

USE OF THE DYNAMIC THRESHOLD FOR STINK BUG MANAGEMENT IN THE SOUTHEAST

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Abstract

From 2004 through 2008, a series of 19 replicated “progressive spray” tests was conducted in NC, SC and in GA; 9 in NC, 4 in SC and 6 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 effects 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 4 replicates, with initial sprays beginning just after at anthesis. The “most protected” treatment was sprayed weekly until cutout, most often six or seven applications of a medium to high rate of dicofol (Dicofol 8E @ 0.3 to 0.5 lb. ai/acre) plus a medium to high rate of a pyrethroid (usually Baythroid 2E @ 0.03 to 0.04 lb. ai/acre). The subsequent 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 viridula* (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, but few green stink bugs. Plant bugs, *Lygus lineolaris* (Palisot de Beauvois), added only minimally to the boll damage at most sites, with tests showing 1) low dirty bloom levels, 2) low numbers of plant bugs captured with ground cloth sampling, and 3) high square retention during the initial 5 weeks of blooming. Protection from bug damage during the first 2 weeks of blooming appeared to have little or no impact on yields, while protection between weeks 3 to 5 or 6 weeks of blooming showed a major positive impact on yield, and protection after the susceptible 3 to 5 week bloom period showed little return on investment. These findings further

confirm the use of a dynamic threshold that utilizes higher thresholds both early and late in the bloom. Threshold evaluations undertaken from 2005 to 2008 confirmed that a 50, 30, 10, 10, 10, 30, 30 50% dynamic threshold (by week of bloom) returned greater profits when compared to other static thresholds (such as 10, 20 and 30%) under various stink bug population densities.

Introduction

Boll weevil eradication and *B.t.* cottons are largely responsible for the current “low insecticide spray environment” that exists on over 90% of the cotton acreage across the southeast (Williams, 2007). Stink bugs are now able to exist at higher and more damaging levels on cotton, have become major pests in a relatively short time, and appear to be expanding their populations. Stink 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, in fact, poor grades 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 (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). New advanced *B.t.* cottons (e.g. Bollgard II® and WideStrike®) will require very little insecticide treatment for caterpillars, further worsening 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 several sub-projects of this grant is gaining a better appreciation of how cotton plant phenology and various degrees of protection impact it’s susceptibility to the sucking bug complex as measured by yield and quality. A series of 19 studies, one in 2004, and the remainder in 2005 through 2008 (Table 1) were conducted in NC, SC and GA to better understand the nature of these relationships. In initial work presented in 2006 in NC and GA, evidence from 8 tests suggested that damage to quarter-sized bolls both early and late in the bloom could be raised significantly with no loss in yield (Bacheler, et al, 2006). Validation of these findings was carried out with a series of additional studies which also expanded this work into SC. Herein we report the results of the combined studies.

Materials and Methods

Nineteen replicated small plot tests were conducted in NC, SC and GA from 2004 to 2008, as indicated in Table 1 and in Figure 1. To minimize the potential confounding effect of caterpillar damage, all tests were planted to a BG2 cotton variety, also shown in Table 1. Each test contained 6 to 12 rows plots of 50 to 100 ft. in length arranged in a randomized complete block design with 4 replications (Figure 2). Tests had eight treatments. Most sprays were with a tank mix of dicofthos (Bidrin at 0.5 lb. active per acre) plus a medium to high rate of a pyrethroid, most often Baythroid 2E @ 0.04 lb. ai/acre (Figure 2). 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 6 or 7 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 from which this data was taken in parentheses). A table of the data taken at each site also provided in Table 1.

Cadaver counts (8 tests)

Assessments for species composition determination (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 a 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 determine species composition.

Drop cloth sampling (18 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.

Square retention (16 tests)

The presence or absence (missing position) of 25 small terminal squares per plot 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, were assessed.

Dirty blooms (17 tests)

Twenty-five blooms per plot (100 treatment) were evaluated weekly for presence of dirty blooms from a check plot as an additional measure of plant bug activity.

Boll size at 3.5 weeks (variable number of tests depending on data taken)

At anthesis, approximately 12 to 15 randomly selected white blooms from four of the protected plots (approx. 50 bolls total) were 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 from later blooms.

