# COTTON
## RESEARCH-EXTENSION REPORT – 2009

The University of Georgia
College of Agricultural and Environmental Sciences
Edited by G. Ritchie, A. Smith, and G. Collins



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**2009 GEORGIA COTTON**
**RESEARCH AND EXTENSION REPORT**

Edited by Glen Ritchie, Associate editors Amanda Smith and Guy Collins
Compiled by Glen Ritchie

Georgia Agricultural Experiment Stations
Georgia Cooperative Extension
University of Georgia College of Agricultural and Environmental Sciences

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## THE 2009 CROP YEAR IN REVIEW

Guy Collins
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The 2009 production season was frustrating for the most part, largely due to the significant amounts of rainfall that occurred during planting and harvest. The majority of the cotton crop this year was planted very late, with nearly 40 % of the acreage planted in June as opposed to the 2004-2008 average of only 18 %. Frequent summer rains developed and sustained a good crop in most places. The rains did not cease during the fall, which complicated and delayed harvest significantly. Similar to the past couple of years, we experienced relatively cool fall temperatures which significantly slowed or halted late-season boll development and boll opening in many instances, especially in the late-planted fields. Harvest conditions were generally poor due to rainfall and extensive cool, cloudy weather that prolonged drying time and decreased the number of daylight hours suitable for harvest. The already late-maturing crop was set back even further as growers could not get in the field to harvest. According to the National Agricultural Statistics Service, cotton harvest, averaged over the previous 5-year period, has generally been 50% completed by November 1st. This year, nearly 80% of our crop had yet to be harvested by this date. In some regions, cotton was still being harvested in March. Although yields were variable, average yield was last estimated at 882 lbs/acre, a record for our state. This was the fifth consecutive year that the statewide yield has averaged over 800 lbs per harvested acre, which can be attributed to weather patterns, but can also be attributed to the widespread planting of DP 555 BR.

Fiber Quality of Bales Classed, 2007-2009

| | Color Grade 31/41 or better (% of crop) | Bark/ Grass/ Prep (% of crop) | Staple (32nds) | Strength (g/tex) | Mic | Uniformity |
|---|---|---|---|---|---|---|
| 2007 | 39 / 97 | all < 1.0 | 34.3 | 28.6 | 4.7 | 80.0 |
| 2008 | 25 / 93 | all < 1.0 | 34.4 | 28.7 | 4.6 | 80.2 |
| 2009 | 21 / 68 | all < 1.0 | 35 | 28.4 | 4.4 | 80.2 |

Bales classed short staple (< 34) and high mic (>4.9)
2007: 20% and 21% 2008: 22% and 20% 2009: 4.7% and 7.3%
Fiber quality data as of February 11, 2010, 1,796,900 bales classed.
Source: http://www.ams.usda.gov/mnreports/cnwwqs.pdf

Quality of the 2009 crop was similar to slightly better than previous years. Of bales classed as of December 10, 2009, 4.7 percent were short staple (<34) and 7.3 percent were high mic (>4.9). Georgia still ranks near the bottom of the national average in uniformity.

DP 555 BG/RR again dominated the state's acreage in 2009, with over 82 percent of the crop planted to that variety (**http://www.ams.usda.gov/AMSv1.0/**). The USDA Survey estimated that about 12 percent of cotton acres were planted to 2-gene Bt transgenic varieties (Bollgard II and WideStrike), up from 2008. Seed dealers were

allotted roughly 33 percent of the 2009 DP 555 BG/RR seed for planting in 2010. This year will be the last year that DP 555 BG/RR is available to producers, therefore most producers will be planting the majority of their acres to newer varieties. Herbicide resistant Palmer amaranth (pigweed) provided significant production challenges across much of the state.

# BUDGET ANALYSIS OF GLYPHOSATE-RESISTANT PALMER AMARANTH CONTROL AND SEED TECHNOLOGY CHOICES IN GEORGIA COTTON

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## Abstract

Palmer amaranth (pigweed) resistance to glyphosate was first confirmed in Georgia during 2004. By the Fall of 2009, resistance was confirmed in 51 counties infesting over 1 million acres of land. In 2010, producers must consider both technology choices and Palmer amaranth resistance management when choosing which varieties to plant.

A survey of county Extension agents was conducted in 2009 in Georgia counties already known to be confirmed with glyphosate-resistant Palmer amaranth. In counties considered to have severe resistance, approximately 90% of acres were treated with a DNA herbicide (Prowl, Treflan, etc.) or other residual herbicide in 2008 after having resistance compared to only 25% in 2004 prior to having resistance. Conservation tillage declined from over 80% of acres in 2004 to less than 50% in 2008. Also in 2008, 20 to 25% of the acres were cultivated and 45% required hand weeding.

Typical weed control costs have increased from $25 per acre prior to resistance to $46 to $64 per acre if managing for moderate to heavy resistance. In 2010, single-gene Bt technology is no longer available and producers must shift to two-gene technologies while also managing glyphosate resistance.

There are differences in production costs associated with the choice of technology. Estimates show that “system costs” (seed, technology fees, herbicides, insecticides, and application) can vary by as little as $2 to $3 per acre to as much as $35/acre or more. These differences, however, are considered relatively small.

The key factor in variety and technology choice will continue to be yield potential. Differences in cost are relatively minor and can be offset by small differences in yield.

## Situation and Background

Over 99% of Georgia’s cotton acreage is planted to transgenic (herbicide-tolerant and/or insect tolerant) varieties (USDA-AMS, 2009). More importantly, one such variety, DP555BR, has dominated the state’s acreage since its availability. DP555BR comprised 86% of Georgia acres planted in 2008 and 82.5% in 2009.

The fact that a single variety and technology account for the overwhelming majority of acreage is critical because single-gene BollGard® technologies such as B and BR

expired on September 30, 2009. Beginning with the 2010 crop, with exception of any remaining single-gene stocks available for purchase, cotton producers must switch to non-Bt or 2-gene varieties Widestrike® (W) or Bollgard II® (B2).

Most W and B2 varieties are packaged with Roundup-Ready® (R or RR), Roundup-Ready Flex® (RF or F), or Liberty-Link® (LL) technology. DP555BR has been a high-yielding variety for Georgia producers. The majority of Georgia producers, if planting a 2-gene variety, must switch from BR to B2R, B2RF, LLB2, W, WR, or WRF varieties.

Palmer amaranth (pigweed) resistance to glyphosate was first confirmed in one county in Georgia in 2004 and by season's end of 2009 it was confirmed in 51 cotton-producing counties (Culpepper, et al, 2010). Resistance is expected to be confirmed in all major cotton producing counties by the end of 2010. In 2010, producers must consider both technology choices and Palmer amaranth resistance management when choosing varieties to plant.

## Objectives

An objective of this study is to explore trends in seed technology in Georgia cotton. This study will also examine the glyphosate resistance issue and how herbicide costs have changed over time due to the need for producers to manage resistance.

This study compares seed technology choices and related herbicide and insecticide program options for 2010 and cost estimates for these various choices. Herbicide programs assume the producer is managing glyphosate-resistant Palmer amaranth and based on University of Georgia Extension recommendations (Collins, et al., 2010).

Extension recommendations are numerous and encompass many alternatives. Likewise, producers vary in their approach and use of various products. The weed control programs used in this research are thought to be typical of those used on Georgia farms but are not meant to represent the only possible program, nor are they an endorsement or recommendation for a particular product.

## Results

When RR varieties were first released in the late 1990's, grower acceptance was slow due to their low yield. When "stacked-gene" BR technology became available, growers accepted these varieties more quickly– as much for the yield compared to RR as for the utility of the technology. Most of the BR acreage planted in Georgia has been to a single, very high-yielding variety– DP555BR. In paying for the BR technology and planting this variety, producers were willing to pay for the additional yield potential as well as the technology.

In the past few years, acreage of B2, W, and RF varieties has increased. Two-gene technology accounted for just over 14% of acres in 2009— 9% to B2 packaged with R, RF, or LL and over 5% to W or W packaged with R or RF (USDA-AMS, 2009).

BR acreage has still been over 80% of Georgia plantings, however, and Georgia growers have been slow to adopt these newer technologies as long as DP555BR was available. With the loss of single-gene Bt technology after the 2009 crop season, 2010 will usher in a shift in varieties planted and seed technology.

## Glyphosate Resistance

A survey of county Extension agents was conducted in 2009 in Georgia counties already known to be confirmed with glyphosate-resistant Palmer amaranth. Agents were asked to compare weed control regimes in 2004, prior to resistance, to 2008 with resistance (Table 1).

In counties considered to have severe resistance, approximately 90% of acres were treated with a DNA or other residual herbicide in 2008, compared to only 25% in 2004. Strip-till (the predominant conservation tillage system in Georgia) declined from over 80% of acres in 2004 to less than 50% in 2008. Also in 2008, 20 to 25% of acres were cultivated and 45% required hand weeding.

Table 1. Results of a 2009 survey of county extension agents in Georgia counties with glyphosate-resistant Palmer amaranth.

| | GR Palmer amaranth Infestation Level in 2008 | | | | | |
|---|---|---|---|---|---|---|
| | Severe | | Light to Moderate | | Light | |
| | 2004[a] | 2008 | 2004[a] | 2008 | 2004[a] | 2008 |
| % Acres Treated with a DNA Herbicide | 25 | 92 | 75 | 95 | 70 | 91 |
| % Acres Treated with Residual Herbicide other than DNA | 25 | 88 | 61 | 95 | 35 | 71 |
| % Acre in Strip-Till Production | 83 | 48 | 45 | 45 | 30 | 60 |
| % Acres Using PPI Herbicide | 0 | 5 | 0 | 0 | 0 | 0 |
| % Acres Using Glufosinate | 0 | 26 | 0 | 5 | 0 | 2 |
| % Acres Cultivated | 0 | 20 | 0 | 25 | 22 | 12 |
| % Acres Hand-Weeded | 0 | 45 | 0 | 35 | 1 | 37 |

[a]No resistance present in 2004 but confirmed by 2008.

In counties with both light and moderate infestations, use of DNA and other residual herbicides has also increased. Strip-till production has remained about the same or increased. Use of Ignite® herbicide (glufosinate) has increased especially in counties with a severe resistance problem.

After the adoption of Roundup-Ready cotton technology but before glyphosate-resistant Palmer amaranth, weed control (herbicides only) was a $25 per acre expenditure (Table 2). This estimate is based on 2010 herbicide prices and UGA Extension recommendations for what was considered a typical regime at that time. Morningglory and spiderwort have been a problem for many producers. For that reason, residual

chemistries have often been used even in a glyphosate-based program prior to resistance.

When resistance began to be a concern, UGA Extension recommended that producers increase the use of residual herbicides and reduce the use of glyphosate. The objectives in weed control were to delay further development of resistance to glyphosate, reduce the spread of resistance geographically, and reduce the seed-bank. Increased use of residual herbicides in a glyphosate-based, RR cotton program resulted in weed control costs of $30 to $35 per acre based on UGA recommendations at 2010 herbicide prices (Table 2).

Table 2. Example herbicide programs in Roundup Ready cotton.

| | Pre-Resistance | | | Delaying Resistance | | |
|---|---|---|---|---|---|---|
| Application | Material | Rate | Cost/Acre | Material | Rate | Cost/Acre |
| Preplant or PPI | | | | | | |
| PRE | Prowl | 2pts | $6.88 | Prowl | 2pts | $6.88 |
| POST OTT | Glyphosate | 32 oz | $4.00 | Glyphosate | 32 oz | $4.00 |
| | + Dual | 1 pt | $10.60 | + Staple | 1.9 oz | $10.45 |
| POST Directed | Glyphosate | 32 oz | $4.00 | Glyphosate | 32 oz | $4.00 |
| | | | | + Diuron | 2 pt | $5.40 |
| Total | | | $25.48 | | | $30.73 |

## Technology Choices and Managing Resistance

Producers could purchase any remaining single-gene Bt seed stocks available by September 30, 2009. These seed can be planted in 2010. Otherwise, cotton producers have two seed technology choices for 2010 and beyond - plant non-Bt varieties and/or plant two-gene varieties. Non-Bt varieties include conventional (non-transgenic), Roundup Ready (RR or R), Roundup-Ready Flex (RF or F), or Liberty Link (LL). Two-gene varieties include Bollgard II (B2) and Widestrike (W), and most come combined with R, RF, or LL (B2, B2R, B2RF, LLB2, W, WR, and WRF).

Producers must select a non-Bt or two-gene variety (B2 or W) while also considering the need for managing glyphosate-resistant Palmer amaranth. Producers will have choices among glyphosate-based systems (R or RF) or an Ignite (glufosinate)-based system (LL).

Tables 3 and 4 are example weed control programs based on UGA Extension recommendations (Culpepper and Kichler, 2010), assuming resistance is present and the producer is managing resistance. Table 3 illustrates example recommended programs in conventional and strip-till production for R and RF varieties. Table 4 illustrates example recommended programs in conventional and strip-till production for LL varieties.

In these programs, there is little or no difference between irrigated and non-irrigated practices. It should be especially noted, however, the glyphosate-based production in

non-irrigated conservation-tillage situations where resistance is present is very risky. This is due to lack of preplant tillage and soil incorporated herbicides and uncertainty of rainfall needed for timely activation.

In this situation, Ignite (glufosinate)-based programs (Table 4) are more effective if there is a significant level of glyphosate-resistant Palmer amaranth. Otherwise, non-irrigated conservation tillage will almost certainly require hand weeding and/or deep plowing prior to conservation tillage and/or use of a very heavy cover crop to eliminate the emergence of Palmer amaranth seed.

Table 3. Example herbicide program, managing resistance in Roundup Ready cotton.

| Conventional | | Strip-Till | |
|---|---|---|---|
| Application | Product | Application | Product |
| Preplant Broadcast | | Preplant Broadcast | Valor |
| PPI | | PPI | |
| PRE | Prowl[1] + Reflex | PRE | Prowl + Staple + Diuron |
| POST OTT | Glyphosate + Staple | POST OTT | Glyphosate + Dual |
| POST Directed | MSMA + Diuron | POST Directed | MSMA + Diuron |

[1]Applied PPI in non-irrigated production.

Table 4. Example herbicide program, managing resistance in Ignite-based programs.

| Conventional | | Strip-Till | |
|---|---|---|---|
| Application | Product | Application | Product |
| Preplant Broadcast | | Preplant Broadcast | Valor |
| PPI | | PPI | |
| PRE | Prowl + Reflex | PRE | Prowl + Staple |
| POST OTT | Glufosinate + Dual | POST OTT | Glufosinate + Dual |
| POST Directed | MSMA + Diuron | POST Directed | MSMA + Diuron |

Ignite® (glufosinate) herbicide is used in conjunction with Liberty Link® technology. There are only a few differences between the example Ignite-based programs and Roundup Ready programs illustrated in Tables 3 and 4. The only significant difference is the use of glufosinate instead of glyphosate. Both systems rely on similar use of residual herbicides and modes of application.

## Cost Comparison of Seed Technologies and Weed Control Systems

Tables 5 and 6 are a cost comparison of two-gene systems based on UGA recommendations (Tables 3 and 4) and 2010 prices. These costs are “systems costs”—the cost of inputs and production practices that are strictly a function of seed technology choice. These costs are based on managing for glyphosate-resistant

Palmer amaranth and are the average of irrigated and non-irrigated production. Cost excludes hand weeding, if needed. Cost includes the cost of herbicide and insecticide application (Shurley and Smith, 2010).

Weed control costs (number of applications, amount applied, and other materials used) are assumed the same for R and RF, as weed control programs are identical for both these technologies in areas with resistance. These estimates also assume no difference in insect control and cost between B2 and W. Cost includes in-furrow insecticide and 2 sprays for bugs but no sprays for caterpillar pests.

Table 5. Systems cost per acre for two-gene seed technologies, managing glyphosate resistance in strip-tillage.

| | Seed Technology | | | | | |
|---|---|---|---|---|---|---|
| | B2R | B2RF | LLB2 | W | WR | WRF |
| Seed | $22.38 | $22.15[a] | $39.77[b] | $21.17 | $21.17 | $21.17 |
| Technology Fees | $52.99 | $59.87 | $30.46 | $15.01 | $47.24 | $56.75 |
| Herbicides | $46.45 | $46.45 | $56.59 | $56.59[c] | $46.45 | $46.45 |
| Insecticides | $19.40 | $19.40 | $19.40 | $19.40 | $19.40 | $19.40 |
| Application | $10.44 | $10.44 | $8.69 | $8.69 | $10.44 | $10.44 |
| TOTAL | $151.66 | $158.31 | $153.91 | $120.86 | $144.70 | $154.21 |

[a]Average of DeltaPine, Stoneville, and Fibermax varieties. All technologies are 36-inch rows, 2.5 seed per foot.
[b]Includes Liberty Link fee.
[c]Ignite program- not endorsed by Dow AgroSciences or Bayer CropScience, not recommended by UGA Extension.

Table 6. Systems cost per acre for two-gene seed technologies, managing glyphosate resistance in strip-tillage.

| | Seed Technology | | | | | |
|---|---|---|---|---|---|---|
| | B2R | B2RF | LLB2 | W | WR | WRF |
| Seed | $24.62 | $24.36[a] | $42.65[b] | $23.29 | $23.29 | $23.29 |
| Technology Fees | $58.29 | $65.86 | $33.51 | $16.51 | $51.96 | $62.42 |
| Herbicides | $56.77 | $56.77 | $63.95 | $63.95[c] | $56.77 | $56.77 |
| Insecticides | $19.40 | $19.40 | $19.40 | $19.40 | $19.40 | $19.40 |
| Application | $10.02 | $10.02 | $10.02 | $10.02 | $10.02 | $10.02 |
| TOTAL | $169.10 | $176.41 | $169.53 | $133.17 | $161.44 | $171.90 |

[a] Average of DeltaPine, Stoneville, and Fibermax varieties. All technologies are 36-inch rows, 2.75 seed per foot.
[b]Includes Liberty Link fee.
[c]Ignite program- not endorsed by Dow AgroSciences or Bayer CropScience, not recommended by UGA Extension.

Widestrike (W) without R or RF assumes these varieties are produced using an Ignite-based program. While *not endorsed by Dow and Bayer and not recommended by UGA Extension*, if planted in a resistance situation, Ignite is likely being used (glyphosate could not be used, leaving glufosinate or residual chemistries only as the options). While not endorsed or recommended, it is nevertheless likely being done.

In conventional production (Table 5), cost ranges from $121 to $158 per acre. Excluding W, cost varies from $145 to $158 per acre. In conservation tillage (strip-till) production (Table 6), cost ranges from $133 to $176 per acre. Excluding W, cost varies from $161 to $176 per acre. The Widestrike systems (WR and WRF) tend to be cheaper than similar Bollgard II systems (B2R and B2RF) but differences are relatively minor.

Both conventional and strip-till estimates are the average of irrigated and non-irrigated production. In non-irrigated conservation tillage, if significant resistance is present, Ignite-based systems are the most effective option. Non-irrigated conservation tillage with resistance present is risky and almost surely will require hand weeding and/or heavy cover crop. Results from a UGA Extension survey noted that hand weeding occurred on 54% of the Georgia cotton acres during 2009 with cost ranging from $3 to $100 per acre with an average expense of $26 per acre.

## Summary and Conclusions

Due to glyphosate-resistant Palmer amaranth, weed control cost has more than doubled when compared to a period prior to resistance management. If managing for moderate to heavy infestation, herbicide cost can be $46 to $64 per acre; excluding application, hand weeding if needed, and seed technology fee.

In 2010, single-gene Bt technology is no longer available and producers must shift to other technology while, for an increasing number of producers, also managing glyphosate resistance. Two-gene technologies include B2 and W and are most often available only as packaged with R, RF, or LL technology.

There are differences in production cost associated with the choice of technology. Estimates show that "system costs" (seed, technology fees, herbicides, insecticides, and application) can vary by as little as $2 to $3 per acre to as much as $35/acre, or more. These differences, however, are considered relatively small.

When purchasing seed, producers are purchasing a management regime. Choice of variety determines not only yield and fiber quality potential, but also a set of recommended management practices.

Although costs can vary, the key factor in variety and technology choice is likely to continue to be yield potential. The differences in cost are relatively minor and can be offset by small differences in yield. Choice of variety is likely to continue to be determined by yield and the technology that best suits the weed and insect management needs of the individual producers.

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# AN ECONOMIC ANALYSIS OF IRRIGATION AND TILLAGE FOR COTTON IN SOUTHWEST GEORGIA

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## Introduction

Cotton production continues to be a capital-intensive crop because of its specific input and equipment needs. In light of recent droughts and weed management problems, farmers continue to look for the most economical methods to grow cotton.

Tillage and irrigation are two production methods that may be adjusted to create an increase in revenue through higher yield or a decrease in costs. Nearly half of all Georgia cotton acres were irrigated in 2008 (Harrison, 2009). Irrigation was, and continues to be, used by farmers to manage yield risk.

Over half of all cotton acres in Georgia were produced under some form of conservation tillage (Shurley, 2006). The majority of those conservation tillage acres were planted through strip tillage methods. In addition to the perceived benefits of reduced soil erosion and improved water infiltration, conservation tillage is believed to save farmers time (labor) and money through reduced wear on equipment (Shurley, 2006). Optimal profit should occur when an ideal yield is reached using minimal costs.

## Objective

The purpose of this project is to examine the economics of cotton grown under conventional tillage and conservation tillage production at full- and deficit-irrigation.

## Materials and Methods

The trial was conducted during 2009 at Stripling Irrigation Research Park in Camilla, GA using DP0935 cotton in a 2x4 split-plot design. Conventional tillage and conservation tillage production were compared at four levels of irrigation.

The conventionally tilled plots were disked twice, ripped and bedded and then planted. The conservation tilled plots were planted into a burned-down, winter rye cover crop using a strip and plant operation. All plots were planted on May 20.

The four irrigation levels were 100%, 70%, 30% and 0% irrigation. Irrigation application amounts and timing were determined through the use of soil-based watermark sensors at the 100% irrigation level.

All other inputs were constant across all plots and based on the UGA Cooperative Extension Service recommendations for irrigated cotton (The University of Georgia Cooperative Extension Service, 2009).

Rainfall data were collected throughout the growing season from planting to defoliation on September 28. Figure 1 shows the rainfall events and the four irrigation applications. There were heavy rainfall events that occurred after two of the four irrigation applications. Furthermore, there was significant rainfall that occurred after the fourth irrigation application. These heavy rainfall events may have had a negative impact on yield, meaning the cotton received too much water.

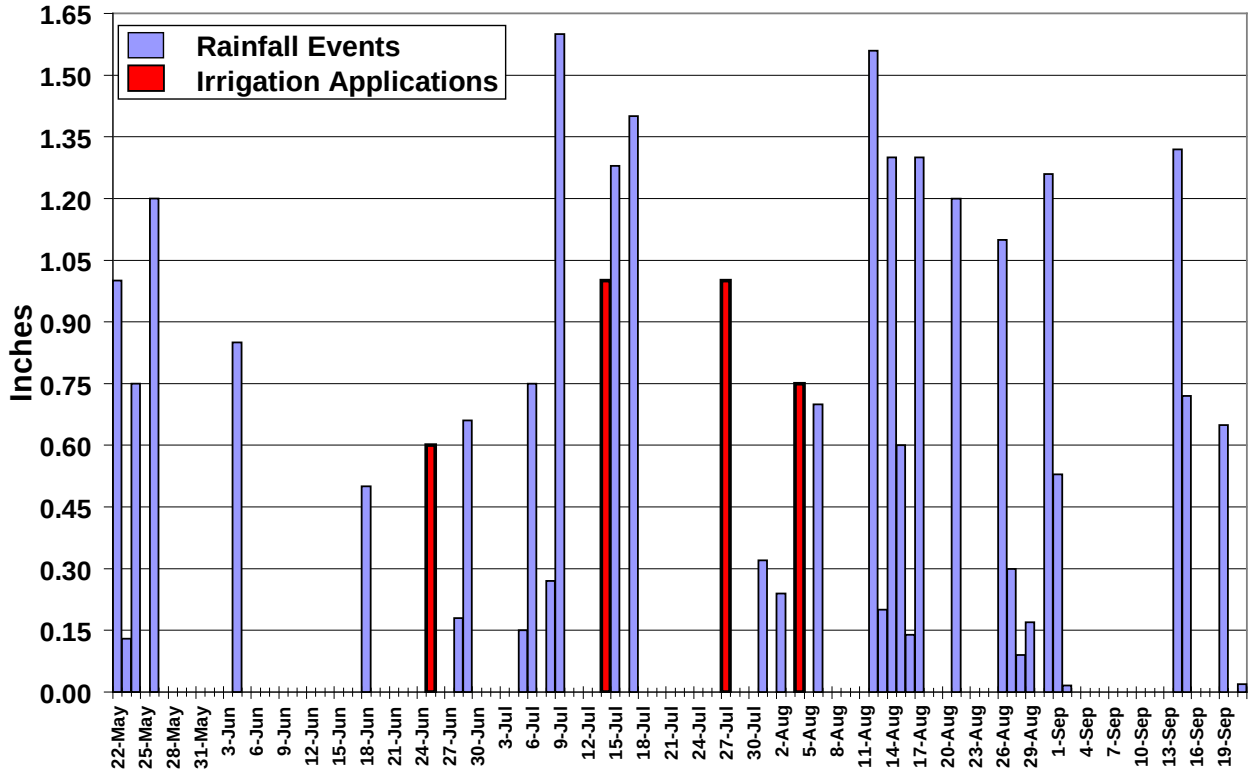


Figure 1. Rainfall events and irrigation applications from planting to defoliation.

