development), yield and quality. In NC, green, *Acrosternum hilare* (Say) and brown stink bugs, *Euschistus servus* (Say), predominated, with greens more common; in SC, green and southern green, *Nezara veridula* (L.) and green stink bugs were present in approximately equal numbers with fewer brown stink bugs; in GA, southern green stink bugs, were overwhelmingly the dominant species with some brown stink bugs also present. Plant bugs, *Lygus lineolaris* (Palisot de Beauvois), added only minimally to the boll damage at most sites, with tests showing both low dirty bloom levels and low numbers of plant bugs captured with ground cloths. Additionally, most sites showed high square retention rates during the first 5 weeks of blooming. The relationship between quarter-sized boll damage and yield was extremely variable between tests, varying from a low of -0.6 lb. lint per 1% seasonal quarter-sized boll damage (higher yield loss in the weekly sprayed treatment than in the unsprayed treatment) in the 2006 Scotland County, NC site to a high of 14 lb. of lint per 1% seasonal quarter-sized damage in Tift County, GA in 2005. Protection from bug damage during the first 2 weeks of blooming appeared to have little impact on yields, while protection between weeks three, four, and five showed a major positive impact on yield. These findings suggest that high internal boll damage thresholds could be used both early and later in the season, thus avoiding unneeded sprays.

Introduction

Boll weevil eradication and *B.t.* cottons are responsible for the current "low insecticide spray environment" that exists on over 90% of the cotton acreage across the southeast (Williams, 2007). Stink bugs, and to a variable degree plant bugs, now are present at much higher and more damaging levels on cotton, have become major pests in a relatively short time, and appear to be expanding their populations. Bugs can cause significant yield losses and reduce cotton lint quality (Barbour, et al. 1990, Bundy, et al. 1999, Greene and Herzog 2001, Willrich et al. 2003, Emfinger et al. 2004). Indeed, bugs are believed to be a possible factor in Georgia's recent "poor quality cotton problem" and have led some cotton mills to reject lint grown in that state (Phillip Roberts, pers. com.). Additionally, insecticide use for stink bugs in GA has gone up dramatically (Fig. 1) (Williams 2005). In North Carolina in 2004, stink bug damage to bolls in a large random sample of producer-managed Bollgard cotton fields revealed a mean damage level five-fold higher than the average of the previous 8 years (Bacheler and Mott, 2005)(Fig. 2). New advanced *B.t.* cottons (e.g. Bollgard II® and WideStrike®) will require very little insecticide treatment for caterpillars, further increasing the potential damage from this complex of bugs. In recognition of the seriousness of this problem and to foster cooperation between scientists in the respective states, in 2005 Cotton Incorporated began funding a project entitled "Identifying Practical Knowledge and Solutions for Managing the Sucking-Bug Complex in Cotton: Research in the Southeast Region" through the Southeast Regional State Support Committee. One of the subprojects of this grant is gaining a better appreciation of how cotton plant phenology and various degrees of protection from bug damage impact cotton's susceptibility to the sucking bug complex as measured by yield and quality. A series of 14 studies, one in 2004, seven 2005, and six in 2006 were conducted in NC, SC and GA to better understand the nature of these relationships. In initial work presented in 2006 from NC and GA, evidence from 8 tests suggested that damage to quarter-sized bolls both early and late in the bloom could be raised with no loss in yield (Bacheler, et al, 2006). Validation of these findings was continued in 2006 and expanded work into SC.