Boll size (17)

Beginning at bloom initiation in the most protected plots, boll sizes (the largest outside diameters) of the first 25 consecutive 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 were measured). 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).

Quarter-sized boll damage assessments (19)

Twenty-five quarter-sized bolls/plot (100/treatment) 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. In the reporting of the results, however, a boll was considered damaged if it had either internal stained lint or at least one wart on the internal carpal wall. Each of the phased in treatments constituted the plot from which the damaged 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 (14)

Just prior to boll opening, 25-50 randomly selected bolls/plot (100 to 200/treatment) were assessed for damage. These bolls were selected from rows adjacent to the middle two harvest rows. Each boll was evaluated separately for: no internal damage, internal warts only, stained lint only, and stained lint plus internal warts. However, as was the case with quarter-sized bolls, a boll was considered damaged if it had either internal stained lint or at least one wart on the internal carpal wall. 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 following freezing of the bolls. The bolls were then later thawed prior to the damage assessments. This approach did not appear to compromise the accuracy of the boll damage evaluations.

Yield and fiber quality assessments (19)

Cotton yields were harvested from the middle 2 rows of each plot with a mechanical harvester (except at the 05PQ location which was hand picked), weighed, stored, and most samples 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. All of the cotton fiber quality results are being published separately (Phillip Roberts, personnel communication). Additionally, yield adjustments based on gin turnout have not yet been added to the results reported herein.

Results

Species composition

The proportion of green, southern green and brown stink bugs is shown in Figure 3. 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 viridula* (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. A small number of other species were also reported from Georgia in 2008. In NC the association of green stink bugs moving in high numbers from peanut into cotton has not been observed, as is often the case with southern green stink bug in GA when high populations are present (Phillip Roberts, pers. com.). Brown stink bugs constituted a significant proportion of the overall stink bug complex in most years at most locations. This help account for the common producer practice of using a pyrethroid plus dicofos tank mix to control this stink bug complex.

Drop cloth sampling

At the 16 tests reported in Figure 4, sites at which drop cloth samples were taken, plant bug levels (adults plus nymphs) averaged over the first 6 weeks of blooming, with the exception of one North Carolina location in 2006, were less than any state threshold.

Plant bug-damaged squares

The retention of upper squares averaged over the first 5 weeks of blooming was extremely high (over 90%), as shown in Figure 6. As expected, but not shown in this figure, the retention of small squares dropped dramatically following the fifth to sixth week of blooming in most tests.

Dirty bloom assessments

The mean percentage of “dirty blooms” was generally very low, again demonstrating that plant bug damage was a very minor contributor to overall bug damage at these locations during the 2004 to 2008 test period (Figure 5).

Rationale for use of dynamic threshold for stink bug management

A hypothetical relationship between boll damage by stink bugs and yield as influenced by the degree of increasing insecticide protection by week of bloom is indicated in Figure 7. In this case, the initial application treatment began just after anthesis, and this plot was sprayed weekly until the season’s end, and received a total of seven insecticide applications for stink bugs. The next plot initiated one week later and protected for the remainder of the season; the third a week later, and so on. This approach is identical to the one used in our study described above. In Figure 7, the yield difference between each plot that received one less treatment than the previous treatment was identical (the 50 pounds of lint shown between the dotted lines).

In our test results, the yield difference was not identical between consecutive treatments as in the above example, but varied by week of bloom (Figure 8). As can be seen in the figure, no penalty was found between the regime treated weekly beginning at first bloom and the regime beginning at the second week of bloom. The same result was noted between beginning the insecticide series at the second vs. the third week of bloom. However, the yield difference between the application series that began during the 3rd vs. the 4th week of bloom showed that protection during this period resulted in a positive gain (10.4 lb./acre). The largest gain was shown between the regime that began in week 4 was much more protective (higher yields) than the regime that began in week 5 of bloom (59.3 lb. lint/acre). The next series also showed a positive gain of 19.1 lb. lint/acre. However, no yield gain was noted between beginning the insecticides regime at the 6th vs. 7th week of bloom.