Economic analysis was conducted using a partial budget approach (Shurley and Smith, 2009). Partial budgeting enables the analysis of changes in costs and revenues as a result of changes in production methods. The result of a partial budget analysis can be defined as adjusted revenue, or in the case of this research; revenue adjusted for tillage and irrigation costs.

Revenues were calculated by multiplying yield by southeast base price for November of $0.675/lb (USDA AMS, 2009). Quality data was unavailable when this publication was submitted, so quality premiums and discounts were not included in the analysis. Table 1 shows the average yield and gross revenue per acre by tillage and irrigation level. Within the column, the 100% irrigated plots yielded less than the deficit-irrigated plots. Consequently the fully irrigated plots had the lowest average gross revenue per acre.

The only difference among tillage methods was at the 100% fully irrigated level. At full irrigation, the strip tilled plots yielded 124 lbs/ac higher. This additional yield resulted in higher gross revenues of $84/ac.

Table 1. Average yield and gross revenue by tillage and irrigation.

| Irrigation Level | Conventional Tillage | | | Strip Tillage | | |
|---|---|---|---|---|---|---|
| | Yield (lbs/ac) | Gross Revenue ($/ac) | | Yield (lbs/ac) | Gross Revenue ($/ac) | |
| 100% * | 1,076 | $726 | A | 1,200 | $810 | X |
| 70% | 1,244 | $840 | B | 1,327 | $896 | Y |
| 30% | 1,305 | $881 | B | 1,389 | $938 | Y |
| 0% | 1,320 | $891 | B | 1,473 | $995 | Y |

[A, B, X, Y] Different letters indicate significant differences within columns at α=0.05
* Denotes significant difference in tillage at the 100% irrigation level

Costs were based on irrigation application, tillage operations and ginning and storage cost with a credit for cottonseed. Irrigation costs included only the application costs, because the water was not paid for. Furthermore, it cost more to irrigate an inch of water than half an inch. This was because the pivot was able to move faster and used less fuel when applying less water. Irrigation application costs were based on electric irrigation. Fixed costs were estimated to be $100/ac (Shurley and Smith, 2009). All plots received 0.80" water to initiate growth. The 100% irrigated plots received 4.15" for a cost of $19.27/ac. The 70% irrigated plots received 3.10" for a cost of $9.85/ac. The 30% irrigated plots received 1.85" for a cost of $3.43/ac and the 0% irrigated plots received 0.80" of water for a cost of $1.90/ac.

Tillage costs included labor at $11/hr, fuel at $3/gal, repairs and maintenance and fixed costs (Shurley and Smith, 2009). The strip tillage plots also included the cost of planting the cover crop, paying for cover crop seed, and the chemical used to burndown the cover crop. The conventionally tilled plots cost $46.36/ac and the strip till plots cost $44.71/ac.

Other yield-related costs included ginning, storage, and warehousing costs with a credit for cottonseed. A credit of $115/ton for cottonseed was used in the analysis (USDA NASS, 2009).

## Results

Figure 2 shows the average cost by irrigation level. Average cost is defined as the cost of tillage operations, irrigation application, ginning, storage, and warehousing fees minus a credit for cottonseed. The results indicate that the 100% irrigation level cost an average of $4/ac more than the 70% irrigation level and $8/ac more than the 30% and 0% irrigation levels when averaged across both types of tillage.

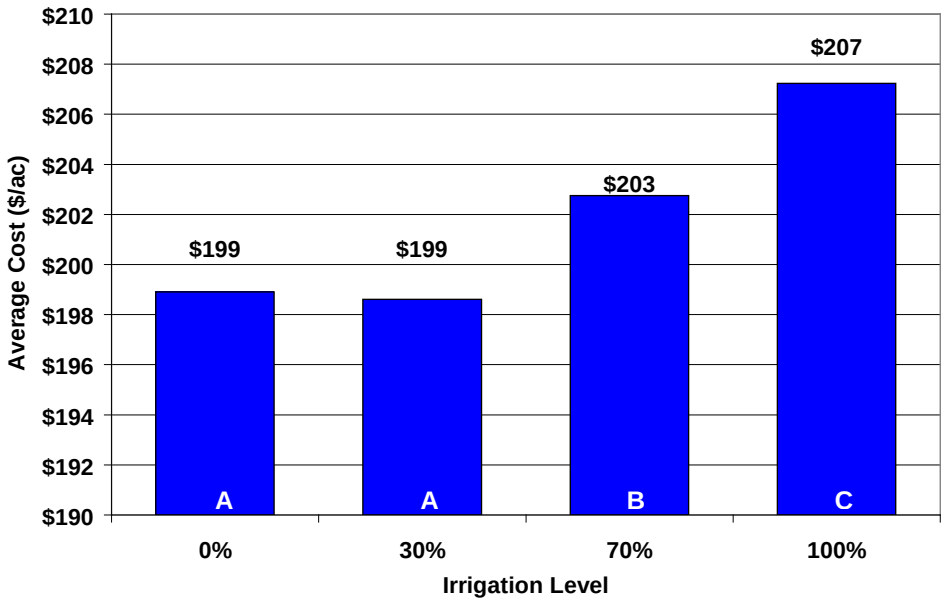


Figure 2. Average cost by irrigation level, across tillage.
[A, B] Different letters indicate significant difference at α=0.05

Figure 3 breaks the costs down by tillage and irrigation level. On average, strip till plots cost $3.50/ac more than the conventional plots. This was mainly the result of yield-based costs, because the strip tilled plots had a yield advantage over the conventional plots.

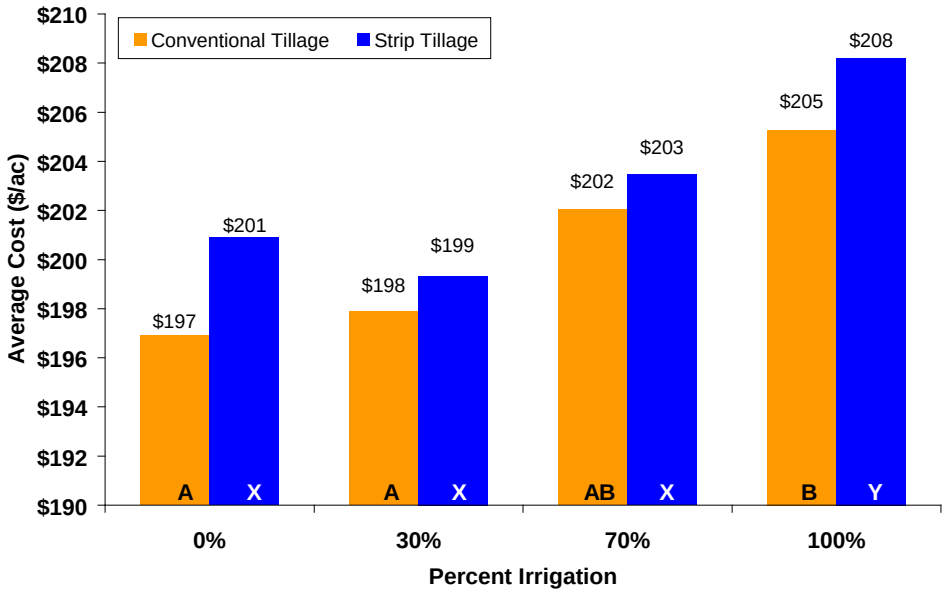


Figure 3. Average cost by tillage and irrigation.
[A, B, X, Y] Different letters indicate significant difference at α=0.05

Figures 4 and 5 show the average adjusted revenue (defined as revenue adjusted for irrigation application, tillage and ginning, storage and warehousing costs with a credit for

cottonseed). The deficit irrigated plots appeared to be more profitable during 2009 (Figure 4). The 0%, 30% and 70% irrigation levels were $90/ac more profitable on average than the 100% irrigation plots. The conservation tillage plots also appeared to be more profitable (Figure 5). At the 100% irrigation level, strip till plots were more profitable than the conventional till plots by an average of $71/ac.

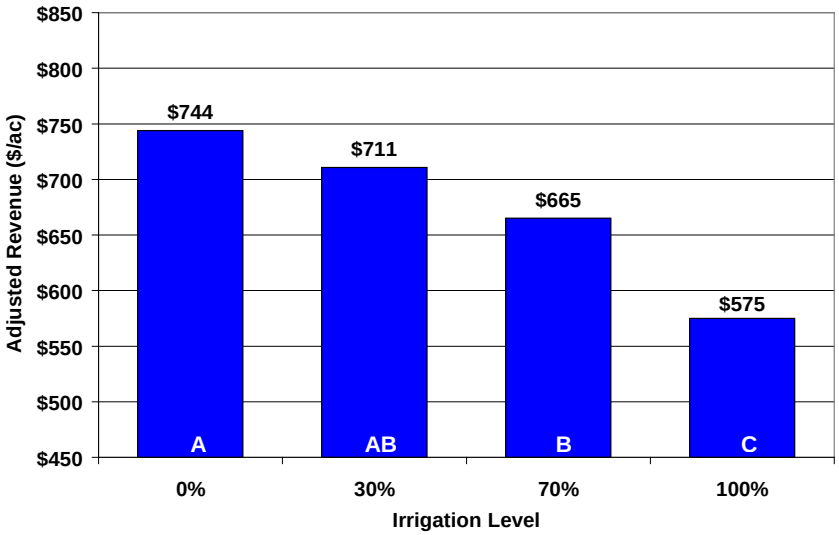


Figure 4. Average adjusted revenue by irrigation level, across tillage.
[A, B] Different letters indicate significant difference at α=0.05

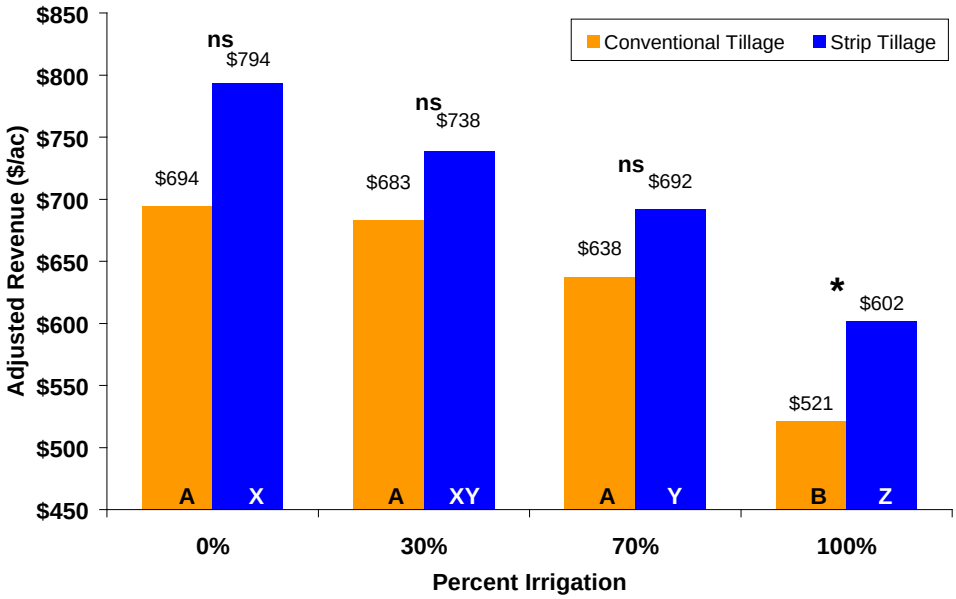


Figure 5. Average adjusted revenue by tillage and irrigation.
[A, B, X, Y] Different letters indicate significant difference at α=0.05
* Denotes significant difference in tillage at the 100% irrigation level

An analysis of risk, or variance, was also conducted (Figure 6). The average adjusted revenue and corresponding variance were plotted to show a risk-return framework for tillage and irrigation level. The data indicate that plots receiving higher irrigation amounts had less risk, but also less reward (lower average adjusted revenue). In other words, the average adjusted revenues were more consistent at the higher irrigation levels, but were consistently less in value. The lower irrigation levels had more variance in the amount of adjusted revenue (profit potential) but were more likely to have a higher profit potential than the higher irrigated plots.

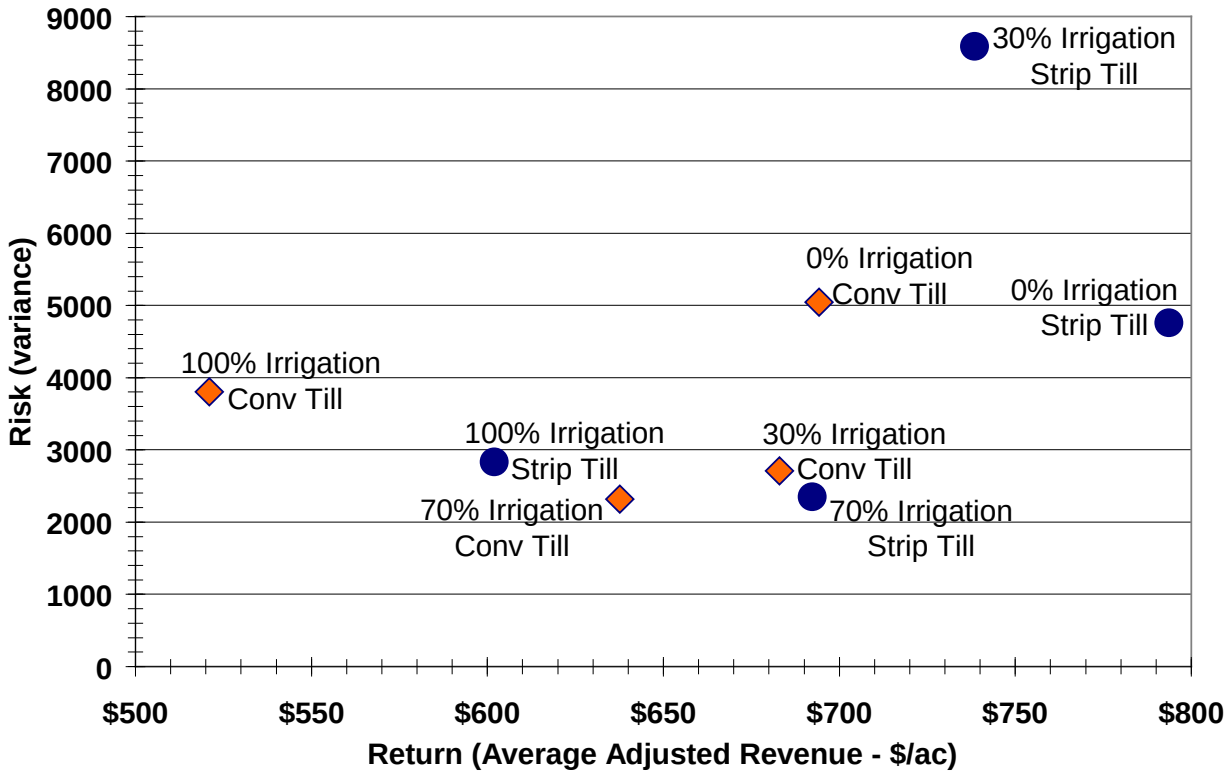


Figure 6. Risk-return plot by tillage and irrigation

The results are not fully conclusive because they are based on only one year of data. Furthermore, heavy rains throughout the growing season likely had a negative impact on yield for the plots at the 100% irrigation level. Farmers should consider future precipitation expectations in addition to the soil-based watermark sensors to determine irrigation application amount and timing. Further research is needed to compare yields of conventional and conservation till cotton under full and deficit irrigation.

## Acknowledgments

The authors wish to express appreciation to the Georgia Cotton Commission and Cotton Incorporated for financial support of this research.

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# COLQUITT COUNTY SYSTEMS TRIAL

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## Introduction

In 2009, over 83% of Georgia's cotton acreage was planted to BR (Bollgard® plus Roundup-Ready®) technology with over 82% of the states acreage planted to a single variety - Deltapine 555 BR (USDA-AMS, 2009a). Registration for this and all single-gene Bollgard technology and related variety types (B and BR) expired September 30, 2009. Single-gene plantings in 2010 will be limited to remaining seed in stock purchased prior to the expiration. It is estimated that less than 35% of Georgia's cotton acreage will be planted to BR technology in 2010.

Because this technology has dominated the Georgia cotton landscape and because one variety, DP555BR, accounted for the vast majority of these acres, Georgia producers are concerned about the loss of single-gene technology, and more specifically, DP555BR. Grower surveys conducted in Colquitt County during the winter and spring of 2009 indicated that, while producers planned to plant significantly more acres of available two-gene technologies (B2 & W) in 2009, they would not embrace these technologies at a level adequate to provide them with the significant experience or confidence going into the 2010 season.

## Objective

Growers lack experience with non-BR technology and varieties other than 555, specifically. Two-gene technologies (B2 or W) often come packaged with Roundup Ready Flex® (RF) rather than R. Furthermore, due to the rapid increase/spread of glyphosate resistance in Palmer amaranth, producers require good local data on the production, performance and economics of Liberty-Link (LL) technology. This LL technology allows them to use an Ignite (glufosinate) herbicide-based program for control of this weed.

The objective of this study was to compare lint yield, lint turn-out, cottonseed yield, fiber quality, cost of production, and net return for B2RF, WR, WRF and LLB2 technologies.

## Materials and Methods

This research was conducted at Windy Pond Farm, Doerun, GA in Colquitt County. Producer cooperators were Tony Lassiter and Kelly Walker. Production was conventional tillage, irrigated. The test was planted on May 11, 2009. All varieties were planted on 36-inch row spacing at a rate of 2.5 seed per foot of row (36,300 seed/acre).

The test consisted of 7 varieties, in 4 technology packages: LLB2- FiberMax 1735 and 1845, WR- Phytogen 370, WRF- Phytogen 375, and B2RF- DeltaPine 0935, FiberMax 1740, and Stoneville 5458. Variety selection for inclusion in the test was made by the participating seed company from a list compiled by researchers based on technology and germplasm diversity to fit the Colquitt County area. The test consisted of field length plots. Each plot was approximately the same length and was measured with GPS equipment to determine exact harvested area. The 7 varieties were randomized once as shown in Figure 1. This pattern was then repeated 2 more times in the same field for a total of three replications.


Figure 1. Example of variety plot design, replicated 3 times.

The sprayer was 30 rows (90 feet) wide. LL varieties (FM 1735 and 1845) were grown side-by-side so both could be sprayed in the same pass over the field. Every other plot was 18 rows wide. Rows 13-18 of the 18-row plots were the spray middle and not harvested to avoid any effects of the sprayer pass or formation of a traffic pan. A Widestrike variety (PHY 370 or 375) was planted on either side of the LL plots to intercept any Ignite or glyphosate drift which may cause injury and impact results of the competing technology. Six rows of each plot were harvested (Figure 1).

Herbicide and insecticide applications were made in accordance with UGA Extension recommendations (Roberts, et al, 2009) and the technology requirements for each variety. Each variety also received insecticide, fungicide, and nematicide seed treatment. The FiberMax and Stoneville varieties were treated with Aeris plus Trilex seed treatment. The Phytogen varieties were treated with Avicta. The DeltaPine

varieties were treated with Acceleron (Acceleron by Monsanto will not be commercially available until 2011. For this study, Acceleron was priced the same as Avicta).

All other inputs and production practices were the same regardless of variety and technology. All varieties were treated the same in fertilizer application and defoliation. Each variety was evaluated individually to determine plant growth regulator (PGR) needs. There were no differences noted, thus each variety received the same amount of PGR at similar timing of application.

All plots were harvested on October 21, 2009. Each plot was individually harvested with a 6-row cotton picker and weighed using a scaled boll buggy to determine the seed cotton yield per acre based on the weight and exact harvested area of each plot.

A 25-30 lb seedcotton sample was randomly collected from each plot and ginned at the UGA Microgin in Tifton. Both lint and seed weight were determined from the sample. Lint turnout (lint weight as a percent of seedcotton weight) was determined and applied to the seedcotton yield from each plot to determine lint yield per acre.

The ginned cotton from each plot was HVI classed at the USDA Cotton Classing Office in Macon. Lint was valued based on fiber quality. Lint price was the Georgia average price received during November and December 2009 for base quality Color 41-Leaf 4/ Staple 34 cotton (USDA, 2009b) then adjusted for the fiber quality of each plot. Cotton seed was valued as the Georgia average price received during November and December 2009 (USDA, 2010).

For each variety plot, “system cost” was calculated. This cost was seed, technology fees, seed treatments, herbicides, insecticides, and the cost of application. All other inputs and production practices were the same regardless of technology and variety. For each variety plot, the net cost of ginning, warehousing, storage, and promotions and marketing (GSWM) was also calculated. This must be considered to account for differences in lint yield, lint turn-out, and cottonseed yield. This was 11.19 cents per pound (Shurley and Smith, 2008) minus the value of cottonseed. Net return was calculated for each variety plot as follows:

Net Return = (Lint Yield/Acre x Price) – SC – GSWM

where Price = the quality adjusted price/lb of lint;
SC = systems costs; and
GSWM = net cost after cottonseed value.

## Results and Discussion

All varieties received 1.75 pt/acre of Treflan impregnated on fertilizer which was preplant incorporated prior to bedding and planting (Table 1). There was no charge for impregnation. No separate cost of application was charged since the Treflan was applied with the fertilizer. All varieties also received 14 oz of Reflex at planting.

Each system received 3 post-emergence herbicide applications. There was no difference in herbicide applications between Roundup Ready® varieties (WR) and Roundup Ready Flex® varieties (FM1740B2RF, DP0935B2RF, PHY375WRF). Table 1 summarizes the applications made for R/RF and Liberty-Link (LL) varieties.

There was no difference in insect control (sprays) required for B2 and W varieties (Table 2). B2 and W varieties required the same spray materials and applications. PHY370 and 375, however, did require additional treatment for thrips. Over 7 inches of rain fell within the first 15 days after planting. This resulted in soil saturation and caused leaching of the insecticide from the Avicta seed treatment, but not from the Aeris and Acceleron treatments. The differences in thrips control requirements between varieties were due to the solubility of the insecticidal components of the seed treatments used. Orthene was applied to PHY370 and 375 to control thrips.