Methods

Fourteen replicated small plot tests were conducted in NC, SC and GA from 2004 to 2006. In NC, one test was conducted in Wayne County in 2004, five additional tests were carried out in 2005 in Edgecombe, Wayne, Scotland, Union, and Perquimans counties, and two were added in 2006 in Wayne and Scotland Counties (Fig. 3). In SC, two tests were carried out in Barnwell County. In GA, two tests were carried out in Tift County in 2005 and two additional tests were conducted in, one each in Tift and Moultrie counties, in 2006. To minimize the potential confounding effect of caterpillar damage, all tests were planted to a BG2 cotton variety (Table 1). Each test was composed of 50 to 100 ft. rows of 6 to 12 rows per plot in a randomized complete block design with 4 replications. Tests had eight treatments (Fig. 4). Most sprays were with a tank mix of dicrotophos (Bidrin at 0.5 lb. active per acre) plus the highest labeled rate of a pyrethroid, most often Baythroid 2E @ 0.04 lb. ai/acre. Each treatment represented a different degree of "protection". The initial "most protected" treatment began just after anthesis, and was sprayed weekly until the season's end, and most often received seven applications. The next treatment was started one week later and protected for the remainder of the season; the third a week later, and so on.

The following data were taken (with the number of tests this data were taken in parentheses). A schematic of the data taken at each site is provided (Table 1).

<u>Species composition</u> (Cadaver counts – 7 tests; ground cloth samples – 13 tests) - Assessments for species composition (mostly green, southern green and brown stink bugs) were taken 2-3 days behind each progressive spray treatment (one per week) by counting all stink bug cadavers on the ground between the middle two to four rows in each recently spray plot (400 to 800 row-ft total). This assessment was conducted by crawling. Drop cloth samples were also added to the above cadaver counts to help estimate species composition.

<u>Drop cloth sampling</u> (13 tests)- Beginning at first bloom, and just prior to spraying the next treatment, two drop cloth samples (6 feet/sample) per plot were taken in each replicate (48 row-feet total) from an untreated check. All plant bug and stink bug adults and nymphs were identified and counted.

<u>Plant bug-damaged squares</u> (11 tests) - The presence or absence (missing position) of 25 small terminal squares per plot (100 squares per test) was assessed weekly in the untreated plots to be treated next. Yellowish to blackened squares were counted as missing positions. One terminal square and a non-terminal square in an upper node with a total length of 1/8 inch, or greater, or its missing position was assessed.

<u>Dirty blooms</u> (13 tests) - Twenty-five blooms per plot (100 test) were evaluated weekly for presence of dirty blooms from a check plot as an additional measure of plant bug activity.

<u>Boll size at 3.5 weeks</u> (6 tests) - At anthesis, approximately 12 to 15 randomly selected white blooms from four of the protected plots (approx. 50 bolls total) was tagged and the largest outside diameters of 10 bolls per plot were measured with a digital caliper 3.5 weeks later to provide a comparison of boll growth rates between test sites. Three and one half weeks is generally regarded as the time beyond which a boll is "safe" from economic damage from stink bugs (Greene and Herzog 2001). At some locations, 50 additional white blooms were also tagged at 3 and 5 weeks after initial anthesis to gain an appreciation for growth rates of bolls derived later blooms.

<u>Boll diameters</u> (13 tests) - Beginning at bloom initiation in the most protected plots, the largest outside diameters of the first 25 bolls encountered were measured with digital calipers, beginning approximately 10 ft. into each plot, in each of the 4 replicates (100 bolls/week from the same plot). Each of the 4 starting points per plot was marked with a wire/plastic flag, and the distance required to obtain the 25 bolls was recorded. This provided an estimate of the number of bolls/acre of various sizes (and an indication of the level of bug-susceptible bolls over time). The same flagged starting point was used for the subsequent weekly "25-boll distance" counts from the same most protected plot (the end flag changed weekly).

Checklist of data taken by location (Y- data taken; N- data not taken; P- data partially taken)