Use of higher thresholds during initial weeks of bloom

The above results suggest that thresholds should be higher during times during the bloom period of low probability of yield loss due to stink bug damage and lower during times of the bloom period when damage from stink bug is associated with a yield loss. Our preliminary data suggested these results and proposed the use of a dynamic threshold that capitalizes on these findings: damage boll thresholds of 50, 30, 10, 10, 10, 30, 30 and 50% by week of bloom 1 through 8 (Figure 9) (Bacheler, 2006).

The rational for utilizing higher thresholds (50 and 30%, respectively, during the first two weeks of bloom in this study) are also supported by our additional data:

- 1) The number of susceptible bolls per acre is low during the first two weeks of the bloom period (Figure 10). In this example, one can see that the level of stink bug-susceptible bolls is very low during the initial two week of blooming.
- 2) During the initial two weeks of bloom, the level of stink bug adults and nymphs (averaged over the 8 tests in which stink bug levels were assessed weekly) was also low (Figure 11). Additionally, the stink bug nymphs found in these assessments were mostly first and second instars (Barbour, 1990). As can be seen in Figure 12, early stage stink bug cause minimal damage.
- 3) As is shown in the example (Figure 13), even in tests with high stink bug levels (this test showed a yield loss of approximately 500 lb. of lint/acre from stink bug damage; weekly protection vs. untreated), yield loss during the initial 2 weeks of bloom was minimal. This finding was consistent with the other tests in this study.

Use of higher threshold after weeks 5 to 6 of bloom

After the 5th week of bloom, the proportion of bolls that is safe from stink bug damage increases. This physiological occurrence can be used to justify the use of increasingly higher damaged boll thresholds as the crop phenology advances beyond the time of maximum vulnerability of boll damage from stink bugs (week 3-5 of the bloom period):

- 1) Bolls with an outside diameter of 1.25 inches (at or close to the stage in which their age is 3.5 weeks) are no longer susceptible to damage from stink bugs (Bachelier, 2009; Greene and Herzog, 2001; Emfinger et al, 2004) (Figures 14 and 15).
- 2) The level of “stink bug-safe” bolls shows a predictable, physiological increase as the crop advances toward cutout (Figure 16), a finding the justifies the use of higher internal boll damage threshold as the crop advances toward cutout.

Conclusions

The above series of 19 tests represents a 5-year data set conducted under various levels of stink bug pressure and agronomic conditions at multiple locations in North Carolina, South Carolina and Georgia. Due to both the low levels of stink bug-susceptible bolls and low levels of stink bugs in most tests during the initial two weeks of blooming, and because no yield penalty was observed even when stink bug pressure was high, significantly higher thresholds than the two static thresholds currently recommended in the Southeast (10 or 20% internal boll damage throughout the bloom period) should be used during the initial two weeks of the bloom period.

Conversely, protections from stink bug damage during the 3rd to 5th week of bloom resulted in a significant increase in yield during this period, indicating a low threshold for internal damage to quarter-sized bolls is indicated during this time of the bloom period.

Evidence was also presented that the internal boll damage threshold should be increased as the proportion of stink bug-safe bolls increases during the bloom as the crop proceeds toward cutout.

In this way, the internal boll damage threshold can be aligned with the susceptibility and vulnerability of the cotton crop during the bloom period, with higher thresholds being used during times of low yield loss to stink bug damage both early and late in the bloom period, and lower, more protective, thresholds deployed during weeks 3 to 5 of the bloom period, an interval of high probability of yield loss due to stink bug damage to quarter-sized bolls.

Finally, the dynamic threshold cited above (50, 30, 10, 10, 10, 30, 30, 50% during weeks 1 to 8 of the bloom period) was evaluated in a series of 47 threshold evaluations comparing the dynamic threshold to a number of static (the same threshold used season long) thresholds, such as 10, 20 and 30%. Under various levels of stink bugs and associated damage (as defined as the number of sprays required at the 20% internal boll damage level), the dynamic threshold showed higher profit levels (yield value minus the cost of application) than any of the static thresholds (Greene, et al, 2009).