Table 1. Herbicides applied by technology.

| | Roundup and Roundup Ready Flex | | Liberty Link | |
|---|---|---|---|---|
| Application | Materials | Rate Per Acre | Materials | Rate Per Acre |
| Preplant | Treflan | 1.75 pt | Treflan | 1.75 pt |
| PRE- At Planting | Reflex | 14 oz | Reflex | 14 oz |
| POST OTT | Touchdown<br>+Staple | 23 oz<br>2.6 oz | Ignite | 29 oz |
| POST Directed | Glyphosate<br>+Envoke | 32 oz<br>.125 oz | Ignite | 29 oz |
| POST Layby | Diuron<br>+MSMA | 2 pt<br>2 pt | Diuron<br>+Ignite | 2 pt<br>23 oz |

Table 2. Insecticide spray applications.

| Application | Materials | Rate Per Acre |
|---|---|---|
| Spray OTT[1] | Orthene | 3.2 oz |
| Spray OTT | Bidrin<br>+bifenthrin | 4 oz<br>4 oz |
| Spray OTT | Bidrin<br>+bifenthrin | 4 oz<br>4 oz |
| Spray OTT | bifenthrin<br>+Curacron | 6.4 oz<br>12 oz |

[1]Tankmixed with Touchdown. Applied to PHY370 and 375 and DP0935 only.

## Yield and Fiber Quality

Yield for the 7 varieties ranged from 1,390 lbs/acre to 1,194 lbs per acre (Table 3). The highest yielding variety was FM1740B2RF, but the 4 highest yielders were not statistically different. These varieties were FM1740B2RF, ST5458B2RF, PHY375WRF, and PHY370WR.

The three B2RF varieties averaged 1,342 lbs/acre. The two Widestrike® (WR and WRF) varieties averaged 1,304 lbs/acre. The two Liberty-Link® (LL) varieties averaged 1,235 lbs/acre.

Fiber quality was not statistically different among varieties. FM1845LLB2 had the highest Staple, Strength, and Uniformity of the 7 varieties in the test. Staple for 1845 was statistically higher than all other varieties but Strength and Uniformity were not. Color, Leaf, and Micronaire were not different among any varieties.

The average price for "base quality" Color 41-Leaf 4 and Staple 34 for the two month period November-December 2009 was 69.205 cents per pound (USDA-AMS, 2009b). This price was adjusted for fiber quality premiums and discounts on the quality of each variety. Price did not vary greatly but ranged from a high of 71.83 cents per pound for PHY375WR to 70.77 cents per pound for ST5458B2RF. All varieties graded well and there were no discounts for any quality parameters.

Table 3. Lint yield, turnout, seed yield, and fiber quality by variety.

| | Lint Yield[1] | % Lint Turnout | Seed Yield | C1 | C2 | Leaf Grade | Staple[2] | Strength | Micronaire | Uniformity |
|---|---|---|---|---|---|---|---|---|---|---|
| FM1740B2RF | **1,390** | 39.31 | 1,872 | 3.67 | 1.00 | 3.00 | 36.7 | 31.0 | 4.5 | 82.8 |
| ST5458B2RF | **1,340** | 39.00 | 1,884 | 3.33 | 1.00 | 4.00 | 36.5 | 30.1 | 4.8 | 82.1 |
| PHY375WRF | **1,310** | 39.23 | 1,749 | 3.00 | 1.00 | 2.67 | 36.2 | 30.6 | 4.3 | 83.1 |
| PHY370WR | **1,297** | 39.86 | 1,710 | 3.33 | 1.00 | 3.33 | 35.3 | 30.6 | 4.6 | 82.8 |
| DP0935B2RF | 1,296 | 41.13 | 1,645 | 3.00 | 1.00 | 3.33 | 36.4 | 30.1 | 4.5 | 82.9 |
| FM1735LLB2 | 1,275 | 36.68 | 1,931 | 3.67 | 1.00 | 3.00 | 36.5 | 31.0 | 4.5 | 82.8 |
| FM1845LLB2 | 1,194 | 36.43 | 1,848 | 4.00 | 1.00 | 3.33 | **38.7** | 32.6 | 4.6 | 83.4 |

[1]Top four varieties (in bold) not statistically different at 95% probability. LSD = 201 lbs/acre.
[2]Highest Staple (in bold) is statistically different from all other varieties at 95% probability.

## Costs and Net Returns

This analysis compares costs and net return associated with yield, fiber quality, and choice of seed variety and technology (Table 4). Costs include seed, technology fees, insecticide and fungicide seed treatments, herbicides, insecticides, cost of application, and ginning, storage, warehousing, and marketing and promotion (GSWM). GSWM is the net cost after deducting the value of cottonseed. Cottonseed was valued at $127 per ton (USDA, 2010). All other inputs and costs were the same for all varieties and technologies and thus do not need to be considered for comparison.

Seed and technology fees ranged from lows of around $66 per acre to highs of almost $80 per acre. Including seed treatments, cost ranged from about $85 per acre to around $97 per acre. WR and LLB2 were the least expensive in terms of seed costs and technology fees. B2RF was the most expensive.

Herbicide expenses for LL were cheaper than R and RF. Herbicide costs were $54.01 per acre for LL varieties and $60.44 for R and RF varieties. Insecticides were the same for B2 and W. Cost was slightly higher for varieties PHY375 and 370 due to the use of Orthene for thrips control but that was not a function of system choice.

Total system costs ranged from $178.98 per acre for FM1845LLB2 and FM1735LLB2 to $198.28 per acre for FM1740B2RF and ST5458B2RF. LLB2 was the least expensive system at an average of approximately $179 per acre, B2RF averaged approximately $198 per acre, and WR/WRF averaged $191 per acre.

When considering both systems cost and the net cost of ginning (Net GSWM) due to lint turn-out and cottonseed yield, FM1740B2RF resulted in the highest net return at $755.56 per acre. The next highest net return was for ST5458B2RF at $719.59 per acre.

Net returns followed yield. Regardless of variety and technology, the highest 3 yielders were also the highest in net return. However, FM1735LLB2 ranked 4$^{th}$ in net return although it ranked 6$^{th}$ in yield. This was somewhat due to the low cost for the LL technology, but largely due to high seed yield resulting in low net cost of ginning.

## Summary

The objective of this study was to compare lint yield, lint turn-out, cottonseed yield, fiber quality, cost of production, and net return for B2RF, WR, WRF and LLB2 technologies. Analysis compared costs and net return associated with yield, fiber quality, and choice of seed variety and technology. The test consisted of 7 varieties, in 4 technology packages: LLB2- FiberMax 1735 and 1845, WR- Phytogen 370, WRF- Phytogen 375, and B2RF- DeltaPine 0935, FiberMax 1740, and Stoneville 5458. Herbicide and insecticide applications were made in accordance with UGA Extension recommendations and technology requirements for each variety.

Table 4. Value, costs, and net return by variety.

| | Lint Yield | Price | Lint Value | Seed | | | Herb-icide | Insect-icide | Appl. | Total System Costs | GSWM | | | Net Return |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Seed | Tech | Treat. | | | | | GSWM | CS Value | Net GSWM | |
| FM1740B2RF | 1,390 | .713 | $991 | 21.12 | 58.33 | 18.27 | 60.44 | 26.34 | 13.78 | $198.28 | 155.68 | 118.87 | $36.81 | $755.56 |
| ST5458B2RF | 1,340 | .708 | $948 | 21.12 | 58.33 | 18.27 | 60.44 | 26.34 | 13.78 | $198.28 | 150.08 | 119.63 | $30.45 | $719.59 |
| PHY375WRF | 1,310 | .718 | $941 | 19.89 | 55.18 | 18.07 | 60.44 | 28.14 | 13.78 | $195.50 | 146.72 | 111.06 | $35.66 | $709.81 |
| FM1735LLB2 | 1,275 | .712 | $908 | 37.62[a] | 28.96 | 18.27 | 54.01 | 26.34 | 13.78 | $178.98 | 142.80 | 122.62 | $20.18 | $708.77 |
| PHY370WR | 1,297 | .714 | $927 | 19.89 | 45.67 | 18.07 | 60.44 | 28.14 | 13.78 | $185.99 | 145.26 | 108.59 | $36.67 | $704.05 |
| DP0935B2RF | 1,296 | .715 | $927 | 20.62 | 58.24 | 18.07 | 60.44 | 26.34 | 13.78 | $197.49 | 145.15 | 104.46 | $40.69 | $688.46 |
| FM1845LLB2 | 1,194 | .710 | $848 | 37.62[a] | 28.96 | 18.27 | 54.01 | 26.34 | 13.78 | $178.98 | 133.73 | 117.35 | $16.38 | $652.74 |

[a]Includes Liberty-Link (LL) fee.

Seed and technology fees ranged from lows of around $66 per acre to highs of almost $80 per acre. WR and LLB2 were the least expensive in terms of seed and technology fees. B2RF was the most expensive. Total system costs ranged from $178.98 per acre for FM1845LLB2 and FM1735LLB2 to $198.28 per acre for FM1740B2RF and ST5458B2RF. LLB2 was the least expensive system at an average of approximately $179 per acre, B2RF averaged approximately $198 per acre, and WR/WRF averaged $191 per acre.

FM1740B2RF resulted in the highest net return at $755.56 per acre. The next highest net return was for ST5458B2RF at $719.59 per acre. Net returns followed yield. Regardless of variety and technology, the highest 3 yielders were also the highest in net return. Costs due to choice of technology (seed, technology fees, herbicides, insecticides, and application) varied about $20 per acre. Yield, therefore, remains an important consideration in variety and technology choice.

## Acknowledgments

Appreciation is expressed to cotton producers Tony Lassiter and Kelly Walker and to Delta and Pine Land/Monsanto, Phytogen, and Bayer CropSciences (FiberMax and Stoneville) seed companies for their contributions to this study.

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# COTTON FIBER QUALITY MEASUREMENT USING FRAUNHOFER DIFFRACTION

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## Abstract

Properties of single cotton fibers may provide a better way for cotton processors and producers to predict and characterize the properties of a bulk sample of cotton. In this work a relatively simple and easily replicable approach is developed to determine the diameter ("ribbon-width") of single cotton fibers and this knowledge may then be used to characterize single cotton fiber quality parameters such as fineness, maturity, and micronaire. The overall objective of this research was to conduct a fundamental study of the optical properties (light diffraction) of individual cotton fibers with the interaction of a monochromatic light beam. Diffraction patterns generated from the interaction of each cotton fiber and the laser light are captured by using a linear CCD camera. Each fiber was measured at multiple points. The diameter of each fiber was determined from the distance between consecutive fringes of the diffraction patterns generated. Preliminary results show that the average fiber diameters obtained fall within the range of 15-20μm, which is approximately the expected range for a cotton fiber. The shape of the diffraction patterns observed is consistent with the shape of the theoretical solution of light obstructed by a thin wire/fiber. Moreover, the distribution of the diameters follows the tendency of a normal distribution. The approach used in this research may be integrated with existing cotton fiber measurements systems such as HVI and AFIS systems to provide a better characterization of cotton fiber quality.

## Introduction

The use of cotton for a particular application depends on the quality of the cotton. The quality of cotton depends on the cotton fiber properties, namely length, length uniformity, strength, fineness, maturity, trash content, leaf grade, color grade, preparation, and extraneous matter. Currently, the methods used to characterize the quality of cotton fibers involve analyzing the properties of bulk samples. The properties of single cotton fibers if needed are then extracted from the properties of the bulk samples. Although, analyzing the properties of bulk samples of cotton fibers may provide a cheap and rapid technique to characterize cotton fiber quality, it may not however provide the properties of individual cotton fibers. Fundamentally, knowledge of a single cotton fiber should be used to characterize the properties of a bulk sample of cotton.

One method to analyze individual fibers may be to develop an optical sensing tool that can be used to characterize single cotton fiber quality as proposed by Thomasson et al. (2009). Such an optical approach has been developed in this study. Assuming that cotton producers and processors have the same method of characterizing cotton fiber quality, producers can prevent the amount of discount they may receive by turning in cotton fibers they know have a high quality and processors will not need a set of

multiple devices to determine the quality of a bale of cotton. Variations in the quality of cotton fibers exist between different portions of a cotton field, from plant to plant, and even within the same plant. Moreover, the quality of fibers on a single seed may vary in length, shape, thickness, and maturity as described in Jost (2005). By studying individual cotton fibers from different parts of a seed, different plants, and different locations on a field, it may be possible to determine the causes of the variation in cotton fiber quality and this is similar to the work done by Cui et al. (2003).

The overall objective of this research project was to conduct a fundamental study of the optical properties of individual cotton fibers with the interaction of a laser beam and how this interaction can be related to cotton fiber quality parameters, such as fineness, maturity, and micronaire. More specifically the experimental approach used in this work may be used to develop a simple and inexpensive optical sensing tool to rapidly and accurately measure single cotton fiber quality parameters, investigate the anisotropic nature of the diameter of single cotton fibers by analyzing multiple points along each fiber, and to develop a software program that may be used to automatically characterize the quality of single cotton fibers.

## Materials and Methods

The schematic of the experimental setup used in this work to study the optical properties of single cotton fibers is shown Figure 1. The experimental setup, which was assembled in Advanced Fiber Quality Sensing Laboratory (AFQSL), consists of a light source, polarizing lenses (P1), an iris (I1), a single cotton fiber holder (S1), a collecting lens (CL), and a linear CCD camera (CCD).

The cotton samples used for this study were obtained from the USDA classing office and from the University of Georgia Micro Gin facility. Eight (8) cotton varieties with different micronaire values were obtained and used for this work. Specifically, the cotton fiber varieties are Lint 101 (BCS 614), Lint 108 (ST 5327), Lint 110 (DPL 0924), Lint 203 (PHY 370), Lint 205 (DPL 901), Lint 209 (BCS 0727), USDA 2.6, and USDA 5.47. A total of fifty-six (56) fibers (seven (7) fibers from each variety) were used for the preliminary results presented in this paper. Over 50 diffraction patterns at different points along the axis of each fiber were measured. By measuring multiple points along each fiber the anisotropy (non-uniformity) of the diameter of cotton fibers can be studied and analyzed.

The diameter of a single cotton fiber can be computed from the diffraction pattern generated by illuminating it with a light source. Figure 2 shows a theoretical diffraction pattern simply to illustrate how the diameter of a fiber can be computed from a diffraction pattern. The normalized intensity (in arbitrary units) is plotted against the length of the observation plane. In order to compute the diameter of a fiber, the dark fringes (low peaks) are identified on either side of the center peak (center fringe). The dark fringes are identified with circular symbols in Figure 2. The distance between consecutive dark fringes are then calculated. A similar technique was used to calculate the diameter of wider wires/fibers in Khodier (2004). Ideally the distance between the

first and second order fringes should be the same for the distance between the second and third order fringe and this applies for higher order fringes. In some cases we were only able to observe first and second order fringes on either side of the center fringe.

## Results and Discussion

In Figure 3, we present diffraction patterns generated as a result of illuminating with the laser light at single point along the axis of a single cotton fiber. Although the figures show diffraction patterns for the Lint 101, Lint 209, USDA 2.6, and USDA 5.47 varieties, similar patterns were observed for the other four cotton varieties used in this work. Figure 3 shows the normalized intensity of the diffraction pattern versus the position along the observation plane. The symbols in Figure 3 represent the experimental data and the solid lines are the denoised signals. The noisy nature of the experimental data obtained presented a challenge (determining the precise location of the high and low peaks) in interpreting the diffraction patterns therefore the experimental signals were denoised by using a MATLAB denoising function. As the figures show, the denoised signals agree well with the experimental data.

The selected diffraction patterns presented in Figure 3 are in good agreement with the theoretical diffraction pattern (Figure 2). As expected, we observed a high peak (center fringe) in the diffraction pattern as well as first and second order fringes on either side of the center fringe. In some cases we were able to observe what may appear to be higher order peaks as shown in Figure 3, but further work is needed to verify if indeed these correspond to higher order fringes. It would appear from Figure 3 that there are two center fringes in each diffraction pattern but this is not the case. In order to prevent the CCD line camera from being saturated, the portion of the observation plane where the center fringe was incident on the CCD was blocked out. The width of the block out material used was chosen so as to not block out the entire center fringe but leave some portion unblocked to verify that the shape of the diffraction patterns generated agreed with the theoretical solution. This explains why the diffraction patterns appear to have two center fringes.

It was observed that the height of the higher order peaks (fringes) is not uniform from pattern to pattern and this may be due to the nature of the cotton fiber itself. Further analysis of the preliminary results presented in this work will be needed to determine the cause(s) of the change in shape of the diffraction patterns. This change in shape of the diffraction patterns was observed to vary within the same cotton variety as well as between different cotton varieties. Not all diffraction patterns generated at each point along a single cotton fiber generated the same results presented in Figure 3. In some cases there were no diffraction patterns noticeable in the observation plane even though the cotton fiber was clearly illuminated by the laser beam. The inability to measure diffraction patterns may be attributed to two main reasons. The width of the CCD line camera was so small that any slight deviation of the diffraction pattern from the detecting portion of the camera will result in diffraction patterns that cannot be observed. Furthermore, from the first point it can be deduced that the angle at which the diffraction pattern is incident on the CCD camera is very important. In order to relax

this limitation(s) it may be useful to use a two-dimensional observation plane as opposed to a line observation plane. In this way the deviation of the diffraction pattern will be observed irrespective of the angle of deviation.

In Table 1 we present the average diameter for each cotton variety obtained by using our laser diffraction technique. These preliminary results seem encouraging because the average diameters fall within the expected range for cotton fibers in general, that is, between 15-20μm. For more accurate results, more fibers will need to be tested to form a better representation of the particular variety. The average diameters obtained for each variety are too close to each other to be used to differentiate between the cotton varieties but all the varieties used for this study have different micronaire values. If we can relate the measured diameter of each fiber to the micronaire values, then we may be able to differentiate each variety by using our optical method.

A single cotton fiber or a sample of cotton fibers observed under a microscope reveals that the diameter of a cotton fiber is not uniform along the fiber axis. A distribution of average diameters measured for the Lint 108 cotton variety is presented in Figure 4. The expected results from such a study would suggest that the shape of such a distribution should show a normal (Gaussian) distribution. This may be the case if more fibers and more points are measured. Nonetheless, encouraging results can be seen from Figure 4. The figure shows that most of the points measured were about the average (15 μm). The values of the diameters seem to fall off on either side of this average value. Although not the expected normal distribution, the trend seen in the figure suggests the same trend as that of a normal distribution. A very similar trend may be deduced from Figure 4 but further work is needed to make such a concrete generalization.

## Conclusion

The optical properties of single cotton fibers was studied and analyzed by illuminating single cotton fibers with a monochromatic laser light. The diffraction pattern generated as a result of the interaction between the laser light and each single cotton fiber was analyzed and presented. A relatively simple methodology was used to measure the average diameter (ribbon-width) for each cotton variety used in this work. Diffraction patterns generated are in good agreement with the theoretical solution even though the theoretical solutions are for fibers illuminated by uniform light and not Gaussian light beams as the approach used in this study. Numerical algorithms and techniques have been developed to detect the dark fringes within each diffraction pattern and to compute the average diameter of a single point along the fiber axis. Diameter measurements obtained fall within the expected range (15~20 μm) for the diameter of a cotton fiber.

More work is needed to determine the quality parameters of the single cotton fibers. Since the micronaire values for each cotton variety used are known then in order to validate the methodology an algorithm to compute micronaire values is paramount in the next stage of this work. The distribution of diameters for each cotton variety follows the trend of a normal distribution and more samples will be tested to provide a more accurate generalization of a cotton variety. Obtaining consistent diffraction patterns for

every point along a fiber may be accomplished by using a two-dimensional observation plane instead of a line CCD camera which may not be able to detect diffraction patterns that are not along the same axis.

It can be deduced from the preliminary results that the current methodology is capable of determining the diameter of single cotton fibers. A correlation between the measured diameter and cotton fiber quality parameters, specifically fineness, maturity, and micronaire will be developed to validate the accuracy of our technique. The diameter of single cotton fibers was verified to be anisotropic in nature confirming the presence of convolutions along the axis of the single fibers. Research currently underway will continue to optimize numerical techniques developed and to develop numerical models to determine the fineness, maturity, and micronaire values by illuminating single cotton fibers with a laser light.

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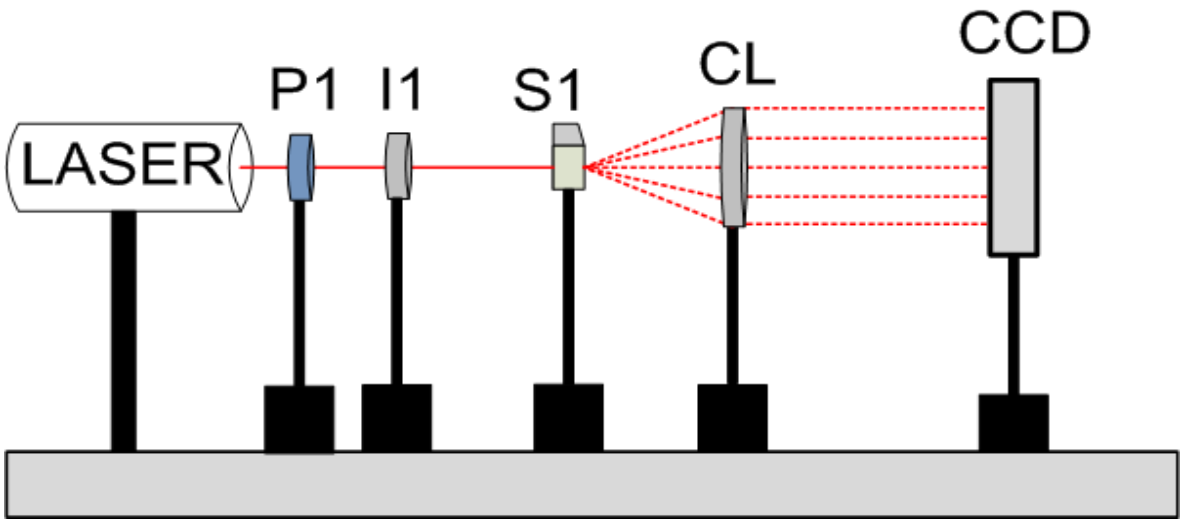


Figure 1. Schematic of experimental setup used to implement tabletop Fraunhofer diffraction.

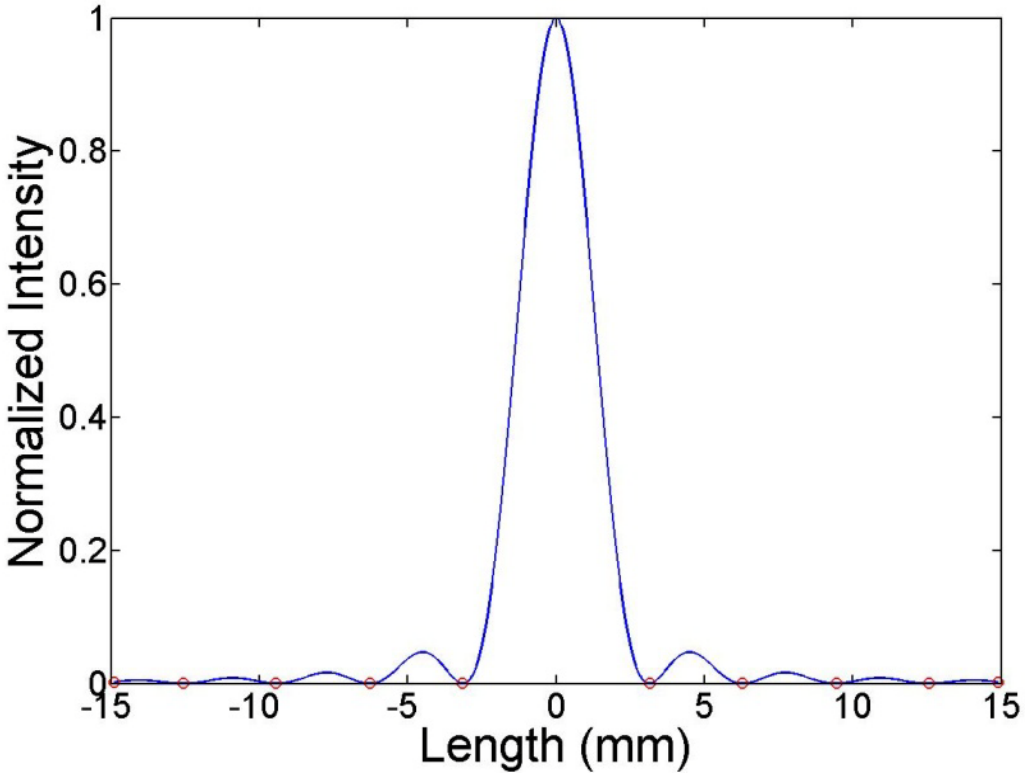


Figure 2. Theoretical solution for diffraction pattern generated by illuminating a single fiber.