Data	04NCW	05NCE	05NCW	05NCS	05NCU	05NCP	05GAPR	05GAJR	06NCW	06NCS	06SCF	06SCE	06GAL	06GAE
Square retention	N	Y	Y	Y	Y	N	Y	N	Y	Y	Y	Y	Y	Y
Dirty bloom counts	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y
Beat cloth samples	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Damaged quarter-sized bolls	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Size of bolls @ 3.5 weeks/ 1 week tag	N	Y	Y	N	Y	Y	Y	N	Y	Y	Y	Y	N	N
Size of bolls @ 3.5 weeks/ 2 week tag	N	Y	N	N	N	N	N	N	N	N	N	N	N	N
Size of bolls @ 3.5 weeks/ 3 week tag	N	Y	Y	N	N	N	Y	N	N	Y	Y	Y	N	N
Size of bolls @ 3.5 weeks/ 5 week tag	N	Y	Y	N	N	N	Y	N	N	Y	N	N	N	N
Cadaver counts	P	Y	Y	Y	Y	N	Y	1 Time	Y	Y	N	N	N	N
Boll sizes in most protected plot	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y
Row length/ 25 bolls	N	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y
Final boll damage	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y
Yields	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Variety	DP 960 BG II R	DP 969 BG II R	DP 960 BG II R	DP 543 BG II R	DP 444 BG II R	ST4646 B2R	DP 543 BGII R	DP 424 BGII R	DP 960 BG II R	DP543 BGII R	DP 164 B2RF	DP 117 B2RF	DP 543 BG2RR	DP 543 BG2RR
Plot size # rows x length	6 x 50 ft	6 x 50 ft	6 x 50 ft	6 x 50 ft	6 x 50 ft	8 x 75 ft	6 x 50 ft	6 x 90 ft	6 x 50 ft	6 x 50 ft	12x75 ft	12x75 ft	12x75 ft	12x75 ft
Notes: planting date, Rows picked & Surrounding vegetation	May 10 Center 2 rows. Cotton & soybean	May 11 Center 2 rows. Corn.	May 11 Center 2 rows. Wheat early, cotton late.	May 9 Center 2 rows. Corn and cotton	June 3 Center 2 rows. Cotton.	May 12 Hand-picked 17 ft./. Cotton and corn field.	May 19 Center 4 rows. Large peanut field.	May 19 Center 2 rows. Peanuts 6 rows on each side.	May 3 Center 2 rows. Cotton & Peanuts.	May 6 Center 2 rows. Cotton.	May 12 Center 4 rows. Inter-planted with soybean	June 7 Center 4 rows. Cotton, Inter-planted with soybean	May 8 Center 2 rows. Peanuts.	May 4 Center 2 rows. Cotton.

<u>Locations</u>: 04NCW- 2004 Wayne Co., NC; 05NCE - 2005 Edgecombe Co., NC; 05NCW - 2005 Wayne Co., NC; 05NCS - 2005 Scotland Co., NC; 05NCU - 2005 Union Co., NC; 05NCP - 2005 Perquimans Co., NC; 05GAPR - 2005 Tift Co., GA (P. Roberts); 05GAJR - 2005 Tift Co., GA (J. Ruberson); 06NCW - 2006 Wayne Co., NC; 06NCS - 2006 Scotland Co., NC; 06SCF - 2006 Blackville, SC (early planted); 06SCE - 2006 Blackville, SC (late planted); 06GAL – 2006 Tifton Co., GA (P. Roberts); 06GAE – 2006 Moutre Co., GA (P. Roberts);

<u>Quarter-sized boll damage assessments</u> (13 tests) - Twenty-five quarter-sized bolls/plot (100 per test) were evaluated weekly for internal and external damage from an untreated check. In most tests, they were stratified into the following categories: no damage, external damage, internal warts only, stained lint only and warts plus stained lint. Each of the phased in treatments constituted the plot from which the damage assessments were made just prior to that treatment's initial application. Thus, the assessments provided a weekly measure of the bug pressure in an untreated situation.

Year-end boll damage assessments (13 tests) - Just prior to boll opening, 25 randomly selected bolls/plot (100/treatment) were assessed for damage Four hundred bolls per treatment were assessed in the 05 GA1 test. These bolls were selected from rows adjacent to the middle two harvest rows. In most tests each boll was evaluated separately for: no internal damage, internal warts only, stained lint only, and stained lint plus internal warts. A boll was scored as damaged overall if it showed a wart(s), stain, or both. The picked bolls were either evaluated in the field, or more often were placed into labeled bags and taken to a lab or other indoor facility for the damage assessments. In most cases, the bolls were frozen for subsequent assessments. The bolls were then later thawed prior to the damage assessments. This approach did not appear to compromise the boll damage evaluations.