The dynamic threshold offers producers and consultants a bloom period-based threshold that suggests remedial treatments during times of maximum economic return, and avoids wasted applications during times of a low expected economic return. Although some fine tuning of this threshold may be warranted for different areas, the

success of this approach in tests under stink bug pressure that varied from high to virtually non-existent over the course of 5 years in 3 SE states suggests that the dynamic threshold evaluated in this study offers producers and consultants a more profitable approach to managing stink bugs than any of the currently-recommended static thresholds. This threshold has been recommended in North Carolina for the three years (Bacheler, 2009).

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Acknowledgements

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Table 1. Checklist of data taken by location (Y- data taken; N- data not taken; P- data partially taken)

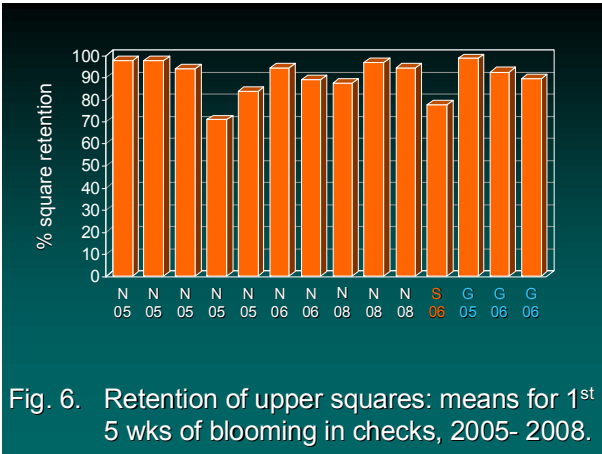
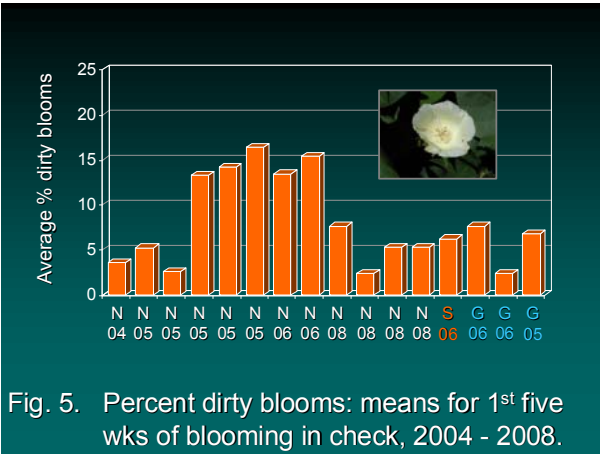
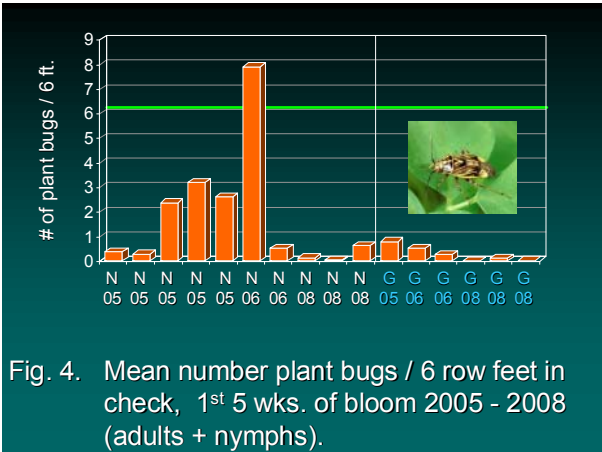
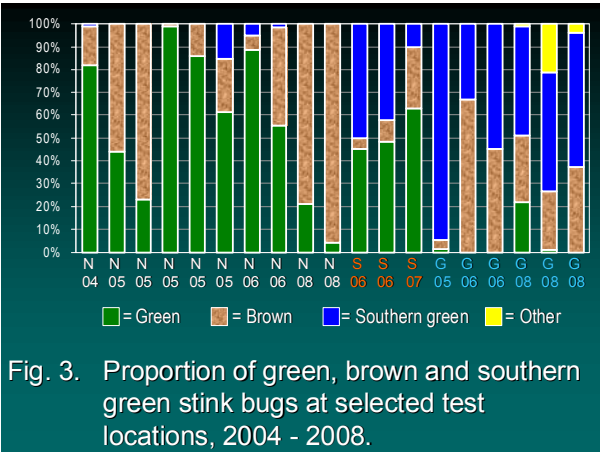
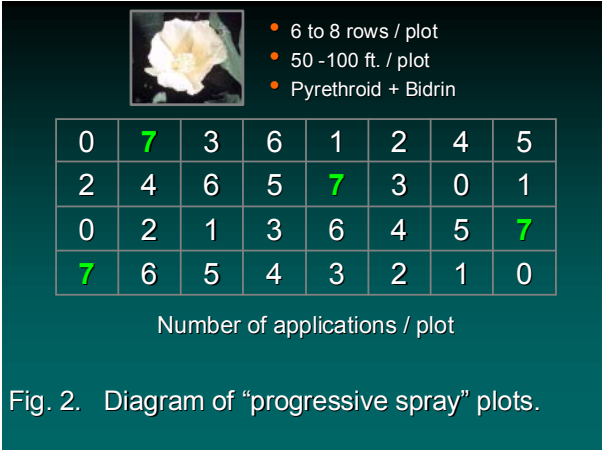
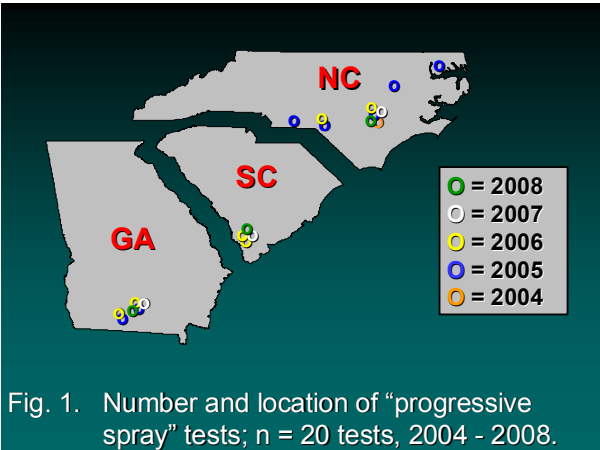
Data	04NCW	05NCE	05NCW	05NCS	05NCU	05NCP	05GAPR	05GAJR
Square retention	N	Y	Y	Y	Y	N	Y	N
Dirty bloom counts	Y	Y	Y	Y	Y	Y	Y	N
Beat cloth samples	N	Y	Y	Y	Y	Y	Y	Y
Damaged quarter-sized bolls	Y	Y	Y	Y	Y	Y	Y	Y
Size of bolls @ 3.5 weeks/ l	N	Y	Y	N	Y	Y	Y	N