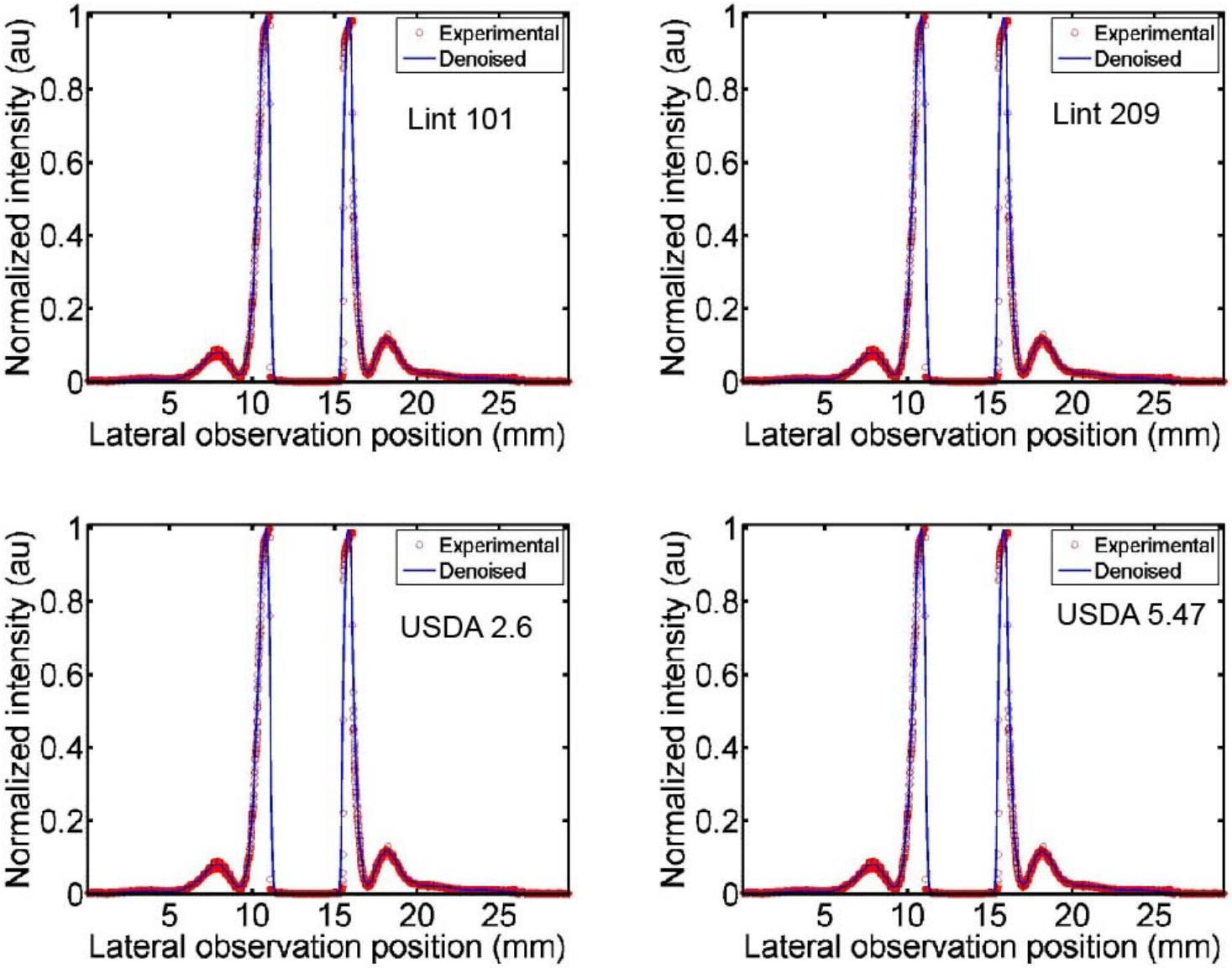


Figure 3. Sample diffraction patterns generated by illuminating a single cotton fiber of four cotton cultivars.

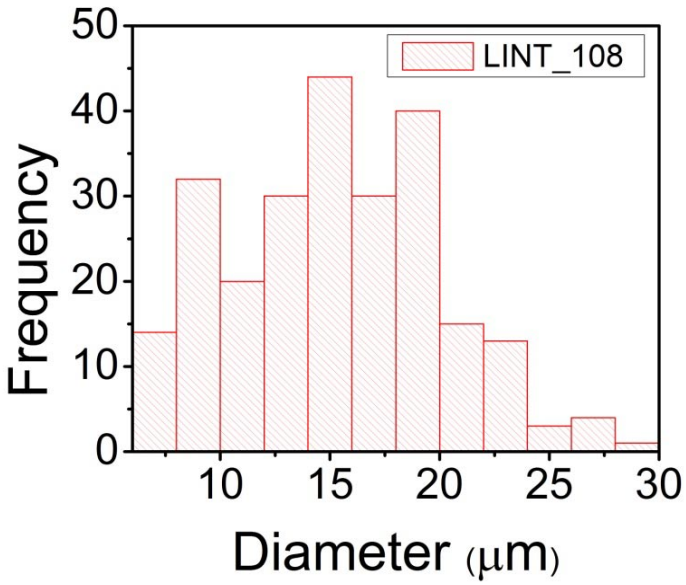


Figure 4. Distribution of cotton fiber diameters for the Lint 108 variety.

Table 1. Average diameter computed from the resulting diffraction pattern of each cotton variety.

| Cotton Variety | Average Diameter (μm) |
|---|---|
| LINT 101 | 16.517 |
| LINT 108 | 15.521 |
| LINT 110 | 15.354 |
| LINT 203 | 15.609 |
| LINT 205 | 17.182 |
| LINT 209 | 16.578 |
| USDA 2.6 | 15.195 |
| USDA 5.47 | 15.072 |

# COMPARISON OF THE UGA MICROGIN, A LABORATORY GIN, AND COMMERCIAL GINS IN GEORGIA: SECOND YEAR STUDY

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## Abstract

Previous studies have shown that small sampling methods and lab gin stands could not accurately predict the true fiber lint quality and lint yield. The UGA Microgin was built to simulate the performance of commercial gins and to gin cotton samples from the whole research plot. The goal of this study was to investigate whether the UGA Microgin can accurately estimate fiber properties of lint ginned from commercial gins. Six commercial gins in south GA were selected and compared with the UGA Microgin and a Continental Eagle 10-saw laboratory gin stand. Five cotton varieties (DPL 555, DPL 0935, FM 1740, ST 5458, and PHY 370) from non-irrigated and irrigated land were ginned in this study. Same cotton varieties from the same location were ginned across the three types of gin in order to have a fair comparison. Both the lint yield and HVI fiber quality data were compared among three types of gin. Nine HVI quality properties were analyzed by the one-way ANOVA test. The lab gin had zero success rate in estimating the performance of commercial gins in color grade and leaf grade. In contrast, the Microgin successfully predicted the color grade and leaf grade of lint ginned by commercial gins in 53% and 65% of times, respectively. The UGA Microgin had 77% and 82% success rates in estimating commercial gin performance for staple and uniformity, respectively; the lab gin stand only achieved 35% and 18% success rates in these two measures. These data confirmed that the UGA Microgin did a far superior job to the lab gin stand in estimating the fiber length and uniformity from commercial gins. The Microgin and lab gin stand did an equally good job in estimating commercial gins in micronaire and strength with a success rate of 65% in micronaire and 77-88% in strength. Given the large intra-sample variations in cotton samples and variations between commercial gins, these data provided strong evidence that the UGA Microgin performs better than the lab gin stand in estimating lint yield and most fiber quality properties obtained from commercial gins. This study proved that the UGA Microgin is a valuable tool for cotton research.

## Introduction

Cotton researchers generally use small research plot trials to evaluate fiber quality from certain varieties, different field treatments, as well as various growing conditions (Boykin, 2008). These small research plots cannot generate enough cotton samples for a commercial gin to separate the lint from seeds, which is a necessary step for fiber lint quality evaluation. Researchers typically use laboratory gin stands to gin a small amount of cotton samples collected from research plots by sub-sampling methods such as boll sample or grab sample (Calhoun et al., 1996). However, sub-sampling methods invariably leads to the biases due to lack of true representation of the whole research

plot (Boykin, 2008). Indeed, it has been well documented that gin machinery has a significant impact on fiber quality including length, color, trash content (Anthony, 1990; Anthony, 1994; Anthony, 2002). Therefore, the selection of the right gin is critical in estimating the true fiber quality of lint ginned from commercial gins.

The University of Georgia Microgin facility was built to address this issue. The UGA Microgin was designed to simulate commercial gins with all standard machinery and procedures typically used in commercial gins such as drying, seed cotton cleaning, and lint cleaning. However, as its name suggests, the UGA Microgin is in a much smaller scale than a typical commercial gin. All machine parts in the UGA Microgin is one foot wide compared to 8-10 feet wide in most commercial gins. The Microgin was designed to overcome limitations in small lab gins. It enables researchers to gin cotton samples harvested from the whole research plot for up to 2500 lbs, far exceeding the limit in laboratory gin stands. Nevertheless, one question still remains unanswered: whether the Microgin can better estimate lint yield and cotton fiber quality of lint ginned from commercial gins than lab gin stands? Although a few previous studies were attempted to fill this knowledge gap (Brown et al., 2004; Li et al., 2009), these studies had limitations by selecting only one commercial gin for comparison or not providing adequate sample replicates in fiber quality data for statistical analysis. The overall goal of this study was to investigate whether the UGA Microgin can outperform a laboratory gin stand in estimating lint yields and HVI fiber quality properties of lint ginned from the same seed cotton in commercial gins.

## Materials and Methods

The UGA Microgin was made by Lummus (Lummus Inc., Savannah, GA) and Cherokee (Cherokee Fabrication Inc., Salem, Alabama), and it uses the same equipment layout as used in a typical commercial gin. The major difference between the UGA Microgin and a commercial gins is that all the machines in the Microgin are one foot instead of 8-10 feet wide in most commercial gins. The equipment is arranged in the standard configuration for spindle picked cotton. Unlike the laboratory gin, the UGA Microgin provides full drying as well as seed cotton and lint cleaning. The schematic diagram of the UGA Microgin is illustrated in Figure 1.

Six commercial gins in southern Georgia were identified in this study. For the purpose of confidentiality, their names were coded by letters from A to F. The six gins had similar setup with cylinder seed cotton cleaner, dryer, stick machine, cylinder cleaner, extractor feeder, gin stand, and saw type lint cleaner. All six gins used the Samuel Jackson “moisture mirror” (Samuel Jackson, Inc., Lubbock, TX) to monitor the moisture content in cotton and to determine the dryer temperature. However, minor differences in setup existed. For instance, some gins were older than the others; two gins (A and B) were equipment with the Intelligen (Uster Technology, Knoxville, TN); one gin (E) by passed the stick machine; one gin (F) used two lint cleaners instead of one.
The lab gin stand used in this study is a 10 saw lab gin made by Continental (Continental Eagle Corporation, Pratville, AL). It does not have any drying, seed cotton cleaning, and lint cleaning equipment.

## Cotton sample collection

Cotton was grown in Colquitt County in Georgia and harvested in October and November, 2009. Five cotton varieties, i.e., DPL 555, DPL 0935, FM 1740, ST 5458, and PHY 370, were selected in this study due to their popularity and wide availability in Georgia. Some varieties were grown in non-irrigated and some were in irrigated land. In order to compare the performance of the three types of gin with the same cotton variety grown in the same field, cotton samples for the Microgin and lab gins stand were collected in the field from the boll buggy as the cotton was unloaded into the module builder. Five 30-lb seed cotton samples of each cotton variety were collected in mesh bags for the Microgin and five 1-lb cotton samples were collected in paper bags for lab gin use. These cotton samples in mesh bags and paper bags were put under the shelter immediately after the collection and were stored for about two months before they were ginned at the UGA Microgin facility. The modules stayed in the field mostly just for a few days before they were sent to one of six commercial gins for ginning. The number of cotton varieties ginned at each of the six commercial gins were not uniform due to logistic challenges. As shown in Table 1, commercial gin C ginned all five cotton varieties grown in irrigated land, while other gins ginned 2 or 4 varieties grown in either dry land or irrigated land.

## Cotton conditioning and ginning procedures

Cotton samples ginned by the Microgin and the laboratory gin stand were processed using a set standard operating procedure consisting of conditioning, weighing, ginning, and fiber sample collection. No conditioning procedure was performed in the six commercial gins, in which cotton moisture was monitored by moisture sensors and was controlled by dryers during the ginning process. Turnout at the commercial gins was obtained where available. Since commercial gins ran in a continuous mode, it was challenging to completely stop the commercial gin after one module was ginned, clean the gin, and measure the net lint weight. With our effort, seven varieties in two commercial gins (C and A-only for irrigated cotton) did this for us. Therefore, the turnout rates of these 7 varieties were accurate. For the other two commercial gins, the lint weight was estimated by the bale weight and seed weight, which was not as accurate as in the former case. In the other 6 cases, no turnout rate was recorded. Therefore, there were only 11 turnout rates provided by four commercial gins (A, C, E, and F), to which the turnout of the Microgin and the lab gin stand could be compared. HVI fiber quality data of each bale coming out of the module in the six commercial gins were presented in a standard USDA Classing Office report.

Fiber quality was evaluated by HVI (Uster Technologies, Knoxville, TN) at the USDA Cotton Classing Office in Macon, GA. Nine fiber quality parameters were selected for the purpose of comparison: staple length, uniformity, micronaire, strength, leaf grade, HVI trash, Rd, +b, and color grade.

## Statistical analysis

The one-way analysis of variance (ANOVA) was conducted to test equal means across three types of gins in nine quality parameters. Tukey's LSD (least significant difference) was chosen to determine the significant difference among treatments in ANOVA. ANOVA tests were evaluated at a significance level of 0.05. Standard error was used to depict the measurement variation. The SAS statistical software (SAS Institute, Cary, NC) was used for statistical test and data analysis. Since only one module of each variety was used for turnout rate calculation in the six commercial gins, the variation of turnout rates was not presented in the commercial gins.

# Results and Discussion

## Gin turnout rates

Figure 2 compares the lint yields (gin turnout) of three types of gins. Standard error was not shown in commercial gin data due to only one turnout rate was calculated from one module. From this figure, it is crystal clear that the turnout rates from the laboratory gin are consistently higher than those from Microgin and four commercial gins in all ten cases. The minimum difference between the lab gin stand and the Microgin is 1.5% and the maximum difference between these two gins is 4%. The differences between the lab gin stand and commercial gins range from 1% to 3.7% in ten cases.

Lint yields of cotton ginned from Microgin and commercial gins were comparable in the majority of ten comparisons. The differences between these two types of gins range from 0.1% to 1.9%, which are much smaller than those between the lab gin stand and the commercial gins. A comparison between the Microgin and commercial gin revealed that three commercial gins (A, C, E) had consistently higher or equivalent lint yields than the Microgin across all varieties, while the commercial gin F had lower lint yields than Microgin in the two varieties it ginned.

This result is in agreement with previous studies which reported that lab gins usually have 4-5% higher lint yield than commercial gins (Calhoun et al., 1996), due to the cleaning in the commercial gins. The UGA Microgin has similar machinery layout as most commercial gins, therefore, its turnout rates were comparable to those of commercial gins. However, difference exists between the Microgin and commercial gins and among commercial gins. The UGA Microgin has two saw type lint cleaners, while commercial gins A, C, and E had only one lint cleaner, which contributed to their general higher lint yield than that of Microgin. Instead, commercial gin F had two lint cleaners and usually lint cleaners from commercial gins are more aggressive than those from Microgin, which explains why commercial gin F had a lower lint yield than Microgin. Given the same ginning condition, lint yields should reflect the genetic nature of different cotton varieties. In general, all three types of gin showed similar relative difference among different varieties of cotton. However, the Microgin and the lab gin stand showed almost the exact same pattern across all 10 cotton sources. Commercial gins did not reflect the same relative difference among cotton varieties as the lab gin stand, partly

due to the large variation within and between different commercial gins. Another reason that caused this discrepancy is perhaps because the method to calculate turnout rate in some commercial gins were inaccurate.

Tables 2 and 3 show the fiber quality data obtained from three types of gin for dry land cotton and irrigated cotton, respectively. As shown in Tables 2 and 3, the HVI trash measurement of lint ginned by the Microgin and commercial gins did not show significant difference in 16 out of 17 comparison cases when dry land and irrigated cotton were considered together. The HVI trash of lint ginned by the lab gin stand is significantly higher (dirtier) than either Microgin or commercial gins in all 17 cases. Although measured by classers, leaf grade reflects the same trend as measured by the instrument: in none of these 17 cases, leaf grade from the lab gin agreed with either Microgin or commercial gins. The lab gin stand consistently had 2-4 grades lower (dirtier) in leaf grade than either the Microgin or commercial gins. In contrast, Microgin agreed with commercial gins in leaf grade in 11 out of 17 cases. Among those 6 cases that they did not agree, lint ginned by the Microgin was usually one grade higher (cleaner) than that ginned by commercial gins.

These results confirmed that seed and lint cleaning have significant impact on the trash content and leaf grade in the final lint. As reported previously, HVI trash decreased from about 6 to 4.9, 4.3, and 3.9 when one, two and three stages of lint cleaning were used, respectively (Anthony, 1990; Anthony, 1994). The cleaning machines removed significant amount of trash out of lint, which resulted in much cleaner lint. HVI trash measurement from the Microgin and commercial gins were almost identical and they were significantly lower than that from the lab gin stand. It proved that the seed cotton cleaner and lint cleaner in the Microgin achieved a similar effect as those in commercial gins, although the minor difference between these two types of gin suggest that the Microgin tended to provide cleaner lint than commercial gins. This discrepancy is largely because the Microgin had two saw type lint cleaners while most commercial gins (4 of 5) selected in this study had only one lint cleaner.

In Tables 2 and 3, among 17 cotton sources grown in both non-irrigated and irrigated land, the reflectance of cotton lint ginned at UGA Microgin and commercial gins did not show significant difference in 12 cases, in which lint ginned by these two types of gin showed significantly higher reflectance than that from the lab gin stand. In all 17 comparisons, lint ginned at the lab gin stand showed significantly lower reflectance than that ginned at commercial gins. In those 5 cases in which the Microgin and commercial gins did not agree (A1, F1, A2, C3, and C5), it was observed that the lint reflectance of the Microgin were always higher than that of commercial gins.
Although Rd is an indicator of lint reflectance which is determined by cotton genetic nature, trash content did affect HVI measurement of the Rd. As reported by Thomasson (1990), trash particles on the surface of lint have a negative effect on Rd measurement, i.e., two lint samples with identical color may have different Rd values due to different trash content on the their surface. Cotton lint ginned by the lab gin stand has more trash content and therefore it appears to be darker than that ginned by Microgin and commercial gins. Cotton lint ginned by the Microgin and commercial gins were cleaned

by seed cotton cleaner and lint cleaner, therefore, their reflectance seem to be comparable. Lint from the Microgin showed higher reflectance in five comparisons and it might suggest that the Microgin with 2 lint cleaners tend to have cleaner and brighter lint than the commercial gins that had single lint cleaners.

In both dry land and irrigated cotton samples, yellowness of lint ginned by the UGA Microgin was not significantly different from that ginned by commercial gins in 12 out of 17 comparisons. In contrast, the lab gin stand and commercial gins only agreed in 3 cases. Fiber yellowness from the Microgin and the commercial gins was significantly higher than that from the lab gin stand. Yellowness measured by HVI could also be affected by trash content in lint.

Considering dry land and irrigated cotton samples together, color grade of lint ginned by Microgin did not show significant difference from that ginned by commercial gins in 9 out of 17 comparison cases. Color grade from lint ginned by the lab gin stand (51 or 41) is significantly lower than that ginned by both commercial gins and the Microgin (41 or 31) in all 17 cases. This result is in accordance with the aforementioned differences in brightness and yellowness.

When comparing all samples, the staple length of lint ginned by the Microgin was not significantly different from that of the commercial gins in 14 of 17 cases, while the staple length of lint ginned by the lab gin stand was significantly higher than that of commercial gins in 11 cases. There are four cases in which all three types of gin showed no significant difference in staple length. As shown in Tables 2 and 3, the Microgin and commercial gins did not show significant difference in uniformity of lint in 14 cases; while in contrast, the lab gin stand only agreed with commercial gins in uniformity in 3 cases. For the rest of 14 cases, lint ginned by the lab gin stand has shown significantly higher uniformity than that ginned by commercial gins. The mean values of uniformity showed that lint ginned by the lab gin stand always had highest uniformity, while lint ginned by commercial gins had lowest uniformity in most cases.

The length and uniformity data agree with each other very well and they reflected the same fact that the ginning method has a significant impact on fiber length and uniformity. As reported by Anthony (1990), HVI length could be reduced about 0.05 cm (0.02 in) when lint cleaners were added to the gin equipment sequence. Microgin and commercial gins tend to have shorter fiber with lower uniformity than the lab gin stand because the seed cotton cleaner and lint cleaner tend to break more fiber and more fiber fractions in the final lint result in a shorter staple length and lower uniformity. The lab gin stand does not have any cleaning machineries that may damage the fiber in addition to the ginning itself and therefore longer staple and shorter uniformity was observed in samples ginned at lab gin stand. It seems that the Microgin, although in a much smaller scale, has the similar effect in creating fiber fraction as in most commercial gins. However, minor differences between the Microgin and commercial gins were also observed. The mean values of the fiber length and uniformity of lint ginned by the Microgin appeared to be slightly higher than those by commercial gins. This suggests that the commercial gins tend to be more aggressive than Microgin.

Another possible reason is that the commercial gins used higher heat to heat for drying purposes during the ginning process, which results in a dryer cotton that is more prone to damage and fraction.

### Micronaire

As shown in Tables 2 and 3, micronaire of lint ginned by all three types of gin did not show any significant difference among each other in majority of cases (10/17). In the remaining 7 cases, micronaire of lint ginned by the commercial gins is higher than that ginned by the Microgin and lab gin stand in 4 cases, and in the other 3 cases, it is either at the same level as in the lab gin stand or the Microgin. Given the large variation in cotton samples, this may indicate that the micronaire difference among three types of gin is just caused by random variation. The results clearly supported the previous studies that micronaire should not be affected by ginning methods. Micronaire is only dependent on fiber variety, maturity, and growing conditions.

### Strength

A similar pattern is observed in strength comparison. There are 11 cases in which all three types of gins did not show significant differences in strength, which suggests that fiber strength is not a quality property that can be easily affected by ginning methods. However, minor difference was observed between gins. The Microgin and commercial gins had the same strength statistically in 15 cases, while the lab gin stand agreed with commercial gins in 13 cases. A closer look at the mean values of strength data revealed that the Microgin and commercial gins had slightly lower strength values than lab gin stand in majority of these cases.

These data showed that strength is not affected significantly by ginning methods in general. However, a minor difference did show that the strength estimated by the Microgin was slightly closer to that obtained from commercial gins than that from the lab gin due to the similarity of ginning equipment set up between these two types of gin. Previous literature reported that strength of lint ginned by commercial gins tend to be smaller than that of lab gin stand due to the heat added to cotton samples in commercial gins and dryer lint tends to be more brittle in strength tests. This pattern was observed in the data collected from this study.

## Summary

A comparison of success rates between the lab gin stand and Microgin in predicting fiber quality of lint ginned by commercial gins were depicted in Figure 3. It is striking that the lab gin had zero success rate in estimating the performance of commercial gins in color grade and leaf grade. In contrast, the Microgin successfully predicted the color grade and leaf grade of lint ginned by commercial gins in 53% and 65% of times, respectively.

The Microgin and lab gin stand did an equally good job in estimating commercial gins in micronaire with a success rate of 65%. For strength comparison, although both the Microgin and lab gin stand did good job in predicting the performance of commercial gins, the Microgin showed a slightly higher success rate with 88% versus 77%. Given the large intra-sample variation in cotton samples, these data indicate that micronaire and strength are less likely to be affected by ginning methods.