Yield and fiber quality assessments (14 tests) - Cotton yields were harvested from the middle 2 rows of each plot with a mechanical harvester (except at the 05PQ location), weighed, stored, and transported to the research microgin in Tifton, GA to be ginned under "real world" ginning conditions prior to fiber analyses. Fiber samples were sent to the Cotton Incorporated facility in Cary, NC for analyses. As of this Jan 20, 2007 writing, the harvested seed cotton from the 2007 tests has been weighed and taken to the research gin. Therefore, yield adjustments based on gin turnout for the various treatments have not yet been made, and well as fiber quality parameters.

Results

Species composition- The proportion of green, southern green and brown stink bugs is shown in Figure 5. In NC, green, *Acrosternum hilare* (Say), and brown stink bugs, *Euschistus servus* (Say), predominated, with greens more common; in SC, green and southern green, *Nezara veridula* (L.) and green stink bugs were present in approximately equal numbers with fewer brown stink bugs; in GA, southern green stink bugs, were overwhelmingly the dominant species with some brown stink bugs also present. In NC we seldom see the association of green stink bugs moving in high numbers from peanut into cotton, as is often the case with southern green stink bug in GA (Phillip Roberts, pers. com.).

Drop cloth sampling- At the 13 test sites at which drop cloth samples were taken, plant bug levels (adults plus nymphs), with the exception of Scotland County in 2006, were less than 0.5 per row foot, far less than any state threshold (Fig. 6).

Plant bug-damaged squares- The average retention of upper squares was extremely high, especially given that these assessments were taken during the first 5 weeks of bloom (Fig. 7). As expected, but not shown in this figure, the retention of small squares dropped dramatically after the fifth to sixth week of blooming.

Dirty bloom assessments- Of the 13 locations assessed, the mean percentage of "dirty blooms" was generally very low, again demonstrating that plant bug damage was a contributor to overall bug damage at these locations during the 2004 to 2006 test period (Fig. 8).

Boll size at 3.5 weeks and boll diameters- Although extensive measurements of 3.5 week old bolls were taken from flowers tagged at 1, 2 and 3 weeks of anthesis in six tests, these data are not included herein. Also, the weekly measurements of the first 25 bolls per plot in the most protected plots in recorded row lengths are not presented in this paper. Because this data file was so large and will be collected again in 2007, a complete presentation of this data and its implications in bug management will be presented in 2008.

Figure 9 provides a schematic of the relationship between bolls with a diameter and lack of internal damage, despite evidence of stink bug damage to the outer carpal wall (Fig. 10).

Cotton crop phenology vs. stink bug thresholds - Figures 11 to 14 show the variability in the time at which different cotton fields (ie., locations and years) may take in the time at which the average boll size reaches a "bug size" diameter of approximately 1.25 inches. In Figures 11 and 12, the test sites in Wayne and Scotland counties (2005) were very slow to develop an average boll size of f greater than 1.25 inches, while in Wayne (2004) and in Barnwell (2006) counties, the mean boll size reached the 1.25 inch diameter, "bug safe" stage by the 5^{th} or 6^{th} week of bloom (Figs. 13 and 14 respectively). At the latter two test sites, presumably the threshold could be doubled earlier in the season (by the 5^{th} or 6^{th} week of bloom) by recognizing when half of the bolls were no longer susceptible to boll damage. The stink bug threshold could then be raised further as the crop progressed further toward threshold.

Yield loss of stink bug vs. bollworm damage to bolls – When year end internal boll damage from stink bugs was averaged over all tests and the yield loss per 1% boll damage was compared with that of bollworm damaged bolls, the lint loss per 1% stink bug damaged bolls was 4.3%, while the loss per 1% boll damage for bollworms averaged 12.4% (Fig. 15). This difference was probably due to the variable nature of stink bug damaged bolls (some bolls with minimal damage ranging to other completely damaged with no harvestable locks), while in most cases with bollworms, the locks are completely damaged. However, with stink bugs, we also found significant variation between tests, probably due to a number of factors, such as degree of damage from one test to the next, the degree of plant compensation after initial bug damage, different species composition, and other factors influencing the relationship between damage and yield loss.