week tag								
Size of bolls @ 3.5 weeks/ 2 week tag	N	Y	N	N	N	N	N	N
Size of bolls @ 3.5 weeks/ 3 week tag	N	Y	Y	N	N	N	Y	N
Size of bolls @ 3.5 weeks/ 5 week tag	N	Y	Y	N	N	N	Y	N
Cadaver counts	P	Y	Y	Y	Y	N	Y	1 Time
Boll sizes in most protected plot	Y	Y	Y	Y	Y	Y	Y	N
Row length/ 25 bolls	N	Y	Y	Y	Y	Y	Y	N
Final boll damage	Y	Y	Y	Y	Y	Y	Y	N
Yields	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
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
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.

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

Data	06NCW	06NCS	06SCF	06SCE	06GAL	06GAE	07SCB	07GAT	08NCW	08SCB	08GAT
Square retention	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Dirty bloom counts	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Beat cloth samples	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
Size of bolls @ 3.5 weeks/ 1 week tag	Y	Y	Y	Y	N	N	N	Y	N	N	Y
Size of bolls @ 3.5 weeks/ 2 week tag	N	N	N	N	N	N	N	N	N	N	N
Size of bolls @ 3.5 weeks/ 3 week tag	N	Y	Y	Y	N	N	N	N	N	N	N
Size of bolls @ 3.5 weeks/ 5 week tag	N	Y	N	N	N	N	N	N	N	N	N
Cadaver counts	Y	Y	N	N	N	N	N	N	N	N	N
Boll sizes in most protected plot	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y
Row length/ 25 bolls	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y
Final boll damage	Y	Y	Y	Y	Y	Y	N	N	Y	N	N
Yields	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Variety	DP 960 BG II R	DP543 BGII R	DP 164 B2RF	DP 117 B2RF	DP 543 BG2RR	DP 543 BG2RR	DP 164 B2RF	DP 164 B2RF	DP164 B2RF	DP 164 B2RF	DP 164 B2RF
Plot size # rows x length	6 x 50 ft	6 x 50 ft	12x75 ft	12x75 ft	12x75 ft	12x75 ft	12x60 ft	8x50 ft	8x50 ft	12x75 ft	8x50 ft
Notes: planting date, Rows picked & Surrounding vegetation	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.	May 16 Center 4	May 28 Center 2	May 13 Center 2 Corn & wheat	May 14 Center 4	May 30 Center 2

Locations: 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; 05GAJR - 2005 Tift Co., GA; 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; 06GAE – 2006 Moutre Co., GA; 07SCB - 2007 Blackville, SC; 07GAT - 2007 Tifton Co., GA; 08NCW - 2008 Wayne Co., NC; 08SCB - 2008 Blackville, SC; 08GAT - 2008 Tifton Co., GA.



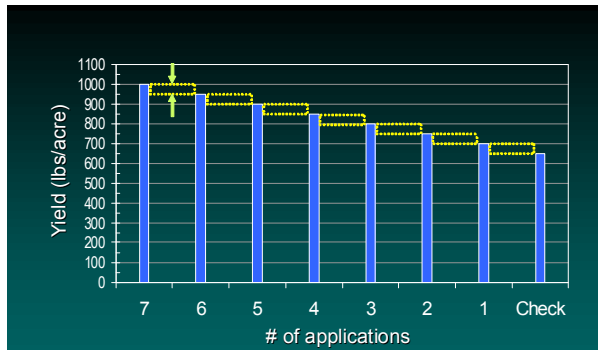


Fig. 7. Theoretical relationship between damaged bolls by stink bugs and yield.

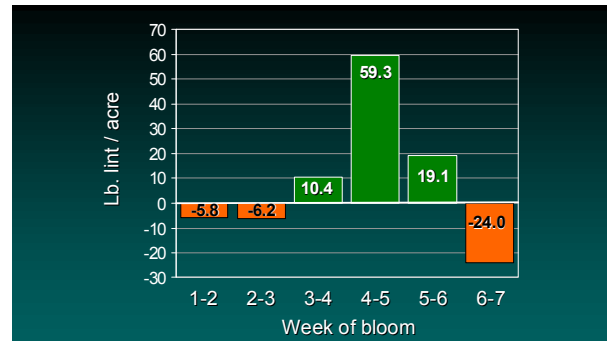


Fig. 8. Yield change from spray at designated weeks of bloom, NC & GA, 2004 - 2007 (n = 16 tests).

Week of bloom	Threshold
1	50
2	30
3	10
4	10
5	10
6	30
7	30
8	50

Fig. 9. Dynamic threshold based on probability of stink bug damage based on week of bloom.