Staple length and uniformity are two indices to describe the fiber length and its distribution. UGA Microgin had 77% and 82% success rates in estimating commercial gin performance for staple and uniformity, respectively; the lab gin stand only achieved 35% and 18% success rates in these two measures. These data confirmed that ginning methods have a significant impact on fiber length and uniformity. The UGA Microgin did a far superior job to the lab gin stand in estimating the fiber length and uniformity from commercial gins. The fiber length and uniformity obtained from the lab gin stand could not be used to estimate these values from commercial gins if an accurate estimation is required.

The data displayed in this study confirm that the UGA Microgin performs better than the lab gin stand in estimating lint yield and fiber quality obtained from commercial gins and is a valuable tool for cotton research.

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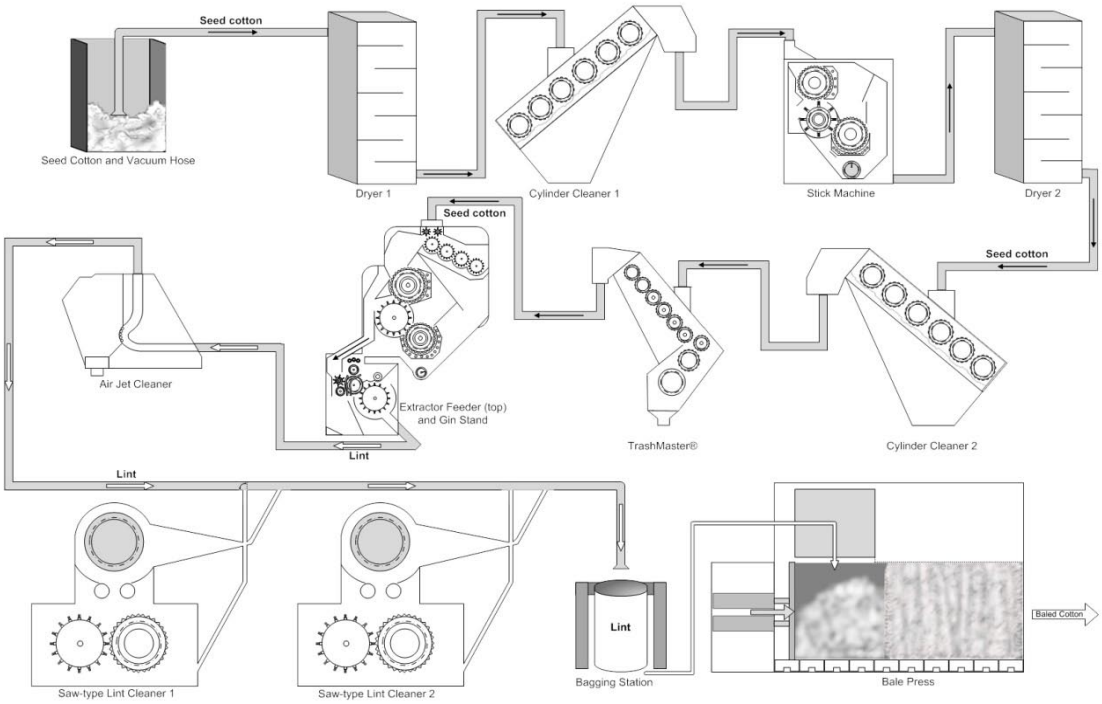


Figure 1. The schematic diagram of the UGA Microgin.

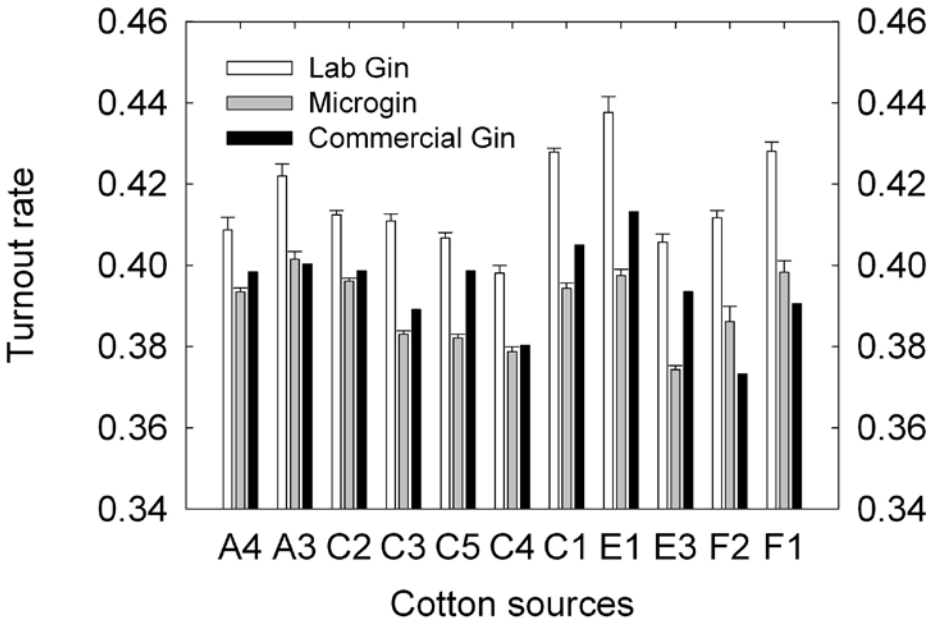


Figure 2. Gin turnout rate comparison among lab gin, UGA Microgin, and commercial gins.

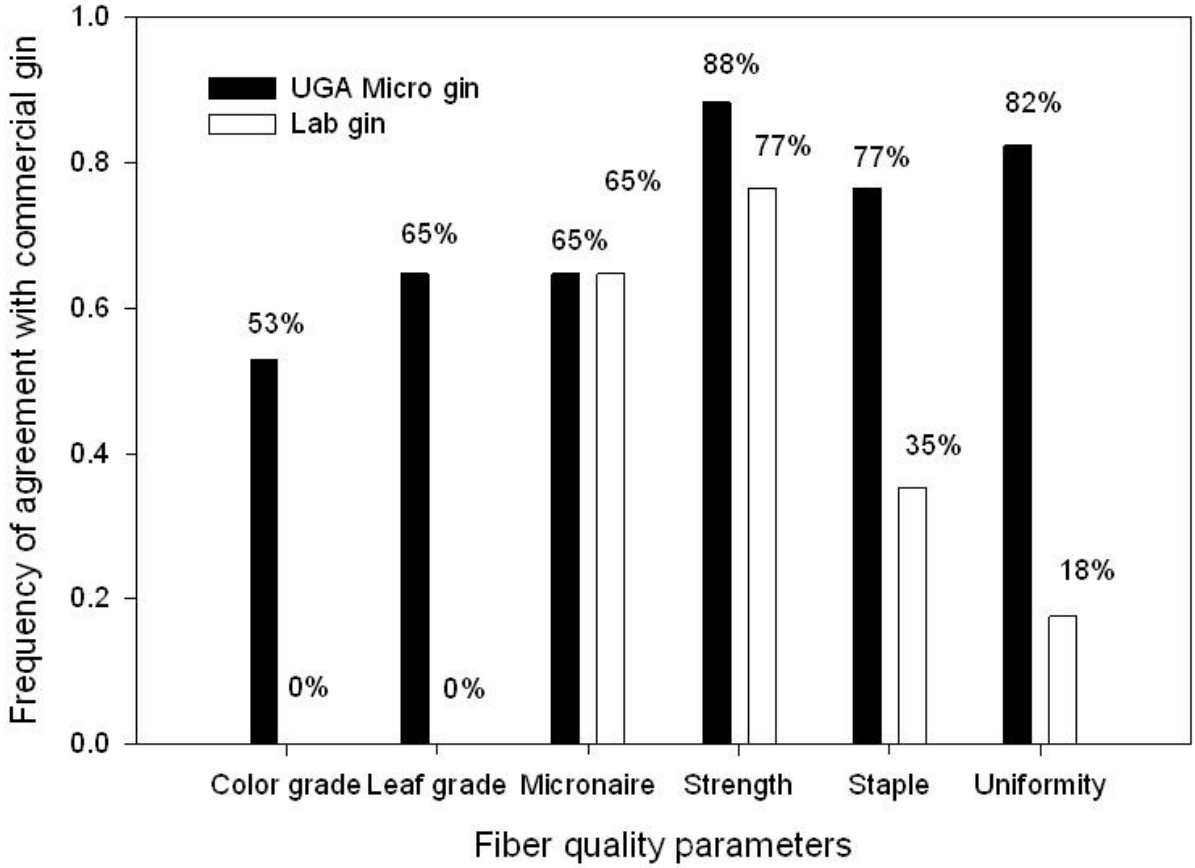


Figure 3. Comparison between the UGA Microgin and the lab gin in estimating commercial gins for six fiber quality parameters

Table 1. Dryland and irrigated cotton varieties ginned at six commercial gins.

| Commercial gins | Cotton varieties | Dry land | Irrigated |
|---|---|---|---|
| A | 1- DP555 | 1,5 | 2,4 |
| B | 2- FM1740 | 1,3 | |
| C | 3- PHY370 | | 1,2,3,4,5 |
| D | 4- ST5458 | | 3,5 |
| E | 5- DP0935 | | 1,2 |
| F | | 1,5 | |

Table 2. Fiber quality comparison among three types of gins for dry land cotton.

| | Color grade | Rd | +b | Staple | Uniformity | Leaf grade | HVI trash | Micro | Strength |
|---|---|---|---|---|---|---|---|---|---|
| LG* | 51 | 67.2 c | 6.9 b | 35 a | 81.1 a | 6 | 1.7 a | 4.5 b | 29.2 a |
| UM | 41 | 76.4 a | 7.7 a | 35 a | 80.4 ab | 3 | 0.2 b | 4.4 b | 30.4 a |
| CM-A1 | 41 | 74.2 b | 7.7 a | 35 a | 79.6 b | 4 | 0.5 b | 4.7 a | 29.4 a |
| LG | 51 | 72.5 c | 6.3 b | 36 a | 81.7 a | 5 | 1.5 a | 4.6 a | 29.8 a |
| UM | 31 | 80.8 a | 7.0 a | 36 ab | 81.2 ab | 3 | 0.2 b | 4.5 a | 28.2 b |
| CM-F1 | 41 | 78.9 b | 7.0 a | 35 b | 80.5 b | 3 | 0.4 b | 4.6 a | 29.3 a |
| LG | 51 | 69.7 b | 6.9 b | 36 a | 82.2 a | 6 | 1.2 a | 4.3 b | 29.6 a |
| UM | 31 | 76.8 a | 7.9 a | 35 a | 80.8 ab | 3 | 0.3 b | 4.4 b | 29.2 a |
| CM-B1 | 31 | 76.6 a | 7.7 a | 34 b | 80.0 b | 3 | 0.4 b | 4.6 a | 28.9 a |
| LG | 51 | 68.7 b | 7.9 c | 36 a | 83.1 a | 6 | 1.2 a | 4.5 b | 30.3 a |
| UM | 31 | 74.4 a | 8.5 a | 35 b | 82.5 ab | 3 | 0.2 b | 4.6 b | 29.7 ab |
| CM-B5 | 41 | 75.2 a | 8.3 ac | 34 b | 81.6 b | 3 | 0.3 b | 4.9 a | 28.8 b |
| LG | 51 | 68.0 c | 7.7 b | 35 a | 81.3 a | 6 | 1.4 a | 4.8 a | 28.8 a |
| UM | 31 | 75.3 a | 8.3 a | 35 a | 81.2 a | 3 | 0.2 c | 4.7 a | 29.0 a |
| CM-A2 | 41 | 71.9 b | 8.4 a | 35 a | 80.3 a | 4 | 0.5 b | 4.9 a | 28.7 a |
| LG | 41 | 72.9 b | 7.1 b | 37 a | 82.6 a | 6 | 1.4 a | 4.3 a | 29.3 a |
| UM | 31 | 77.4 a | 8.1 a | 36 ab | 81.9 a | 3 | 0.3 b | 4.5 a | 29.5 a |
| CM-F2 | 31 | 78.2 a | 7.8 a | 36 b | 80.3 b | 3 | 0.4 b | 4.4 a | 28.1 a |

*LG=lab gin; UM=UGA Microgin; CM=commercial gin. Letters A, B, F represent commercial gins; numbers 1, 2, 5 represent cotton varieties DP 555, FM1740, and DP0935, respectively.

Table 3. Cotton fiber quality comparison among three types of gins for irrigated cotton

| | Color grade | Rd | +b | Staple | Uniformity | Leaf grade | HVI trash | Micro | Strength |
|---|---|---|---|---|---|---|---|---|---|
| LG* | 51 | 69.1 b | 6.8 c | 37 a | 82.8 a | 6 | 1.7 a | 4.5 b | 30.1 a |
| UM | 41 | 76.2 a | 7.8 a | 35 b | 80.8 b | 3 | 0.2 b | 4.7 a | 29.0 a |
| CM-C1 | 41 | 76.9 a | 7.3 b | 35 b | 79.7 b | 3 | 0.4 b | 4.7 a | 29.2 a |
| | | | | | | | | | |
| LG | 41 | 75.6 b | 6.9 c | 37 a | 82.9 a | 6 | 1.1 a | 3.9 a | 30.9 a |
| UM | 21 | 81.1 a | 7.6 a | 36 a | 81.7 b | 2 | 0.4 b | 3.8 a | 29.0 b |
| CM-E1 | 31 | 80.0 a | 7.3 b | 35 b | 80.6 c | 3 | 0.4 b | 3.8 a | 28.8 b |
| | | | | | | | | | |
| LG | 51 | 70.1 c | 7.1 b | 37 a | 83.5 a | 6 | 1.6 a | 4.6 a | 30.9 a |
| UM | 31 | 77.4 a | 7.9 a | 36 b | 82.1 b | 3 | 0.2 b | 4.7 a | 29.9 a |
| CM-C3 | 41 | 75.6 b | 7.8 a | 36 b | 81.8 b | 3 | 0.4 b | 4.7 a | 30.1 a |
| | | | | | | | | | |
| LG | 51 | 73.7 b | 6.4 c | 37 a | 83.7 a | 6 | 1.4 a | 4.1 a | 31.4 a |
| UM | 31 | 79.2 a | 7.8 a | 36 a | 82.3 a | 3 | 0.2 b | 4.18 a | 30.4 a |
| CM-E3 | 31 | 79.3 a | 7.0 b | 37 a | 82.4 a | 3 | 0.5 b | 4.26 a | 30.5 a |
| | | | | | | | | | |
| LG | 51 | 69.8 b | 8.2 a | 36 a | 83.4 a | 6 | 1.3 a | 4.8 a | 30.9 a |
| UM | 31 | 78.3 a | 8.1 ab | 36 a | 82.4 ab | 2 | 0.3 b | 4.5 b | 30.7 ab |
| CM-A3 | 31 | 77.8 a | 7.7 b | 35 a | 82.2 b | 4 | 0.4 b | 4.7 a | 29.9 b |
| | | | | | | | | | |
| LG | 51 | 68.9 c | 7.6 b | 36 a | 83.5 a | 6 | 1.2 a | 4.7 c | 30.2 a |
| UM | 31 | 76.3 a | 8.5 a | 35 b | 82.1 b | 3 | 0.2 b | 4.9 a | 28.1 b |
| CM-C5 | 41 | 74.5 b | 8.3 a | 35 ba | 82.3 b | 4 | 0.3 b | 4.8 b | 29.4 a |
| | | | | | | | | | |
| LG | 51 | 68.4 b | 7.2 c | 36 a | 83.3 a | 7 | 1.4 a | 4.8 a | 31.0 a |
| UM | 31 | 77.6 a | 8.3 a | 35 ba | 81.8 b | 3 | 0.2 b | 4.8 a | 28.4 b |
| CM-D5 | 31 | 76.9 a | 8.1 b | 35 b | 81.5 b | 3 | 0.3 b | 4.8 a | 28.3 b |
| | | | | | | | | | |
| LG | 51 | 70.6 b | 7.1 c | 37 a | 83.2 a | 6 | 1.4 a | 4.6 b | 30.2 a |
| UM | 32 | 74.2 a | 9.0 a | 35 b | 81.4 b | 3 | 0.2 b | 4.6 b | 30.1 a |
| CM-A4 | 41 | 75.0 a | 8.4 b | 35 b | 81.6 b | 3 | 0.4 b | 5.0 a | 30.9 a |
| | | | | | | | | | |
| LG | 51 | 68.8 b | 7.8 b | 37 a | 82.6 a | 7 | 1.5 a | 4.9 a | 30.5 a |
| UM | 31 | 75.3 a | 8.7 a | 36 ba | 81.1 ba | 3 | 0.2 b | 4.9 a | 29.8 a |
| CM-C4 | 41 | 73.8 a | 8.5 a | 35 b | 80.1 b | 3 | 0.5 b | 5.0 a | 28.7 a |
| | | | | | | | | | |
| LG | 41 | 70.4 b | 7.9 b | 36 a | 81.5 a | 7 | 1.3 a | 4.4 a | 28.4 a |
| UM | 31 | 74.9 a | 9.0 a | 35 b | 81.1 a | 3 | 0.2 b | 4.4 a | 29.0 a |
| CM-C2 | 31 | 75.5 a | 8.4 ba | 36 ba | 81.8 a | 3 | 0.4 b | 4.6 a | 28.1 a |
| | | | | | | | | | |
| LG | 41 | 72.2 b | 7.6 a | 36 a | 82.7 a | 5 | 1.1 a | 4.6 a | 29.6 a |
| UM | 31 | 77.2 a | 8.1 a | 35 a | 81.2 b | 2 | 0.3 b | 4.6 a | 29.1 a |
| CM-D2 | 31 | 77.0 a | 8.1 a | 34 b | 79.8 c | 3 | 0.3 b | 4.7 a | 27.6 a |

*LG=lab gin; UM=UGA Microgin; CM=commercial gin. Letters A to F represent six commercial gins; numbers 1 to 5 represent cotton varieties DP 555, FM1740, PHY370, ST5458, and DP0935, respectively.

# PALMER AMARANTH CONTROL AS AFFECTED BY HERBICIDE, METHOD OF APPLICATION, AND WINTER COVER CROP

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[2]USDA/ARS Tifton

## Introduction

Cotton production in the southeastern US exceeds 2.1 million acres a year, with an estimated farm gate value greater than $700 million. Cotton production since 2000 has remained relatively constant in the region. Cotton that incorporates biotechnology (glyphosate or glufosinate resistant, Bt and Bt 2) into the production scheme continues to increase. Since its introduction in 1997, glyphosate-tolerant cotton has been rapidly adopted by growers across the southeast; greater than 89% of the hectarage was planted to these cultivars in 2005. Glyphosate-tolerant cotton allowed growers to reduce or eliminate soil-applied herbicides, abandon cultivation, and transition to conservation tillage, which promotes soil conservation and compliance with government regulation. Approximately 50% of the cotton in Georgia was produced using either no-tillage or strip-tillage techniques by 2005. With the elimination of cultivation as a control tactic in conservation tillage systems, herbicides were the primary, and sometimes only, method used for weed control. Glyphosate was applied two to four times per season on most fields and may have been the only herbicide used in any year given its efficacy against a broad spectrum of annual and perennial grass and broadleaf weeds. In Georgia, 93% of the cotton hectares received at least one glyphosate application in 2005. In 2004, glyphosate-resistant Palmer amaranth was discovered in Georgia; resistant populations are widely distributed across the cotton producing regions of the southeastern and mid-southern US. Additionally, acetolactate synthesis (ALS) resistant Palmer amaranth is also wide spread. Palmer amaranth biotypes with multiple resistance to ALS herbicides and glyphosate now occur in this region.

The use of multiple herbicide modes of action in weed management systems is now required for successful cotton production. Residual herbicides applied PRE for Palmer amaranth control include pendimethalin (Prowl 3EC) and fomesafen (Reflex), while *S*-metolachlor (Dual Magnum) is POST applied to cotton weeds prior to emergence. Growers seeking ways to reduce input costs can impregnate fertilizer with pendimethalin and other herbicides. The simultaneous application of herbicides with fertilizer saves time and labor, reduces soil compaction by eliminating field operations, and reduces application costs.

Early season Palmer amaranth control is essential as cotton becomes established more slowly than other crops (i.e. soybeans, corn). Cover crops, such as rye, can suppress weeds both chemically (through demonstrated allelopathy) and physically (impeding germination and emergence). Combining herbicide-fertilizer impregnation with strip-tillage techniques may improve early season weed control and assist farmers with viably economic cotton production. Weed control effectiveness of cover crops along with

herbicide application using fertilizers were studied in a heavily infested glyphosate-resistant Palmer amaranth field. The main goal was to determine if the herbicides provided residual weed control in each tillage system and cover crop combination, and if crop safety can be improved (i.e. prevent seedling cotton injury from *S*-metolachlor and fomesafen by using fertilizer as a carrier).

## Materials and Methods

Studies were conducted in Macon County, GA in a glyphosate-resistant Palmer amaranth infested field in 2008 and 2009. Main plot tillage methods were (1) conventional rip, hip, and bed, (2) wheat cover crop that was spring rolled followed by strip-tillage cotton planting, or (3) rye cover crop that was rolled and followed by strip-tillage planting. Subplots were herbicide and method of application. Herbicides were pendimethalin, *S*-metolachlor, and fomesafen. Methods of application were impregnated on fertilizer (250 lb/ac) or spray applied with water (15 gal/ac). Trials were initiated with November planting of cover crops (wheat and rye). Cover crops were destroyed by herbicide treatment in early April each year followed by planting of glufosinate-resistant cotton and PRE and POST herbicide treatments. The experiment was a 3 by 8 by 2 factorial in a randomized complete block design with 4 replications (Table 1). Plots were two rows by 25 feet long in Tifton, and two rows by 30 feet long in Plains. Standard agronomic practices were conducted including conventional tillage along with fertility, and pest control recommendations (other than weeds) by the University of Georgia Extension Service.

Applications of herbicides began at planting and to 3 leaf (3LF) stage of cotton. A POST treatment of glufosinate was applied at the 3LF stage of growth to all plots to determine how long the residual herbicide would control Palmer amaranth in combination with the cover crops. Herbicides were applied by tractor or backpack pressurized by compressed air or $CO_2$ delivering 15 gal/ac, or by a Gandy fertilizer applicator. A non herbicide-treated control was included for comparison.

Visual estimates of crop tolerance and weed control (on a scale of 0 to 100%, where 0% = no injury or weed control and 100% = cotton death or complete weed control) were estimated throughout the growing season. For Palmer amaranth stand counts, two counts were taken on 1-$ft^2$ sections of each plot every 7 days after planting to determine emergence. Five cotton stand counts were taken during the course of the study. Data was subjected analysis of variance appropriate for a randomized complete block design for a factorial arrangement of treatments.

## Results and Discussion

Data are presented separately by year for the analysis of variance (Table 2). The two-way interactions between cover crops and application method were not significant for any variable, except for Palmer amaranth control in 2009. The two-way interactions between cover crops by herbicides and herbicides by application method varied by biological measure.

Cotton injury was similar for spray and fertilizer impregnation treatments, with greater injury observed in 2008 than in 2009. PRE *S*-metolachlor injury was unacceptable in 2008; fertilizer application did not prevent cotton injury from occurring. Spray and fertilizer impregnation of *S*-metolachlor are therefore not advised and not registered for PRE application in cotton.

Fomesafen PRE provided good to excellent Palmer amaranth control as compared to the nontreated in all systems. Palmer amaranth populations were greater in 2009 than 2008, likely due to optimal moisture conditions in 2009. Palmer amaranth populations were reduced by rye cover much more effectively than wheat cover crop due, in part, to density of the surface material. Rye averaged 4,200 lb/ac dry biomass while wheat averaged 1,000 lb/ac. Palmer amaranth was controlled more effectively by a combination of fomesafen and rye in 2008 and 2009.