Damage to quarter-sized boll and yield - These tests also showed that the relationship between damage to quarter-sized bolls sometimes extremely variable (Fig. 16). For example, in Wayne County, NC in 2004, seasonally quarter-size boll damage averaging approximately 40% accounted for a 495 lb. lint decrease (protected vs. unprotected); likewise in Tift County, GA, quarter-size boll damage averaging approximately 35% accounted for a 762 lb. lint decrease (protected vs. unprotected). However, in Union County in 2005 and in Scotland County in 2006, seasonal quarter-sized boll damage in the 30% range resulted in a yield differences of 8 and -15% lb. lint/acre, respectively (protected vs. unprotected).

Early boll damage vs. yields - Averaged over 14 tests, protection against stink bug damage during the initial 2 two weeks of blooming did not result in a yield increase (Fig. 18), while protection during the 3-5 week period after anthesis appeared critical. Additionally, yield losses later in the bloom period appeared minimal, in keeping with the increasing preponderance of larger, bug safe bolls.

Conclusions

The above series of 14 tests represents the second of a three-year study and, as such will encompass additional locations, different agronomic conditions, and different stink bug and plant bug pressure in 2007. Also, a significant amount of the data taken in this test, such as the boll diameter information, the post-gin adjusted yields, and the impact of bug damage on various quality parameters, is still forthcoming. Finally, our data will be integrated with that of the other studies conducted under this regional grant. Conclusions made based on these 2005 and 2006 tests should be still be considered preliminary.

These data are strongly suggestive that higher stink bug thresholds may be justified both early and late in the bloom period, with the initial two weeks of bloom appearing safe from yield loss in all 14 tests, and later bloom period raising of stink bug threshold based on the presence of a significant levels of 3.5 week, bug safe bolls, as shown in the schematic in Figure 19. However, these results while encouraging, await further evaluation and additional threshold verification trials. A series of threshold tests carried out in 2006 in NC, SC and GA appeared to be in line with the results reported herein (Green, et al. 2007).

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Acknowledgement

The authors would like to express their appreciation to Cotton Incorporated and to the Southeast Regional State Support Committee for funding this regional project.

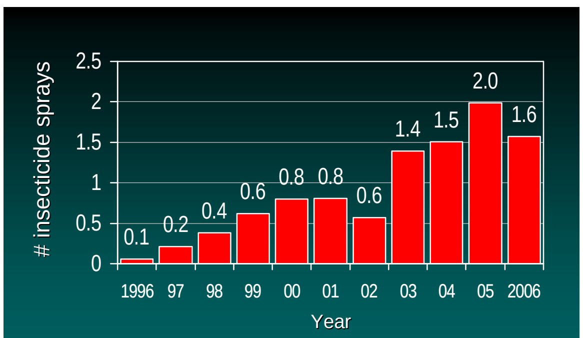

Fig. 1. Stink bug insecticide sprays on cotton in Georgia, 1996 - 2006.

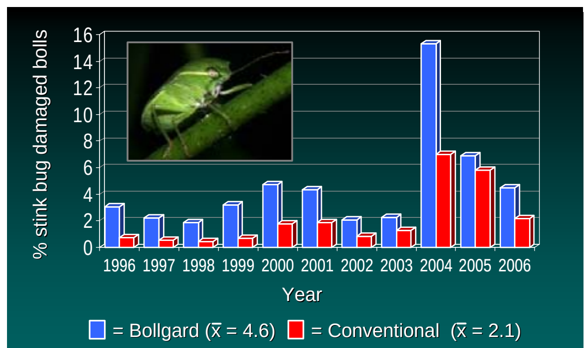

Fig. 2. Bollgard vs. conventional cotton: bug damage to bolls in North Carolina, 1996-2006.