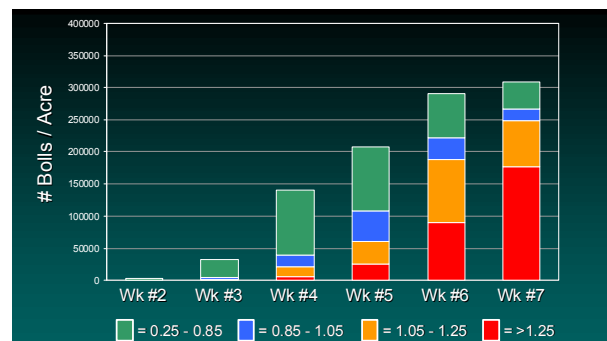


Fig. 10. Boll number & size / acre following blooming, Edgecombe Co., NC, 2005

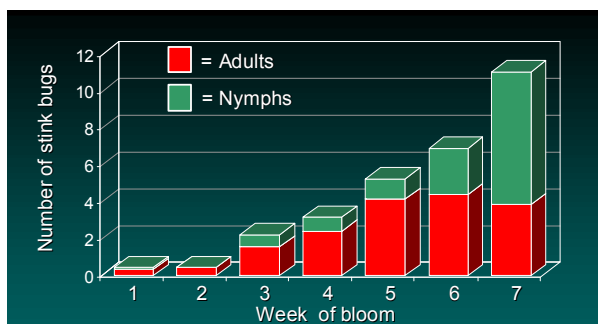


Fig. 11. Average number of stink bugs per 6 row feet (n = 8 tests, 2005 - 2008).

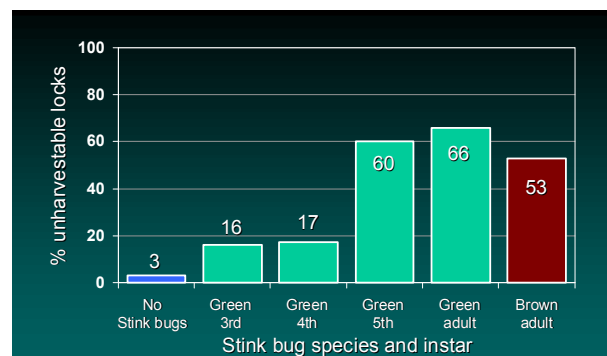


Fig. 12. Impact of stink bug feeding on reduction of harvestable locks, 1987.

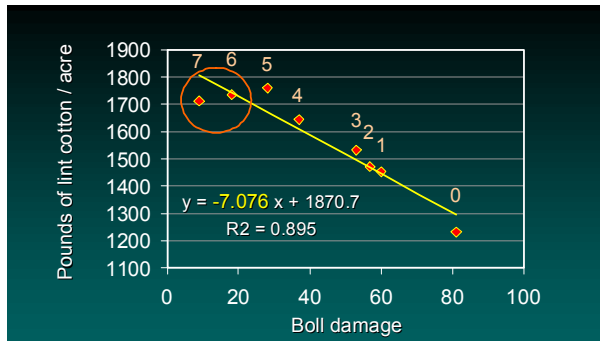


Fig. 13. Stink bug damage to bolls vs. yield, Wayne Co., 2004.

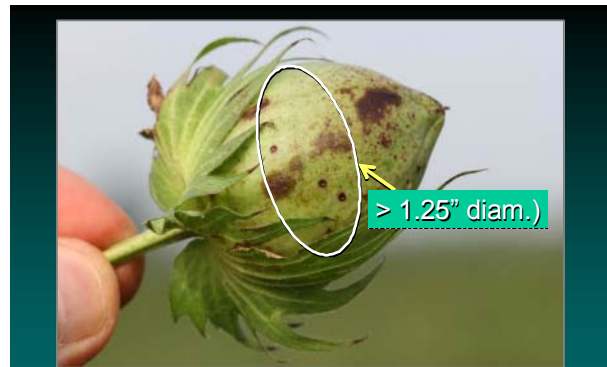


Fig. 14. Bolls at the 3.5+ week safe stage have outer diameter of 1.25 inches or greater.



Fig. 15. Cut away of Fig. 14 boll showing lack of injury.

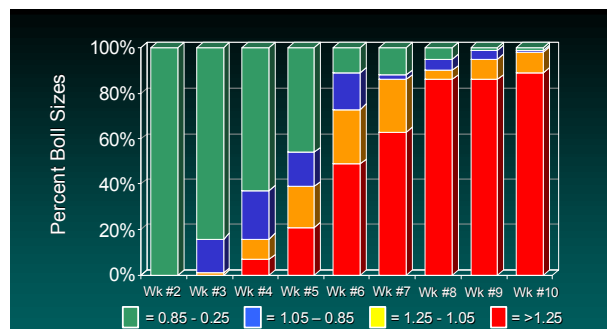


Fig. 16. Bolls size partitioned by diameter and week of bloom; Wayne Co., NC, 2004.