In conclusion, Rye cover reduced Palmer amaranth density and provided extended control as compared to wheat and the nontreated control. Fomesafen provided residual control of Palmer amaranth as either a spray or fertilizer impregnated application. PRE applied S-metolachlor using a fertilizer impregnation did not reduce cotton injury as compared to the spray application. The PRE combination of pendimethalin plus fomesafen provided maximum early season control by mixing two different herbicide modes of action: DNA plus PPO, respectively. PRE herbicide applications must be followed by POST application of glufosinate in order to provide adequate season long control in cotton as this Palmer amaranth is glyphosate resistant.

Table 1. Cover crop, herbicides, and method of application for Palmer amaranth study.

| | | | |
|---|---|---|---|
| Cover crops | | | |
| | Wheat | | |
| | Rye | | |
| | Conventional tillage | | |
| Herbicide treatment | | Rate | Application timing |
| | | —lb ai/ac— | ———— |
| | Pendimethalin | 1.5 | PRE |
| | *S*-metolachlor | 1.25 | PRE |
| | Fomesafen | 0.25 | PRE |
| | Pendimethalin + *S*-metolachlor | 1.5 + 1.25 | PRE |
| | Pendimethalin + fomesafen | 1.5 + 0.25 | PRE |
| | Fomesafen + *S*-metolachlor | 0.25 + 1.25 | PRE |
| | *S*-metolachlor | 1.25 | POST |
| | Nontreated | | |
| Application method | | | |
| | Spray | | |
| | Fertilizer impregnation | | |

Table 2. Analysis of variance for cotton response, Palmer amaranth control as affected by cover crop, herbicide, method of application, and interactions[a].

| | Cotton injury (36 DAP) | | AMAPA Control (18 DAP) | | AMAPA Control (36 DAP) | | AMAPA Density (22 DAP) | | AMAPA Density (36 DAP) | |
|---|---|---|---|---|---|---|---|---|---|---|
| Variable | 2008 | 2009 | 2008 | 2009 | 2008 | 2009 | 2008 | 2009 | 2008 | 2009 |
| Cover | <0.0001 | 0.09 | <0.0001 | 0.56 | <0.0001 | 0.0006 | <0.0001 | 0.12 | <0.0001 | |
| Herbicide | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| Application | 0.24 | <0.0001 | 0.007 | 0.31 | <0.0001 | <0.0001 | 0.34 | 0.56 | 0.28 | 0.008 |
| Cover x herbicide | 0.09 | 0.06 | 0.01 | 0.17 | 0.19 | 0.008 | 0.001 | 0.62 | 0.03 | 0.36 |
| Cover x application | 0.47 | 0.69 | 0.53 | 0.51 | 0.94 | 0.01 | 0.93 | 0.87 | 0.13 | 0.65 |
| Herbicide x application | <0.0001 | 0.84 | 0.009 | 0.34 | 0.02 | 0.13 | 0.53 | 0.03 | 0.007 | 0.19 |

[a]ANOVA for 3 by 8 by 2 factorial arrangement of treatments, $P \leq 0.05$

# MULTIPLE RESISTANCE TO GLYPHOSATE AND ALS-INHIBITING HERBICIDES IN PALMER AMARANTH IN GEORGIA

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## Introduction

In 2004, a glyphosate-resistant (GLY-R) biotype of Palmer amaranth was discovered at a field site in Macon County where glyphosate-tolerant cotton had been produced in a monoculture for at least seven years. In 2006, the grower reported that he was unable to effectively control the same population of Palmer amaranth using the labeled rate of pyrithiobac. The objective of this study was to determine the level of resistance to glyphosate and pyrithiobac in a known GLY-R Palmer amaranth population.

## Materials and Methods

Field studies were conducted in 2007 and 2008 to evaluate the response of the putative GLY/ALS-R biotype to glyphosate and pyrithiobac applied singly and tank mixed. Seventeen herbicide treatments were included in the study: glyphosate applied at 22 (labeled field rate), 48, 88 and 176 oz/A; pyrithiobac applied at 2.5 (labeled field rate), 5, 10 and 15 oz/A; and glyphosate+ pyrithiobac at 22+2.5, 44+5, 88+10 and 176+15 oz/A, as well as a non-treated check. The herbicide treatments were arranged in a randomized complete block design with four replicates. Visual control ratings for each plot (represented as percentage of the non-treated check, where 0 equals no weed control and 100 equals complete weed control) were taken at 1, 5 and 8 weeks after treatment (WAT). Data were analyzed using the PROC MIXED procedure in SAS. Contrast statements were used to make comparisons of Palmer amaranth control between rates within herbicide categories.

## Results and Discussion

Results demonstrated that the GLY/ALS-R biotype was ineffectively controlled (5-28 % control, 1 to 8 WAT) by both glyphosate and pyrithiobac at labeled use rates (22 and 2.5 oz/A, respectively) (Table 1). Palmer amaranth control increased with increased herbicide rate. Glyphosate applied at 44, 88 and 176 oz/A provided between 34 and 89% control 1 WAT. At 5 and 8 WAT, Palmer amaranth control from glyphosate applied at 2-, 4- and 6-times the labeled rate ranged from 5 to 80% and from 5 to 76%, respectively. Pyrithiobac applied at 5, 10 and 15 oz/A provided 39, 39 and 47% control of Palmer amaranth, respectively, at 1 WAT. Control of Palmer amaranth at 5 and 8 WAT ranged from 17 to 65% for the same rates. When glyphosate and pyrithiobac were applied as a tank mixture at rates ranging from 22+2.5 to 176+15 oz/A, Palmer amaranth was controlled 41 to 92% 1 WAT. At 5 and 8 WAT, control ratings ranged from 16 to 90%. Glyphosate and pyrithiobac applied at up to 6-times the labeled rates, alone and in combination, failed to provide commercially acceptable control of this

population indicating that it possesses resistance to both chemicals. This is the first confirmed report of multiple resistances to glyphosate and pyrithiobac in Palmer amaranth in the SE US.

Table 1. Visual control of GLY/ALS-R Palmer amaranth in the field by glyphosate and pyrithiobac, applied singly and tank-mixed, 1, 5 and 8 WAT.

| Herbicide rate | | | Visual control[a] 1 WAT | | 5 WAT | | 8 WAT | |
|---|---|---|---|---|---|---|---|---|
| oz/A | | | ——————————— % ——————————— | | | | | |
| glyphosate | | | | | | | | |
| 22 | | | 5 | | 5 | | 5 | |
| 44 | | | 34 | * | 23 | * | 19 | * |
| 88 | | | 68 | * | 47 | * | 49 | * |
| 176 | | | 89 | * | 80 | * | 76 | * |
| pyrithiobac | | | | | | | | |
| 2.5 | | | 28 | | 25 | | 12 | |
| 5 | | | 39 | * | 32 | | 17 | |
| 10 | | | 39 | * | 51 | * | 28 | * |
| 15 | | | 47 | * | 65 | * | 48 | * |
| glyphosate + pyrithiobac | | | | | | | | |
| 22 | + | 2.5 | 41 | | 31 | | 16 | |
| 44 | + | 5 | 57 | * | 55 | * | 48 | * |
| 88 | + | 10 | 76 | * | 76 | * | 71 | * |
| 176 | + | 15 | 92 | * | 89 | * | 90 | * |

[a] Control values followed by a star within each herbicide are significantly different from the level of control achieved using the field rate (glyphosate = 22 oz/A, pyrithiobac = 2.5 oz/A) as determined using contrast statements.

# REDUCTIONS IN PALMER AMARANTH SEED VIABILITY OVER TIME

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## Introduction

Palmer amaranth (*Amaranthus palmeri*) plants that become established in the field are likely germinating and emerging from relatively shallow depths within the soil profile. According to recent research conducted at the University of Georgia, the majority of Palmer amaranth seedlings are emerging from depths of 0.5 and 1 inch. Theoretically, a deep tillage event should bury a significant proportion of surface/near surface Palmer amaranth seeds to depths below their optimal germination and emergence zone. A reduction in the number of germinable seeds should reduce the number of individuals that will be subjected to chemical and cultural weed management, as well as the number of weed management survivors that can then replenish the seedbank. The success of this proposed strategy for reducing weed population sizes is dependent, in part, by the dormancy and longevity of seeds in the soil. It is currently unknown exactly how long Palmer amaranth seed persist once they enter the soil seedbank

## Materials and Methods

Seed from glyphosate-susceptible (GLY-S) and glyphosate-resistant (GLY-R) parent plants were harvested in October of 2007 and 2008, cleaned, and divided into subsamples of 100 seed each. Each subsample was thoroughly mixed with 10 grams of sand and then sealed in individual 3 inch by 3 inch nylon mesh bags. Bags were buried at depths of 0.5, 1, 4 and 16 inches at the USDA/UGA Jones Farm in Tifton, GA. Four bags of seed for each biotype (GLY-S and GLY-R) were exhumed from each burial depth at 3, 6, and 9 months after burial for both the 2007 and 2008 collection periods. Additionally, four bags of seed for each biotype were exhumed from each burial depth at 12, 18 and 24 months after burial for the 2007 collection. Seed were recovered from the sand, placed on moist filter paper in Petri dishes and put in a germination chamber set to 86 F. Seed germination was monitored for 28 days; germinated seed were counted and removed. Seed that did not geminate after 28 days were evaluated to see if they were diseased or dormant. Freshly harvested seed from each collection were also evaluated for germinability, dormancy and disease to establish a baseline level of viability (0 months).

## Results and Discussion

Freshly harvested seed of both biotypes were 96 to 98% viable. Differences in viability with respect to burial depth were not apparent (data not shown); therefore, data were combined over depths and years. Seed viability decreased as time of burial increased. At 12 months, viability was approximately 60%; after two years, viability had decreased to below 40%. Most of the seeds that did not germinate were diseased, not dormant

(data not shown). There did not appear to be anny differences in seed viability between the biotypes. Results from this study are in agreement with work conducted on other amaranth species.

Our goal is to develop a successful management program for GLY-R Palmer amaranth in cotton. To maximize the effectiveness of current best control practices, we believe that it is necessary to shrink the size of the Palmer amaranth seedbank in infested fields. Results from this study indicate that buried Palmer amaranth seeds will decay rapidly with time and that the seedbank is likely ephemeral.

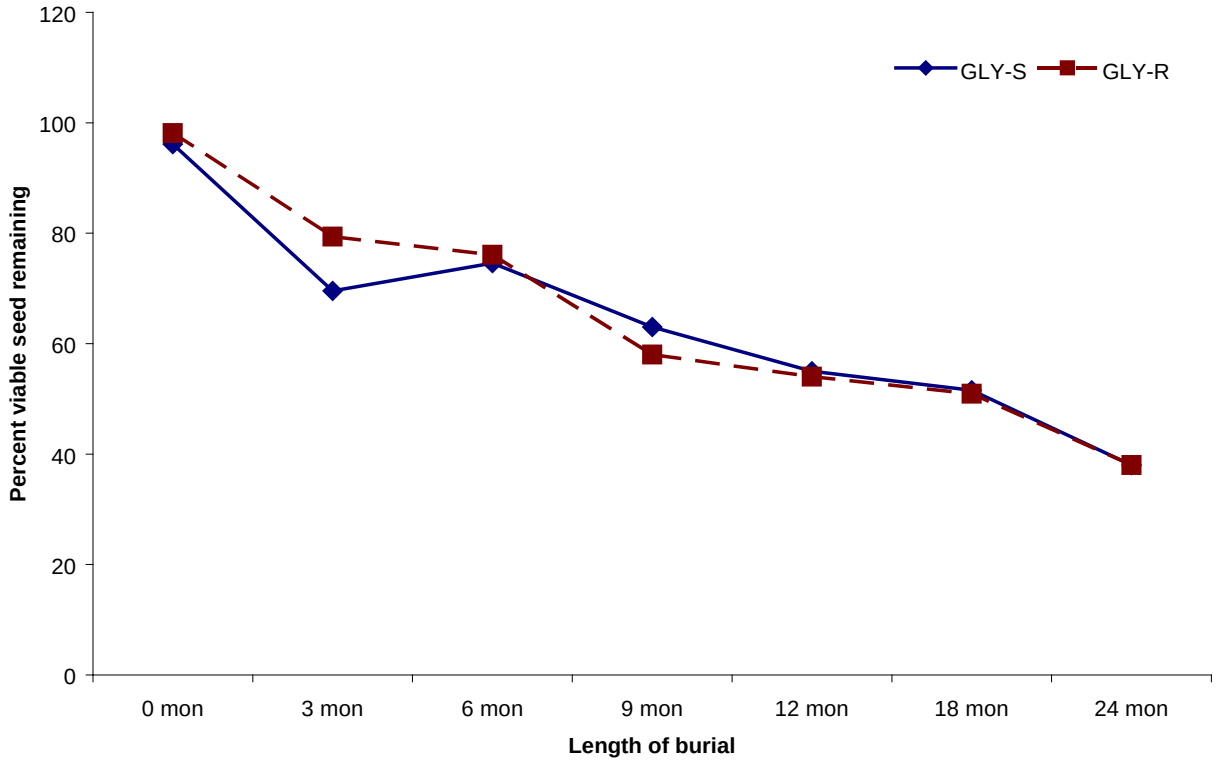


Figure 1. Palmer amaranth seed viability after 0 months to 24 months of burial.

# EFFECT OF COMPENSATORY GROWTH ON PALMER AMARANTH RESPONSE TO GLYPHOSATE

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## Introduction

Incomplete weed control can occur following herbicide applications. One manifestation of this phenomenon, at the individual plant level, is the death of one or many shoot meristems. The loss of apical dominance can lead to compensatory growth, which arises from previously dormant lateral buds. Palmer amaranth dieback and regrowth in response to POST herbicides has been observed in both the field and the greenhouse (Culpepper, Sosnoskie, Webster – personal observations). The objective of this study was to determine if the degree of glyphosate sensitivity differed between intact plants and those undergoing mechanically stimulated compensatory growth for both glyphosate-susceptible (GLY-S) and –resistant (GLY-R) Palmer amaranth biotypes.

## Materials and Methods

Seeds of GLY-S and GLY-R Palmer amaranth were planted in pots filled with commercial potting soil. Plants were thinned to one seedling per pot after emergence. Plants were grown in a greenhouse with supplemental lighting and were watered and fertilized as needed. To stimulate compensatory growth from lateral buds, the apical shoot of was mechanically removed from 4-6 inches tall GLY-S and GLY-R seedlings using scissors. Plants were allowed to regrow to 4-6 inches and then treated with glyphosate. Glyphosate application rates for GLY-S plants were: 0 (non-treated check), 1, 2, 4, 8 and 12 oz/A; glyphosate application rates for GLY-R plants were: 0 (non-treated check), 10, 20, 40, 80, 120 oz/A. Intact GLY-S and GLY-R plants 4-6 inches were also treated. Plants were visually evaluated for injury using a scale ranging from 0 (no visual injury) to 100 (plant death) 7 DAT. The experiment was arranged as a RCB with 5 replications for each glyphosate rate-size class (4-6 inches intact or regrown) combination. The experiment was conducted 4 times. Data were analyzed using statistical software.

## Results and Discussion

GLY-S biotype: Statistical analyses indicated a significant interaction between rate and size class injury; GLY-S Plants that were experiencing compensatory growth (grown to 4-6 inches, cut back, and then regrown to 4-6 inches) were more sensitive to glyphosate than intact plants 4-6 inches tall (Figure 1). Regrown plants were more severely injured than the intact plants at each rate of glyphosate except for 0 oz/A (non-treated check) and the highest dose (12 oz/A).

GLY-R biotype: According to results from statistical analyses, intact and regrown plants did not differ with respect to glyphosate sensitivity (Figure 2). Regrown and intact plants were similarly injured regardless of glyphosate rate.

Age/growth stage and stress can significantly affect weed responses to chemical control strategies. In general, older and stressed plants are less-susceptible to herbicides than younger, healthier ones. Plants that persist following failed herbicide applications may compete with the crop and reproduce, thereby reducing yields and replenishing the soil seedbank, respectively. Future research will evaluate GLY-S and GLY-R Palmer amaranth susceptibility to other POST applied herbicides in cotton production. This will allow us to determine how subsequent weed control measures following herbicide failure may be impacted by compensatory growth.

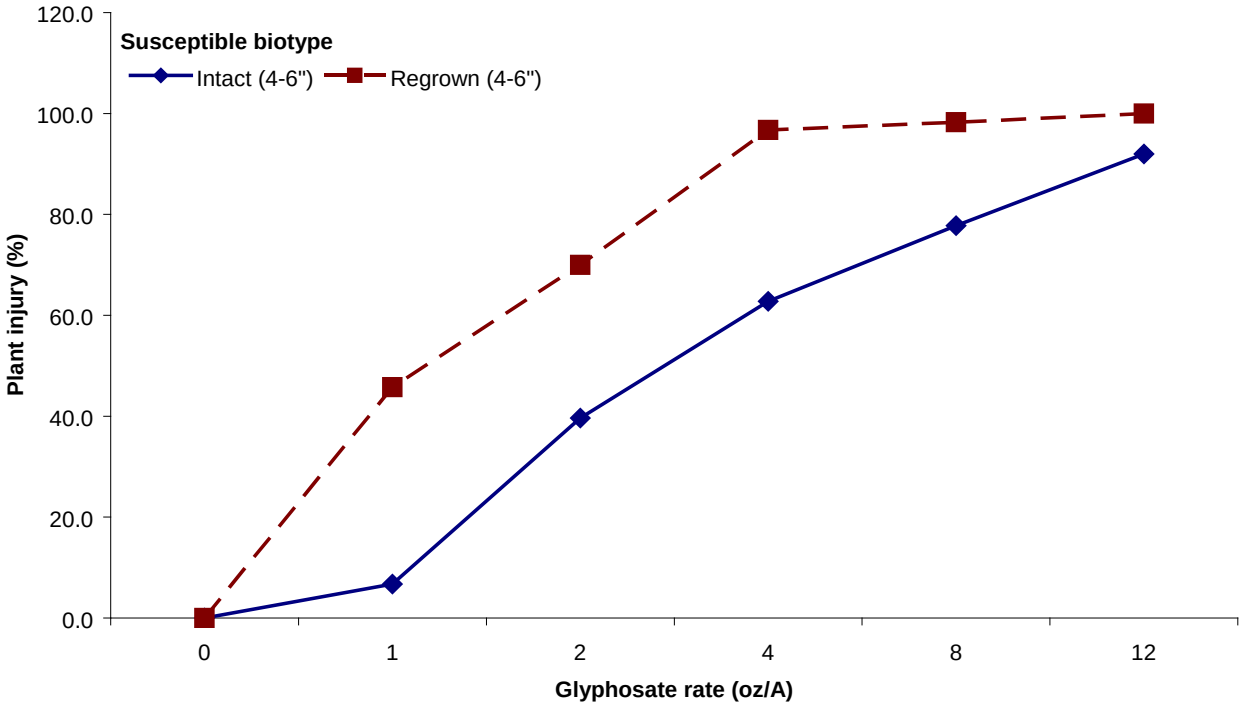


Figure 1. Response of regrown (4-6") and intact (4-6") GLY-S Palmer amaranth to glyphosate at varying rates of application.

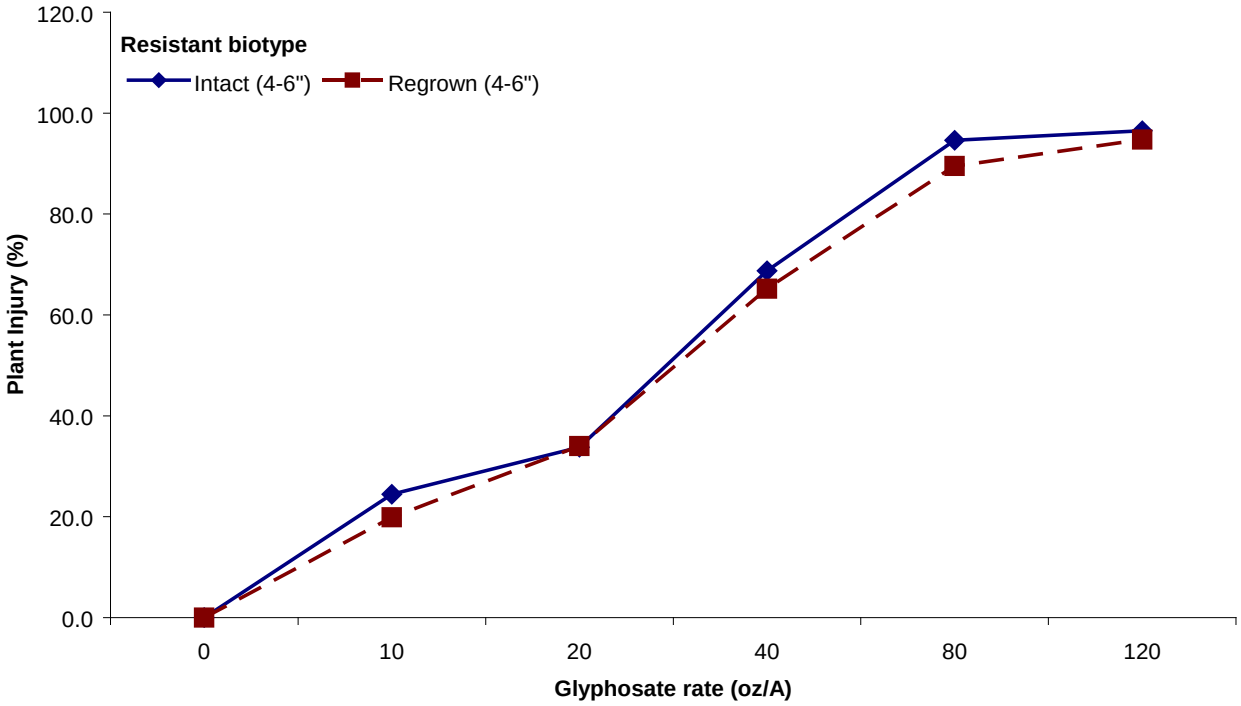


Figure 2. Response of regrown (4-6") and intact (4-6") GLY-R Palmer amaranth to glyphosate at varying rates of application.

# 2009 COTTON OVT VARIETY TRIALS

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## Introduction

The University of Georgia 2009 Cotton Variety Trials (OVT) were conducted at five locations across Georgia, spanning the cotton belt from southwest to northeast Georgia. Irrigated trials were conducted on-farm in Decatur County and at University research stations and/or education centers in Midville, Plains, and Tifton. Dryland trials were conducted on University research stations and/or education centers in Athens, Midville, Plains, and Tifton. Performance data in these tables, combined with data from previous years should assist growers in variety selection, one of the most important if not most important decisions in an economically viable cotton production plan. Data collected from the University of Georgia Variety Testing Cotton Program can be found at the Statewide Variety Testing Website: www.swvt.uga.edu Also, the data is published in the UGA Agricultural Experiment Station Annual Publication 104, January 2010.

## Materials and Methods

The University of Georgia conducts Official Cotton Variety and Strain trials across Georgia to provide Growers, Private Industry, Extension Specialist, and County Agents with performance data to help in selecting varieties. Data from the OVT assists the private seed companies assess the fit of their products in Georgia. The University of Georgia cotton OVT is conducted by J. LaDon Day, Program Coordinator Cotton OVT, Griffin, GA. along with Mr. Larry Thompson, Research Professional I, Tifton, GA. The OVT is split into variety and strain trials with placement of varieties or strains into the particular trial chosen by its owner. Trials are separated by maturity. Irrigated OVT trials are conducted at Bainbridge, Midville, Plains, and Tifton, while dryland OVTs are conducted at Athens, Midville, Plains, and Tifton, thus varieties placed into the OVT are included in eight trials per year, giving a fair size data set with which to evaluate variety performance. The strains trials are irrigated and conducted at Midville, Plains, and Tifton. Trials consist of 4-replicate, randomized complete block designs. An accepted, common, management system is employed at each location for agronomic and pest management, but transgenic cultivars are not produced according to their intended pest management system(s). A random quality sample was taken on the picker during harvest and ginned to measure lint fraction on all plots including the irrigated late maturing trial at Tifton, but a portion of the seed cotton from the later maturity plots was bagged and sent to the Micro Gin at Tifton for processing. All fiber samples were submitted to Starlab, Knoxville, TN, for HVI analyses. All trials were harvested with a state-of-the-art harvest system composed of an International IH 1822 picker fitted with weigh baskets and suspended from load sells. This system allows one person to harvest yield trials where the established bag-and-weigh approach required eight people or more. The electronic weigh system allowed for timely harvest of yield trials.