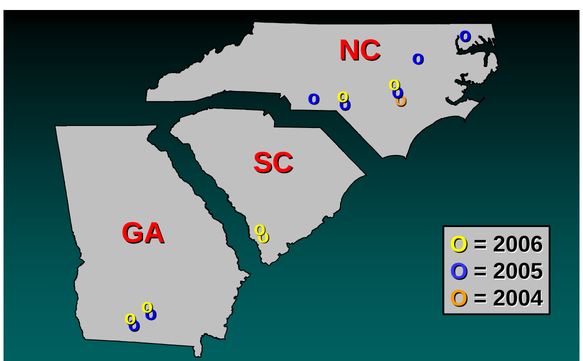

Fig. 3. Tests locations, North Carolina, South Carolina, and Georgia, 2004 to 2006.

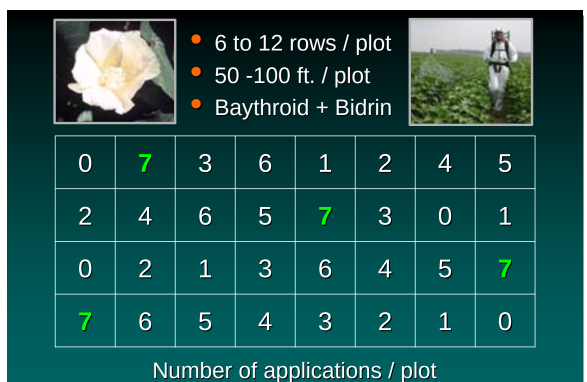

Fig. 4. Diagram of progressive spray tests.

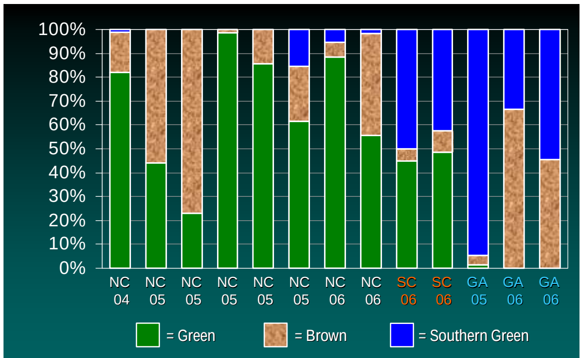

Fig. 5. Proportion of green, brown and southern green stink bugs at test locations, 2004-2006.

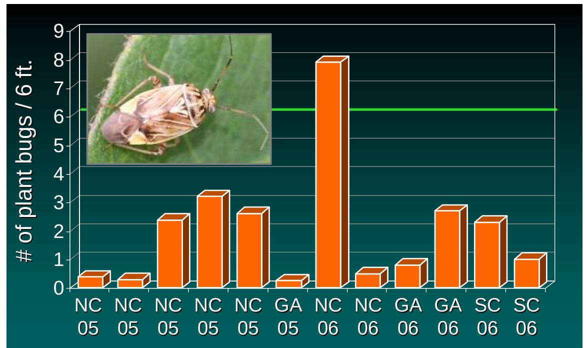

Fig. 6. Seasonal mean number of plant bugs / 6 row ft., 2005 - 2006.

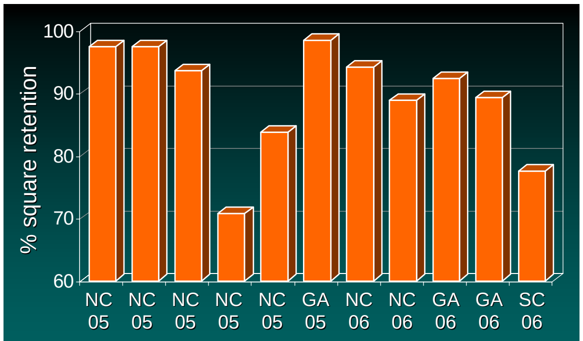

Fig. 7. Seasonal means of upper squares retention for 1st 5 wks of blooming, 2005-2006.