Data from all trials and combined analyses over locations and years are reported as soon as fiber data are available from the test lab in Adobe pdf and Excel formats on the UGA Cotton Team Website maintained at www.ugacotton.com. Also, the data is available at the Statewide Variety Testing Website: www.swvt.uga.edu.

## Results and Discussion

Unlike the three previous droughty springs, 2009 was slowed by wet and cold conditions in early April. Wet conditions and low soil temperatures continued during mid- to late-spring causing planting delays. Overall this was the latest planted spring crop in many years. Spring temperatures were cooler than normal until late May into June when there was a period of near record high temperatures, especially during the first two weeks of June. This period challenged irrigation systems to continue supplying adequate moisture for germinating crops. Wet and cool conditions returned in late fall causing a virtual halt in harvest thus reducing quality of a late maturing crop. At the end of the year up to 30% of some commodities remained in the field un-harvested due to saturated soil unable to support combine equipment.

Crop maturity progressed at 15 to 20% below the 5-year average and persistent rain and wet soil throughout the fall delayed an already late harvest season. During 2009 cotton producers seeded a million acres, 6% more than last year. Cotton per acre yields in 2009 of 882 lbs is a new state record and due to number of acres the total state bale production was up 14% more than last year. Profit margins for Georgia producers of cotton continue to be below long term averages due to high cost of energy.

Among varieties in the Dryland Earlier Maturity Trials, Dyna-Gro2570B2RF, GA2006053, FM1740B2RF, DP0924B2RF, and PHY370WR stand out as varieties with high yield and relative yield stability in the dryland trials averaged over four locations (Table 1). There were also 12 other varieties that were within the top significant group (Table 1). When summarized over two years and four locations GA2004230, FM1740B2RF, DP0935B2RF, and PHY370WR were the top performers (Table 2).

Among the best performing earlier maturing varieties produced under irrigation, 09R619B2R2, FM1740B2RF, DP0920B2RF, Dyna-Gro2570B2RF, and DP0935B2RF were the top five highest averaged over locations (Table 3). Ten other varieties performed well within the top group (Table 3). FM1740B2RF, PHY370WR and DP0935B2RF when averaged over two years and locations in the Irrigated Early Maturity Trials conducted at Bainbridge, Midville, Plains, and Tifton; were the top yielding group (Table 4).

The top Ten later maturity varieties in the trial conducted without irrigation and averaged over four locations revealed the consistent performance of PHY370WR, DP0949B2RF, PHY565WRF, DP555/bg/RR, 09621B2R2, PHY375WRF, ST5458B2RF, FM12845LLB2, DP161B2RF, and DP0935B2RFnt (Table 5). An additional six varieties were within the top yielding group (Table 5). Averaged over locations and years,

DP555BG/RR, DP0935B2RF, DP174RF, and PHY375WRF were the front runners (Table 6).

Under irrigation DP0949B2RF, 09621B2RF, PHY375WRF, DP555BG/RR, PHY370WR, PHY5922WRF, PHY485WRF, PHY565WRF, ST5458B2RF and DP0935B2RF led the standard later maturing trials averaged over locations (Table 7). Averaged over locations and years, DP555BG/RR, PHY375WRF, and DP0935B2RF were the front runners (Table 8).

The Earlier Maturity and Later Maturity Strains Trials portend improved varieties for crop seasons 2010 and beyond (Table 9). Varieties from Monsanto DP, Georgia, and Stoneville were high yielding performer among standard earlier and later maturing entries in the strains trial.

Presented in Table 10 is the Tifton, Georgia, 2009, Later Maturity cotton variety performance, irrigated, data comparing 'small gin' seed/lint with samples processed through the Micro-gin (MG) on the Tifton Campus. The seed cotton from the Later Maturity experiment was sub-sampled during picking, ginned and for HVI analysis processed by Star Lab in Knoxville, Tennessee. The remaining seed cotton was processed through the Micro-gin, Tifton Campus and also for HVI analysis sent to Star Lab in Knoxville, TN.

In summary, several new varieties described herein portend potentially higher yields and improved fiber packages available to Georgia growers.

Table 1. Yield summary for dryland earlier maturing cotton varieties, 2009.

| Entry | Lint Yield[a] Athens | Midville | Plains | Tifton | 4-Loc. Average | Lint | Unif. Index | Length | Strength | Mic. |
|---|---|---|---|---|---|---|---|---|---|---|
| | lb/acre | | | | | % | % | in | g/tex | units |
| Dyna-Gro 2570B2RF | 502 20T | **1730** 2 | **1913** 2 | **1794** 3 | **1485** 1 | 45.6 | 83.5 | 1.14 | 28.2 | 5.0 |
| GA2006053 | 621 6 | **1704** 5 | **1889** 3 | 1671 9 | **1471** 2 | 42.3 | 84.5 | 1.19 | 29.7 | 4.8 |
| FM1740B2RF | 488 22 | **1651** 9 | **1770** 8T | **1939** 1 | **1462** 3 | 45.4 | 83.0 | 1.13 | 28.4 | 4.8 |
| DP 0924 B2RF | 558 13T | **1633** 11 | **1770** 8T | **1874** 2 | **1459** 4 | 44.7 | 83.3 | 1.11 | 28.7 | 4.9 |
| PHY370WR | 537 17 | **1720** 4 | **1756** 9 | **1753** 4 | **1441** 5 | 45.7 | 83.4 | 1.11 | 28.9 | 5.1 |
| ST 5288B2F | **666** 2 | 1537 19 | **1834** 4 | 1652 10 | **1422** 6 | 45.0 | 82.5 | 1.13 | 28.0 | 4.9 |
| GA2004230 | 580 10 | **1726** 3 | **1965** 1 | 1361 23 | **1408** 7 | 44.1 | 84.5 | 1.24 | 30.9 | 4.7 |
| PHY367WRF | 561 12 | **1652** 8 | 1675 14 | **1725** 7 | **1403** 8 | 44.9 | 83 | 1.14 | 28.3 | 4.5 |
| PHY375WRF | 632 4 | **1639** 10 | **1755** 10 | 1569 13 | **1399** 9 | 46.0 | 83.2 | 1.14 | 28.3 | 4.6 |
| 09R619B2R2 | 462 24 | 1570 16 | **1803** 6 | **1695** 8 | **1383** 10 | 46.7 | 83.9 | 1.14 | 27.3 | 4.8 |
| DP 0912B2RF | 597 8 | 1591 14 | **1827** 5 | 1508 17 | **1381** 11 | 44.7 | 83.2 | 1.11 | 29.0 | 5.1 |
| AM1550B2RF | 600 7 | 1508 21 | 1623 18 | **1741** 6 | **1368** 12 | 45.1 | 83.1 | 1.13 | 26.2 | 4.8 |
| DP 0920B2RF | 533 18 | **1660** 7 | **1725** 11 | 1530 16 | **1362** 13 | 44.7 | 83.7 | 1.15 | 27.2 | 5.0 |
| CG 3220B2RF | 523 19 | **1755** 1 | 1537 26 | 1612 11 | **1357** 14 | 43.7 | 83.7 | 1.16 | 26.9 | 4.9 |
| NG3331B2RF | 622 5 | 1510 20 | 1684 13 | 1575 12 | **1348** 15 | 43.7 | 83.4 | 1.12 | 30.1 | 5.1 |
| DP 0935 B2RF | 381 29 | **1702** 6 | **1708** 12 | 1557 14 | **1337** 16 | 45.5 | 83.6 | 1.12 | 27.7 | 4.9 |
| ST 4498B2RF | 589 9 | **1625** 12 | 1577 22T | 1542 15 | **1333** 17 | 44.9 | 83.3 | 1.14 | 29.5 | 4.5 |
| BCSX 1035LLB2 | 553 14 | 1474 24 | 1410 30 | **1746** 5 | 1296 18 | 44.0 | 83.8 | 1.14 | 31.4 | 5.3 |
| CG4020B2RF | 547 16T | 1440 27 | 1593 21 | 1485 20 | 1266 19 | 43.4 | 84.2 | 1.19 | 27.3 | 4.5 |
| NG4370B2RF | 579 11 | 1447 26 | 1552 23 | 1478 21 | 1264 20 | 43.0 | 83.6 | 1.14 | 28.9 | 4.7 |
| GA2004143 | 502 20T | **1601** 13 | 1626 16 | 1320 25 | 1262 21 | 47.5 | 83.7 | 1.18 | 32.3 | 4.7 |
| All-Tex Epic | 426 27 | 1549 18 | **1793** 7 | 1257 27 | 1256 22 | 46.5 | 83.4 | 1.15 | 27.7 | 4.7 |
| ST 4288B2F | 427 26 | 1479 23T | 1625 17 | 1489 19 | 1255 23 | 43.0 | 83.3 | 1.15 | 28.9 | 5.1 |
| GA2006168 | 547 16T | 1479 23T | 1611 20 | 1321 24 | 1239 24 | 42.6 | 84.1 | 1.20 | 30.8 | 4.6 |
| ST 4554B2RF | 551 15 | 1451 25 | 1649 15 | 1303 26 | 1238 25 | 44.6 | 83.1 | 1.13 | 27.9 | 5.0 |
| SSG CT Linwood | **741** 1 | 1565 17T | 1511 27 | 1088 31 | 1226 26 | 44.4 | 83.8 | 1.11 | 32.5 | 5.3 |
| CG3520B2RF | 558 13T | 1382 28 | 1547 24 | 1391 22 | 1219 27 | 44.1 | 83.5 | 1.15 | 26.0 | 4.7 |
| All-Tex A102 | **653** 3 | 1565 17T | 1469 29 | 1180 30 | 1217 28 | 43.6 | 84.2 | 1.19 | 28.5 | 4.4 |
| GA2004303 | 464 23 | 1587 15 | 1577 22T | 1234 28 | 1215 29 | 44.8 | 83.2 | 1.15 | 31.0 | 4.7 |
| GA2006127 | 460 25 | 1494 22 | 1614 19 | 1226 29 | 1199 30 | 44.6 | 84 | 1.20 | 31.3 | 4.6 |
| CG3020B2RF | 498 21 | 1297 30 | 1479 28 | 1505 18 | 1195 31 | 41.8 | 83.3 | 1.13 | 26.1 | 4.3 |
| CG3035RF | 389 28 | 1357 29 | 1540 25 | 1083 32 | 1092 32 | 45.5 | 83.3 | 1.13 | 28.8 | 4.7 |
| Average | 542 | 1565 | 1669 | 1506 | 1321 | 44.6 | 83.5 | 1.15 | 28.8 | 4.8 |
| LSD 0.10 | 93 | 159 | 265 | 264 | 152 | 1.0 | 0.6 | 0.02 | 1.4 | 0.2 |
| CV % | 14.5 | 8.6 | 13.5 | 14.9 | 13.4 | 2.0 | 0.9 | 1.97 | 5.0 | 4.5 |

a Superscripts indicate ranking at that location.

**Bolding** indicates entries not significantly different from highest yielding entry based on Fisher's protected LSD (P = 0.10).

Table 2. Two-year summary for dryland earlier maturity cotton varieties at four locations[a], 2008-2009.

| Variety | Lint Yield | Lint | Uniformity Index | Length | Strength | Micronaire |
|---|---|---|---|---|---|---|
| | lb/acre | % | % | inches | g/tex | units |
| GA2004230 | **1267** | 43.9 | 84.5 | 1.25 | 32.0 | 4.7 |
| FM1740B2RF | **1235** | 44.9 | 83.2 | 1.14 | 30.0 | 4.8 |
| DP 0935 B2RF | **1210** | 44.6 | 83.1 | 1.13 | 29.2 | 4.8 |
| PHY370WR | **1207** | 45.1 | 83.0 | 1.10 | 29.9 | 5.0 |
| DP 0924 B2RF | 1189 | 44.2 | 82.9 | 1.12 | 30.0 | 5.0 |
| GA2004303 | 1171 | 45.0 | 82.8 | 1.14 | 32.3 | 4.9 |
| NG3331B2RF | 1167 | 43.5 | 83.6 | 1.12 | 32.1 | 5.2 |
| PHY375WRF | 1154 | 46.0 | 82.8 | 1.14 | 29.3 | 4.7 |
| GA2004143 | 1150 | 47.1 | 83.3 | 1.19 | 33.7 | 4.8 |
| AM1550B2RF | 1126 | 44.4 | 82.5 | 1.13 | 27.7 | 4.9 |
| ST 4498B2RF | 1116 | 43.4 | 82.9 | 1.14 | 31.4 | 4.7 |
| CG 3220B2RF | 1113 | 43.4 | 82.9 | 1.15 | 28.4 | 4.9 |
| NG4370B2RF | 1111 | 42.6 | 83.2 | 1.14 | 30.2 | 4.8 |
| ST 4554B2RF | 1090 | 43.9 | 82.5 | 1.13 | 29.8 | 5.0 |
| CG4020B2RF | 1078 | 43.2 | 83.3 | 1.18 | 28.1 | 4.5 |
| CG3520B2RF | 1028 | 43.1 | 83.5 | 1.16 | 27.3 | 4.6 |
| CG3020B2RF | 995 | 41.2 | 82.8 | 1.13 | 27.1 | 4.3 |
| CG3035RF | 981 | 44.7 | 83.1 | 1.14 | 29.5 | 4.8 |
| Average | 1133 | 44.1 | 83.1 | 1.15 | 29.9 | 4.8 |
| LSD 0.10 | 67 | 0.4 | 0.5 | 0.01 | 0.8 | 0.1 |
| CV % | 14.4 | 2.2 | 1.0 | 2.01 | 4.5 | 5.0 |

a. Athens, Midville, Plains, and Tifton.
**Bolding** indicates entries not significantly different from highest yielding entry based on Fisher's protected LSD (P = 0.10).

Table 3. Yield summary for irrigated earlier maturity cotton varieties, 2009.

| Entry | Lint Yield[a] Bainbridge | Midville | Plains | Tifton | 4-Loc. Average | Lint | Unif. Index | Length | Strength | Mic. |
|---|---|---|---|---|---|---|---|---|---|---|
| | lb/acre | | | | | % | % | in | g/tex | units |
| 09R619B2R2 | 1466 [15] | **2101** [5] | **2563** [2] | **2034** [3] | **2041** [1] | 45.3 | 84.1 | 1.17 | 26.9 | 4.5 |
| FM1740B2RF | **1683** [4] | **2145** [1] | 2119 [21] | **2187** [1] | **2033** [2] | 44.3 | 83.7 | 1.17 | 27.4 | 4.1 |
| DP 0920B2RF | **1691** [3] | **2100** [6T] | 2166 [18] | **2154** [2] | **2028** [3] | 45.0 | 83.9 | 1.19 | 26.5 | 4.4 |
| Dyna-Gro 2570B2RF | 1538 [11] | **2111** [4] | **2377** [5] | **1980** [7] | **2001** [4] | 44.6 | 83.7 | 1.17 | 27.4 | 4.4 |
| DP 0935 B2RF | 1510 [12] | **2100** [6T] | 2250 [10] | **2006** [4] | **1967** [5] | 44.6 | 83.9 | 1.16 | 26.6 | 4.4 |
| GA2004143 | **1566** [8] | **1966** [14] | **2571** [1] | 1610 [24] | **1928** [6] | 46.5 | 84.0 | 1.21 | 31.2 | 4.2 |
| PHY370WR | 1455 [16] | **1979** [12] | 2255 [9] | **2005** [5T] | **1923** [7] | 44.2 | 83.5 | 1.14 | 28.8 | 4.4 |
| DP 0912B2RF | 1407 [19] | **2050** [9] | 2297 [7] | 1918 [10] | **1918** [8] | 43.1 | 84.0 | 1.16 | 29.3 | 4.6 |
| GA2004303 | **1844** [1] | 1911 [17] | **2417** [3] | 1461 [29] | **1908** [9T] | 44.3 | 83.7 | 1.17 | 29.2 | 4.5 |
| GA2006053 | 1468 [14] | **2029** [10] | 2216 [12] | 1920 [9] | **1908** [9T] | 42.3 | 84.2 | 1.19 | 28.0 | 4.4 |
| GA2004230 | 1546 [9] | **2058** [8] | 2314 [6] | 1616 [23] | **1884** [10] | 42.9 | 84.0 | 1.25 | 28.9 | 4.2 |
| ST 4498B2RF | **1722** [2] | **1972** [13] | 2065 [24] | 1752 [20] | **1878** [11] | 43.3 | 83.5 | 1.17 | 28.7 | 4.1 |
| ST 5288B2F | 1296 [30] | **2140** [2] | 2189 [15] | 1880 [13] | **1876** [12] | 43.6 | 83.4 | 1.17 | 27.3 | 4.5 |
| SSG CT Linwood | **1585** [7] | **1924** [16] | **2410** [4] | 1576 [27] | **1874** [13] | 44.0 | 84.2 | 1.15 | 30.2 | 4.8 |
| PHY367WRF | **1591** [6] | 1883 [18] | 2112 [22] | 1887 [11] | **1868** [14] | 43.7 | 84.3 | 1.20 | 28.4 | 4.0 |
| DP 0924 B2RF | 1438 [17] | **2120** [3] | 2179 [17] | 1649 [22] | 1846 [15] | 43.5 | 84.0 | 1.16 | 28.0 | 4.5 |
| CG 3220B2RF | 1315 [24] | **2083** [7] | 2151 [19] | 1812 [17] | 1840 [16] | 43.0 | 84.1 | 1.19 | 26.7 | 4.5 |
| AM1550B2RF | 1430 [18] | 1762 [24] | 2014 [26] | **2003** [6] | 1802 [17] | 43.9 | 83.8 | 1.15 | 25.4 | 4.3 |
| ST 4288B2F | 1306 [26] | **1941** [15] | 1948 [28] | **1979** [8] | 1793 [18] | 41.2 | 84.1 | 1.20 | 27.5 | 4.7 |
| GA2006127 | 1376 [21] | **1985** [11] | 2204 [14] | 1579 [26] | 1786 [19] | 43.6 | 84.5 | 1.23 | 30.5 | 4.2 |
| BCSX 1035LLB2 | 1301 [27] | 1873 [19] | 1884 [32] | **2005** [5T] | 1766 [20] | 41.9 | 84.0 | 1.15 | 31.1 | 4.8 |
| All-Tex A102 | **1606** [5] | 1539 [31] | 2143 [20] | 1756 [19] | 1761 [21] | 42.4 | 83.9 | 1.19 | 27.7 | 4.0 |
| ST 4554B2RF | 1389 [20] | 1850 [20] | 1893 [30] | 1837 [15] | 1742 [22] | 43.3 | 83.3 | 1.19 | 28.3 | 4.4 |
| PHY375WRF | 1297 [29] | 1765 [23] | 2022 [25] | 1881 [12] | 1741 [23] | 44.1 | 83.6 | 1.17 | 27.5 | 4.1 |
| All-Tex Epic | 1540 [10] | 1651 [30] | 2259 [8] | 1488 [28] | 1734 [24] | 45.1 | 83.8 | 1.18 | 27.6 | 4.2 |
| CG3520B2RF | 1267 [31] | 1742 [26] | 2076 [23] | 1824 [16] | 1728 [25] | 42.2 | 84.4 | 1.20 | 25.6 | 4.2 |
| NG4370B2RF | 1354 [22] | 1770 [22] | 1942 [29] | 1772 [18] | 1709 [26] | 42.5 | 84.0 | 1.16 | 28.2 | 4.3 |
| CG3035RF | 1479 [13] | 1747 [25] | 2185 [16] | 1400 [30] | 1703 [37] | 44.4 | 83.9 | 1.17 | 27.3 | 4.0 |
| NG3331B2RF | 1331 [23] | 1820 [21] | 1954 [27] | 1697 [21] | 1700 [28] | 43.2 | 84.0 | 1.15 | 29 | 4.5 |
| CG4020B2RF | 1262 [32] | 1678 [28] | 2223 [11] | 1585 [25] | 1687 [29] | 42.3 | 84.2 | 1.21 | 25.8 | 4.0 |
| CG3020B2RF | 1313 [25] | 1674 [29] | 1890 [31] | 1845 [14] | 1680 [30] | 41.2 | 84.2 | 1.18 | 26.8 | 3.9 |
| GA2006168 | 1300 [28] | 1733 [27] | 2208 [13] | 1365 [31] | 1652 [31] | 41.7 | 84.1 | 1.22 | 29.2 | 4.1 |
| Average | 1459 | 1913 | 2172 | 1796 | 1835 | 43.5 | 83.9 | 1.18 | 28.0 | 4.3 |
| LSD 0.10 | 281 | 232 | 245 | 236 | 190 | 0.9 | N.S.[b] | 0.02 | 0.7 | 1.3 |
| CV % | 16.4 | 10.03 | 9.6 | 11.2 | 11.6 | 1.9 | 0.9 | 1.72 | 5.2 | 5.3 |

[a] Superscripts indicate ranking at that location.

[b] The F-test indicated no statistical differences at the alpha = .10 probability level; therefore a LSD value was not calculated.

**Bolding** indicates entries not significantly different from highest yielding entry based on Fisher's protected LSD (P = 0.10).

Table 4. Two-year summary for irrigated earlier maturity cotton varieties at four locations[a], 2008-2009.

| Variety | Lint Yield | Lint | Uniformity Index | Length | Strength | Micronaire |
|---|---|---|---|---|---|---|
| | lb/acre | % | % | inches | g/tex | units |
| FM1740B2RF | **1862** | 44.0 | 83.5 | 1.17 | 29.4 | 4.2 |
| PHY370WR | **1841** | 44.2 | 83.1 | 1.13 | 29.8 | 4.4 |
| DP 0935B2RF | **1794** | 44.2 | 83.3 | 1.16 | 28.3 | 4.4 |
| GA2004143 | 1782 | 45.9 | 83.7 | 1.21 | 32.6 | 4.4 |
| DP 0924 B2RF | 1774 | 43.6 | 83.4 | 1.16 | 29.4 | 4.6 |
| ST 4498B2RF | 1746 | 43.2 | 83.4 | 1.16 | 30.4 | 4.2 |
| GA2004303 | 1745 | 44.1 | 83.1 | 1.16 | 31.0 | 4.5 |
| GA2004230 | 1741 | 43.0 | 84.0 | 1.26 | 30.8 | 4.2 |
| CG 3220B2RF | 1721 | 43.2 | 83.4 | 1.18 | 28.4 | 4.4 |
| PHY375WRF | 1705 | 44.2 | 83.2 | 1.16 | 28.6 | 4.1 |
| AM1550B2RF | 1691 | 43.5 | 83.3 | 1.15 | 27.0 | 4.3 |
| ST 4554B2RF | 1670 | 43.1 | 82.9 | 1.17 | 29.9 | 4.4 |
| NG3331B2RF | 1654 | 43.2 | 83.8 | 1.14 | 30.6 | 4.6 |
| NG4370B2RF | 1632 | 42.8 | 83.6 | 1.17 | 29.9 | 4.4 |
| CG3520B2RF | 1630 | 42.4 | 83.9 | 1.19 | 26.5 | 4.1 |
| CG4020B2RF | 1624 | 42.4 | 83.4 | 1.21 | 27.5 | 4.1 |
| CG3035RF | 1602 | 44.0 | 83.5 | 1.17 | 29.1 | 4.2 |
| CG3020B2RF | 1579 | 41.6 | 83.7 | 1.17 | 27.2 | 4.0 |
| Average | 1711 | 43.5 | 83.5 | 1.17 | 29.2 | 4.3 |
| LSD 0.10 | 73 | 0.4 | 0.5 | 0.01 | 0.9 | 0.1 |
| CV % | 10.4 | 2.2 | 1.0 | 1.81 | 5.5 | 5.8 |

[a] Bainbridge, Midville, Plains, and Tifton.
**Bolding** indicates entries not significantly different from highest yielding entry based on Fisher's protected LSD (P = 0.10).