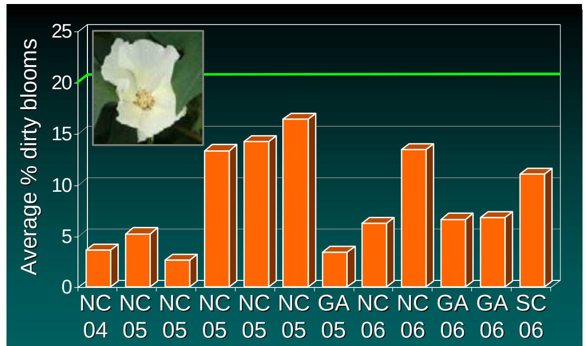

Fig. 8. Mean percent dirty blooms, first five weeks of blooming in check, 2004 - 2006.

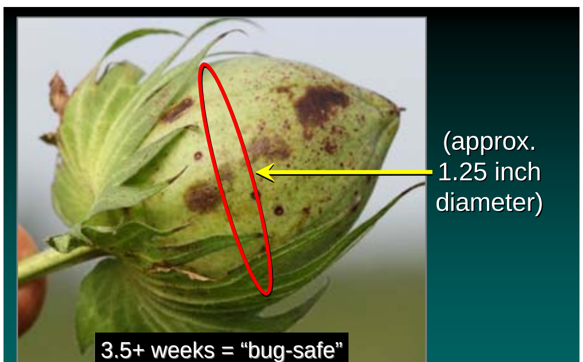

Fig. 9. Boll at 3.5+ week safe stage has outer diameter of approximately 1.25 inches.

Fig. 10. Cut away of fig. 9 boll showing lack of injury.

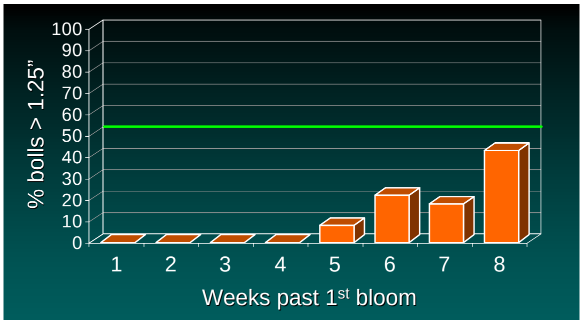

Fig. 11. Percentage of bolls with diameters of more than 1.25 inches per week of blooming, Wayne Co., NC, 2005.

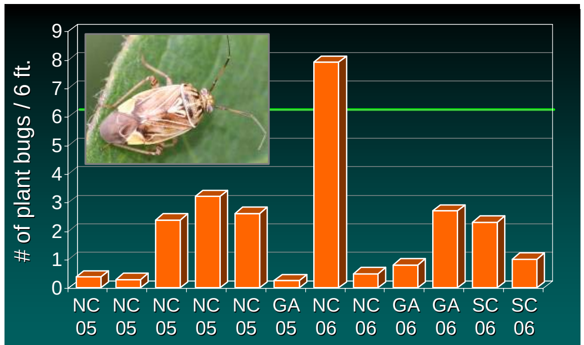

Fig. 6. Seasonal mean number of plant bugs / 6 row ft., 2005 - 2006.

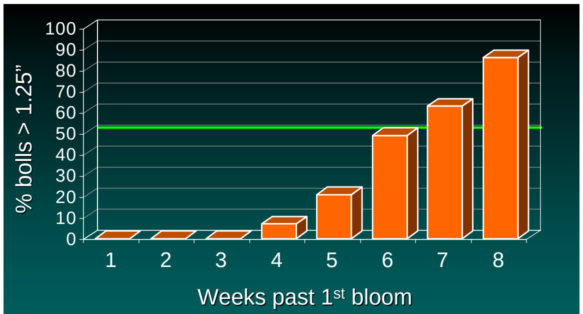

Fig. 13. Percentage of bolls with diameters of more than 1.25 inches per week of blooming, Wayne Co., NC, 2004.

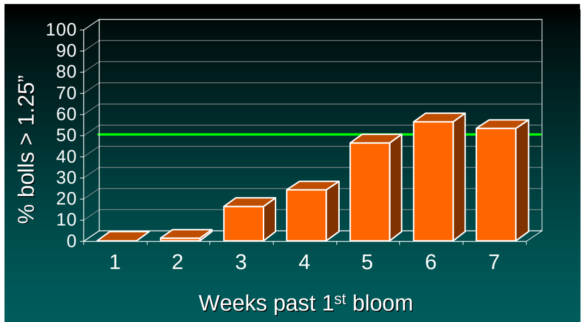

Fig. 14. Percentage of bolls with diameters of more than 1.25 inches per week of blooming, Barnwell Co., SC, 2006.

Lb. lint lost / 1% boll damage	Average
Bollworm	12.4
Stink bug	4.6

Fig. 15. Bollworm and stink bug damage to bolls vs. yield loss in North Carolina (n = 10 and 13 tests, respectively).

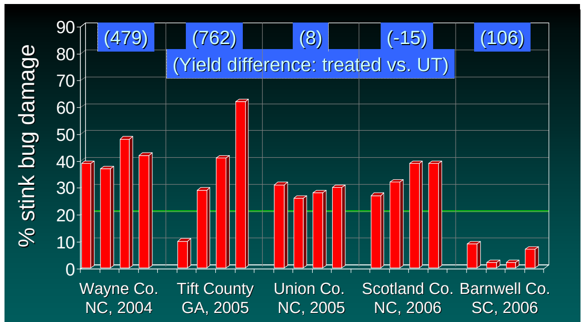

Fig. 16. Stink bug damage to quarter-sized bolls vs. yield loss, 2005 - 2006.

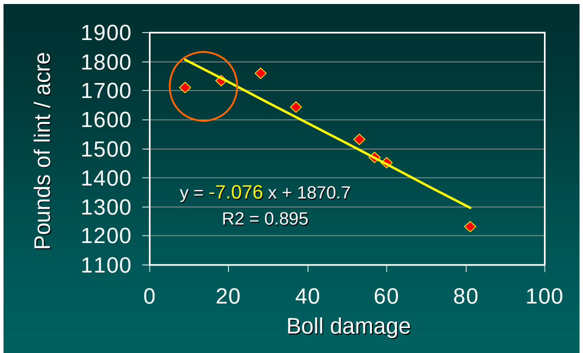

Fig. 17. Stink bug damage to bolls vs. yield Wayne Co., NC, 2004.

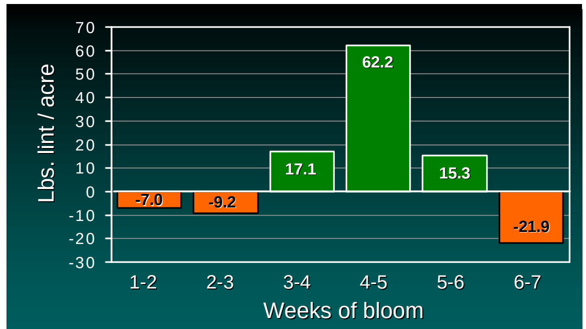

Fig. 18. Yield change from spray protection at different internal intervals during the bloom period, 2004-2006 (n = 14 tests).

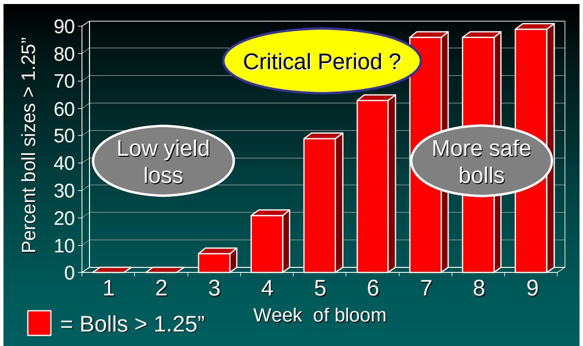

Fig. 19. Rationale for employing dynamic stink bug thresholds.