Table 5. Yield summary for dryland later maturity cotton varieties, 2009.

| Entry | Lint Yield[a] | | | | | Lint | Unif. Index | Length | Strength | Mic. |
|---|---|---|---|---|---|---|---|---|---|---|
| | Athens | Midville | Plains | Tifton | 4-Loc. Average | | | | | |
| | lb/acre | | | | | % | % | in | g/tex | units |
| PHY370WR | **604** 6 | 1441 13 | **1738** 2 | **1868** 2 | **1413** 1 | 45.7 | 83.5 | 1.11 | 30.1 | 5.0 |
| DP 0949B2RF | **597** 9 | **1688** 1 | **1640** 5 | 1678 11 | **1401** 2 | 46.0 | 83.7 | 1.15 | 29.5 | 5.1 |
| PHY565WRF | 571 10T | **1469** 10 | **1818** 1 | 1663 13 | **1380** 3 | 45.4 | 83.6 | 1.15 | 30.9 | 4.8 |
| DP 555 BG/RR | 510 17 | **1662** 2 | **1518** 9 | **1782** 6 | **1368** 4 | 46.2 | 82.5 | 1.12 | 30.0 | 4.7 |
| 09R621B2R2 | 423 21 | **1564** 3 | **1489** 12 | **1944** 1 | **1355** 5T | 47.3 | 84.2 | 1.17 | 27.2 | 4.8 |
| PHY375WRF | **603** 7T | **1532** 5 | **1493** 11 | **1792** 4 | **1355** 5T | 46.0 | 83.2 | 1.13 | 29.0 | 4.6 |
| ST 5458B2RF | 482 19 | **1508** 6 | **1560** 7 | **1777** 7 | **1332** 6 | 45.0 | 82.4 | 1.13 | 30.2 | 5.1 |
| FM 1845LLB2 | **623** 4 | **1491** 8 | **1389** 18 | **1785** 5 | **1322** 7T | 43.5 | 84.5 | 1.21 | 31.3 | 4.8 |
| DP161B2RF | 559 12 | **1470** 9 | **1735** 3 | 1525 22 | **1322** 7T | 42.3 | 84.4 | 1.20 | 31.2 | 4.8 |
| DP 0935 B2RF | 486 18 | 1405 16T | **1549** 8 | **1830** 3 | **1318** 8 | 45.5 | 83.0 | 1.11 | 28.6 | 5.0 |
| DP174RF | **630** 3 | 1421 14 | **1675** 4 | 1532 21 | **1315** 9 | 46.6 | 83.0 | 1.16 | 28.0 | 4.8 |
| ST 5288B2F | 556 13 | 1400 17 | **1614** 6 | 1600 17 | **1293** 10 | 45.3 | 82.9 | 1.14 | 28.0 | 5.0 |
| ST 5327B2RF | 571 10T | **1555** 4 | **1434** 15 | 1607 15 | **1292** 11 | 44.9 | 83.1 | 1.13 | 29.4 | 4.7 |
| PHY5922WRF | **602** 8 | 1292 19 | **1505** 10 | **1753** 8 | **1288** 12 | 44.6 | 84.1 | 1.14 | 30.5 | 4.9 |
| DP 164 B2RF | **639** 2 | 1419 15T | **1368** 19 | 1723 9 | **1287** 13 | 43.2 | 83.7 | 1.19 | 30.2 | 4.7 |
| BCSX 1025LLB2 | **613** 5 | **1500** 7 | **1342** 21 | 1690 10 | **1286** 14 | 43.7 | 83.8 | 1.20 | 31.8 | 4.7 |
| PHY485WRF | **603** 7T | 1405 16T | **1476** 13 | 1535 20 | 1255 15 | 44.0 | 83.4 | 1.14 | 29.8 | 4.9 |
| BCSX 1005LLB2 | 560 11T | 1419 15T | **1392** 17 | 1585 18 | 1239 16 | 42.7 | 83.9 | 1.20 | 32.2 | 5.2 |
| PHY440W | **687** 1 | 1342 18 | **1273** 24 | 1638 14 | 1235 17 | 43.6 | 83.7 | 1.14 | 29.7 | 4.8 |
| BCSX 1010B2F | 538 14 | **1460** 11 | **1356** 20 | 1552 19 | 1227 18 | 43.8 | 83.2 | 1.15 | 29.0 | 4.9 |
| PHY480WR | 560 11T | 1454 12 | **1274** 23 | 1606 16 | 1224 19 | 41.8 | 84.1 | 1.16 | 31.3 | 4.9 |
| BCSX 1015LLB2 | 432 20 | 1236 21 | **1431** 16 | 1674 12 | 1193 20 | 41.9 | 84.0 | 1.24 | 32.7 | 4.8 |
| PHY525RF | 522 16 | 1184 22 | **1474** 14 | 1085 24 | 1066 21 | 44.8 | 83.9 | 1.18 | 28.9 | 4.3 |
| SSG CT 310HQ | 523 15 | 1287 20 | **1290** 22 | 1101 23 | 1051 22 | 42.1 | 83.6 | 1.15 | 34.4 | 4.9 |
| Average | 562 | 1442 | 1493 | 1639 | 1284 | 44.4 | 83.6 | 1.16 | 30.2 | 4.8 |
| LSD 0.10 | 108 | 228 | N.S.[b] | 194 | 152 | 1.0 | 0.8 | 0.02 | 1.2 | 0.2 |
| CV % | 16.3 | 13.4 | 17.0 | 10.0 | 14.4 | 1.9 | 1.1 | 2.14 | 4.9 | 3.9 |

[a] Superscripts indicate ranking at that location.

[b] The F-test indicated no statistical differences at the alpha = .10 probability level; therefore a LSD value was not calculated.

**Bolding** indicates entries not significantly different from highest yielding entry based on Fisher's protected LSD (P = 0.10).

Table 6. Two-year summary for dryland later maturity cotton varieties at four locations[a], 2008-2009.

| Variety | Lint Yield | Lint | Uniformity Index | Length | Strength | Micronaire |
|---|---|---|---|---|---|---|
| | lb/acre | % | % | inches | g/tex | units |
| DP 555 BG/RR | **1280** | 44.9 | 82.7 | 1.14 | 31.6 | 4.7 |
| DP 0935 B2RF | **1239** | 44.7 | 82.6 | 1.13 | 29.2 | 5.0 |
| DP174RF | **1234** | 46.8 | 82.8 | 1.17 | 29.0 | 4.9 |
| PHY375WRF | **1218** | 45.7 | 82.6 | 1.13 | 29.3 | 4.8 |
| DP 164 B2RF | 1189 | 42.0 | 83.5 | 1.19 | 31.6 | 4.7 |
| FM 1845LLB2 | 1184 | 43.0 | 84.1 | 1.21 | 32.8 | 4.9 |
| DP161B2RF | 1180 | 41.7 | 83.8 | 1.20 | 32.5 | 4.9 |
| ST 5288B2F | 1176 | 44.8 | 82.7 | 1.14 | 28.9 | 5.1 |
| PHY485WRF | 1111 | 43.2 | 83.3 | 1.15 | 30.9 | 5.0 |
| PHY480WR | 1109 | 42.0 | 83.5 | 1.16 | 31.4 | 5.0 |
| PHY440W | 1097 | 43.6 | 83.0 | 1.14 | 30.9 | 4.9 |
| Average | 1183 | 43.8 | 83.1 | 1.16 | 30.7 | 4.9 |
| LSD 0.10 | 77 | 0.4 | 0.6 | 0.01 | 0.9 | 0.1 |
| CV % | 15.8 | 2.4 | 1.2 | 2.06 | 5.0 | 4.6 |

a. Athens, Midville, Plains, and Tifton.
**Bolding** indicates entries not significantly different from highest yielding entry based on Fisher's protected LSD (P = 0.10).

Table 7. Yield summary for irrigated later maturity cotton varieties, 2009.

| Entry | Lint Yield[a] Bainbridge | Midville | Plains | Tifton | 4-Loc. Average | Lint | Unif. Index | Length | Strength | Mic. |
|---|---|---|---|---|---|---|---|---|---|---|
| | ---------- lb/acre ---------- | | | | | % | % | in | g/tex | units |
| DP 0949B2RF | 1515 [3] | **2307** [1] | **2084** [6] | **1870** [3] | **1944** [1] | 45.2 | 84.0 | 1.19 | 29.1 | 4.6 |
| 09R621B2R2 | **1733** [1] | 1999 [10] | **2015** [9] | 1773 [8] | **1880** [2] | 44.9 | 84.4 | 1.18 | 28.1 | 4.5 |
| PHY375WRF | **1545** [2] | **2078** [5] | 1884 [12] | **1961** [1] | **1867** [3] | 43.5 | 83.2 | 1.16 | 28.1 | 4.1 |
| DP 555 BG/RR | 1446 [7T] | **2129** [3] | **2099** [4] | 1731 [11] | **1851** [4] | 44.5 | 82.5 | 1.17 | 30.3 | 4.0 |
| PHY370WR | 1443 [8] | 2051 [6] | **1973** [10] | **1906** [2] | **1844** [5] | 44.2 | 83.0 | 1.14 | 29.1 | 4.4 |
| PHY5922WRF | 1466 [5] | **2089** [4] | **2178** [1] | 1608 [19] | **1835** [6] | 43.8 | 84.2 | 1.18 | 29.9 | 4.2 |
| PHY485WRF | 1505 [4] | 1807 [21] | **2130** [3T] | **1839** [6] | **1820** [7] | 44.0 | 84.5 | 1.18 | 30.6 | 4.5 |
| PHY565WRF | 1285 [18] | 2020 [8] | **2130** [3T] | **1843** [5] | **1819** [8] | 43.5 | 83.7 | 1.20 | 31.2 | 4.0 |
| ST 5458B2RF | 1411 [10] | 1857 [18] | **2087** [5] | **1845** [4] | **1800** [9] | 44.0 | 82.5 | 1.19 | 30.0 | 4.6 |
| DP 0935 B2RF | 1412 [9] | **2133** [2] | 1834 [14] | 1786 [7] | **1791** [10] | 44.9 | 83.2 | 1.16 | 28.2 | 4.3 |
| DP161B2RF | 1353 [13] | 2014 [9] | **2047** [8] | 1743 [9] | 1789 [11] | 42.8 | 84.3 | 1.24 | 31.9 | 4.2 |
| BCSX 1015LLB2 | 1316 [16] | 1967 [12] | **2081** [7] | 1634 [18] | 1750 [12] | 41.0 | 84.0 | 1.26 | 31.5 | 4.3 |
| ST 5288B2F | 1317 [15] | 2038 [7] | 1871 [13] | 1730 [12] | 1739 [13] | 44.3 | 83.1 | 1.17 | 27.6 | 4.5 |
| PHY480WR | 1216 [19] | 1905 [15] | **2131** [2] | 1676 [15] | 1732 [14] | 42.4 | 84.4 | 1.19 | 30.2 | 4.5 |
| ST 5327B2RF | 1446 [7T] | 1988 [11] | 1742 [18T] | 1733 [10] | 1727 [15] | 43.8 | 84.0 | 1.18 | 29.9 | 4.3 |
| DP 164 B2RF | 1311 [17] | 1899 [16] | **1943** [11] | 1708 [14] | 1715 [16] | 42.6 | 83.5 | 1.22 | 29.9 | 4.0 |
| PHY440W | 1336 [14] | 1938 [13] | 1788 [15] | 1653 [17] | 1679 [17] | 42.0 | 83.7 | 1.18 | 30.3 | 4.2 |
| FM 1845LLB2 | 1207 [20] | 1923 [14] | 1748 [17] | 1723 [13] | 1650 [18] | 41.0 | 84.5 | 1.24 | 31.0 | 4.2 |
| BCSX 1010B2F | 1356 [12] | 1864 [17] | 1685 [21] | 1670 [16] | 1644 [19] | 40.9 | 83.8 | 1.20 | 29.6 | 4.3 |
| DP174RF | 1454 [6] | 1816 [20] | 1730 [19] | 1510 [22] | 1628 [20] | 45.2 | 83.4 | 1.20 | 28.2 | 4.2 |
| BCSX 1025LLB2 | 1364 [11] | 1831 [19] | 1711 [20] | 1533 [21] | 1610 [21] | 41.9 | 84.0 | 1.24 | 31.7 | 4.2 |
| BCSX 1005LLB2 | 1187 [22] | 1704 [22] | 1742 [18T] | 1599 [20] | 1558 [22] | 40.6 | 84.3 | 1.23 | 32.0 | 4.5 |
| SSG CT 310HQ | 1170 [23] | 1371 [24] | 1761 [16] | 913 [24] | 1304 [23] | 41.8 | 83.4 | 1.17 | 32.7 | 4.1 |
| PHY525RF | 1194 [21] | 1430 [23] | 1304 [22] | 1054 [23] | 1245 [24] | 43.1 | 83.7 | 1.22 | 29.1 | 3.8 |
| Average | 1375 | 1923 | 1904 | 1668 | 1718 | 43.2 | 83.7 | 1.19 | 30.0 | 4.3 |
| LSD 0.10 | 191 | 237 | 264 | 170 | 153 | 1.6 | 0.7 | 0.02 | 1.4 | 0.2 |
| CV % | 11.8 | 10.5 | 11.8 | 8.6 | 10.8 | 2.5 | 0.8 | 1.76 | 4.3 | 6.5 |

[a] Superscripts indicate ranking at that location.
**Bolding** indicates entries not significantly different from highest yielding entry based on Fisher's protected LSD (P = 0.10).

Table 8. Two-year summary for irrigated later maturity cotton varieties at four locations[a], 2008-2009.

| Variety | Lint Yield | Lint | Uniformity Index | Length | Strength | Micronaire |
|---|---|---|---|---|---|---|
| | lb/acre | % | % | inches | g/tex | units |
| DP 555 BG/RR | **1832** | 44.5 | 82.3 | 1.16 | 31.1 | 4.1 |
| PHY375WRF | **1793** | 43.8 | 83.0 | 1.16 | 29.1 | 4.0 |
| DP 0935 B2RF | **1789** | 44.5 | 82.8 | 1.15 | 28.9 | 4.3 |
| ST 5288B2F | 1763 | 44.1 | 82.7 | 1.16 | 29 | 4.5 |
| DP161B2RF | 1748 | 42.6 | 84.2 | 1.23 | 33.3 | 4.1 |
| PHY485WRF | 1743 | 43.5 | 83.9 | 1.17 | 31.2 | 4.5 |
| PHY480WR | 1714 | 42.3 | 84.2 | 1.19 | 31.0 | 4.5 |
| DP174RF | 1678 | 46.0 | 83.5 | 1.20 | 29.1 | 4.2 |
| FM 1845LLB2 | 1659 | 41.4 | 84.4 | 1.24 | 32.4 | 4.2 |
| PHY440W | 1637 | 42.2 | 83.3 | 1.17 | 30.9 | 4.2 |
| DP 164 B2RF | 1620 | 42.9 | 83.1 | 1.21 | 31.4 | 4.0 |
| Average | 1725 | 43.4 | 83.4 | 1.19 | 30.7 | 4.2 |
| LSD 0.10 | 67 | 0.4 | 0.5 | 0.01 | 0.8 | 0.2 |
| CV % | 9.4 | 2.3 | 0.9 | 1.86 | 4.3 | 6.2 |

[a] Bainbridge, Midville, Plains, and Tifton.

**Bolding** indicates entries not significantly different from highest yielding entry based on Fisher's protected LSD (P = 0.10).

Table 9. Yield summary for irrigated cotton strains, 2009.

| Variety | Lint Yield[a] Midville | Plains | Tifton | 3-Loc. Average | Lint | Unif. Index | Length | Strength | Mic. |
|---|---|---|---|---|---|---|---|---|---|
| | lb/acre | | | | % | % | inches | g/tex | units |
| DP 1048 B2RF | **2076** [1] | **2054** [2] | **1746** [3] | **1959** [1] | 46.3 | 83.8 | 1.18 | 26.9 | 4.3 |
| DP 1028 B2RF | **1931** [6] | **2067** [1] | **1781** [2] | **1926** [2] | 46.3 | 84.1 | 1.19 | 28.3 | 4.4 |
| ST 5458B2RF | **2047** [2] | 1695 [9] | **1840** [1] | **1861** [3] | 43.9 | 82.7 | 1.17 | 29.8 | 4.2 |
| GA2007095 | **2023** [3] | **1965** [3] | 1524 [7] | **1837** [4] | 45.4 | 83.3 | 1.16 | 27.6 | 4.2 |
| 09R549B2R2 | **1908** [7T] | 1837 [5] | **1741** [4] | **1829** [5] | 44.9 | 85.0 | 1.22 | 30.4 | 4.5 |
| DP 1032 B2RF | 1807 [8] | 1843 [4] | 1583 [6] | 1745 [6] | 44.3 | 83.9 | 1.21 | 29.5 | 4.1 |
| BCSX 1025LLB2 | **1977** [4] | 1586 [12] | 1594 [5] | 1719 [7] | 42.7 | 84.4 | 1.23 | 29.7 | 4.1 |
| DP174RF | **1959** [5] | 1667 [10] | 1371 [10] | 1666 [8T] | 46.1 | 84.1 | 1.19 | 27.7 | 4.1 |
| GA2006109 | **1908** [7T] | 1796 [7] | 1294 [12] | 1666 [8T] | 45.1 | 84.0 | 1.19 | 28.4 | 4.2 |
| PHY485WRF | 1761 [10] | 1834 [6] | 1362 [11] | 1653 [9] | 43.1 | 84.3 | 1.17 | 29.4 | 4.3 |
| GA2006106 | 1772 [9] | 1739 [8] | 1378 [9] | 1629 [10] | 43.9 | 84.5 | 1.23 | 30.7 | 4.1 |
| GA2006128 | 1691 [11] | 1637 [11] | 1455 [8] | 1594 [11] | 43.7 | 84.4 | 1.21 | 29.1 | 4.3 |
| SSG 59-3-29 | 1209 [12] | 1483 [13] | 1256 [13] | 1316 [12] | 42.7 | 83.4 | 1.18 | 29.4 | 4.0 |
| Average | 1852 | 1785 | 1533 | 1723 | 44.5 | 84.0 | 1.19 | 29.0 | 4.2 |
| LSD 0.10 | 212 | 196 | 233 | 186 | 1.6 | 1.0 | 0.03 | N.S.[1] | N.S. |
| CV % | 9.6 | 9.2 | 12.8 | 10.4 | 1.9 | 0.9 | 1.66 | 6.2 | 6.3 |

[a] Superscripts indicate ranking at that location.

1. The F-test indicated no statistical differences at the alpha = .10 probability level; therefore a LSD value was not calculated.

**Bolding** indicates entries not significantly different from highest yielding entry based on Fisher's protected LSD (P = 0.10).

Table 10. Later maturity irrigated cotton variety performance including Micro-gin[a] quality data, 2009, Tifton, Georgia.

| Variety | Lint Yield | MG[1] Lint Yield | Lint | MG[1] Lint | Unif. Index[2] | MG[1] Unif. Index | Length[2] | MG[1] Length | Strength[2] | MG[1] Strength* | Mic.[2] | MG[1] Mic. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | lb/acre | lb/acre | % | % | % | % | inches | inches | g/tex | g/tex | units | units |
| 09R621B2R2 | 1773 | 1563 | 46.9 | 41.2 | 84.2 | 84.0 | 1.15 | 1.18 | 29.7 | 26.2 | 4.5 | 4.5 |
| BCSX 1005LLB2 | 1599 | 1452 | 41.3 | 37.2 | 83.9 | 83.3 | 1.19 | 1.20 | 32.8 | 29.9 | 4.4 | 4.4 |
| BCSX 1010B2F | 1670 | 1486 | 41.7 | 37.3 | 83.5 | 83.1 | 1.18 | 1.18 | 28.5 | 27.0 | 4.1 | 4.2 |
| BCSX 1015LLB2 | 1634 | 1461 | 40.6 | 36.3 | 84.1 | 83.8 | 1.24 | 1.26 | 32.9 | 30.2 | 4.1 | 4.2 |
| BCSX 1025LLB2 | 1533 | 1361 | 41.6 | 36.9 | 84.4 | 82.9 | 1.22 | 1.22 | 33.1 | 29.6 | 4.1 | 4.0 |
| DP 0935 B2RF | 1786 | **1649** | 45.6 | 41.6 | 83.2 | 82.7 | 1.11 | 1.15 | 30.2 | 26.7 | 3.9 | 4.4 |
| DP 0949B2RF | **1870** | **1607** | 46.4 | 40.3 | 84.0 | 83.2 | 1.16 | 1.17 | 29.5 | 27.1 | 4.2 | 4.5 |
| DP 164 B2RF | 1708 | 1530 | 42.1 | 37.6 | 84.2 | 83.2 | 1.21 | 1.20 | 31.1 | 29.0 | 3.5 | 4.0 |
| DP 555 BG/RR | 1731 | 1525 | 45.8 | 40.2 | 82.9 | 81.8 | 1.15 | 1.14 | 32.8 | 28.9 | 3.7 | 4.1 |
| DP161B2RF | 1743 | 1488 | 43.6 | 37.2 | 84.9 | 83.7 | 1.20 | 1.21 | 33.7 | 28.9 | 4.0 | 4.1 |
| DP174RF | 1510 | 1237 | 47.7 | 39.4 | 82.6 | 83.8 | 1.15 | 1.19 | 27.9 | 26.9 | 4.1 | 4.1 |
| FM 1845LLB2 | 1723 | **1633** | 41.2 | 36.9 | 85.0 | 83.9 | 1.22 | 1.23 | 32.3 | 29.8 | 4.0 | 4.2 |
| PHY370WR | **1906** | **1663** | 44.3 | 38.6 | 83.8 | 82.4 | 1.12 | 1.14 | 30.4 | 28.0 | 4.0 | 4.3 |
| PHY375WRF | **1961** | **1714** | 44.7 | 39.0 | 83.3 | 82.8 | 1.13 | 1.15 | 29.5 | 26.5 | 3.9 | 4.0 |
| PHY440W | 1653 | 1484 | 43.3 | 38.5 | 84.4 | 83.2 | 1.17 | 1.17 | 33.9 | 27.7 | 4.1 | 4.1 |
| PHY480WR | 1676 | 1447 | 42.5 | 36.7 | 84.7 | 84.0 | 1.16 | 1.19 | 31.7 | 28.2 | 4.5 | 4.3 |
| PHY485WRF | **1839** | 1526 | 46.2 | 38.0 | 85.4 | 83.2 | 1.17 | 1.18 | 30.7 | 28.9 | 4.3 | 4.6 |
| PHY525RF | 1054 | 868 | 45.4 | 37.7 | 84.1 | 83.3 | 1.19 | 1.19 | 31.1 | 27.3 | 3.9 | 3.9 |
| PHY565WRF | **1843** | **1608** | 43.9 | 38.4 | 84.2 | 84.1 | 1.19 | 1.19 | 33.9 | 29.9 | 4.1 | 4.0 |
| PHY5922WRF | 1608 | 1462 | 43.2 | 39.0 | 84.0 | 83.2 | 1.15 | 1.16 | 31.4 | 28.9 | 3.8 | 4.3 |
| SSG CT 310HQ | 913 | 754 | 41.3 | 34.1 | 82.4 | 83.0 | 1.11 | 1.17 | 35.7 | 32.6 | 4.2 | 4.1 |
| ST 5288B2F | 1730 | 1529 | 44.1 | 39.0 | 83.2 | 82.9 | 1.16 | 1.17 | 30.8 | 26.7 | 4.6 | 4.4 |
| ST 5327B2RF | 1733 | 1569 | 44.4 | 40.1 | 83.6 | 83.1 | 1.14 | 1.16 | 32.5 | 27.7 | 4.4 | 4.3 |
| ST 5458B2RF | **1845** | **1669** | 43.9 | 39.3 | 82.7 | 82.7 | 1.17 | 1.18 | 30.6 | 28.1 | 4.4 | 4.6 |
| Average | 1668 | 1470 | 43.8 | 38.3 | 83.8 | 83.2 | 1.17 | 1.18 | 31.5 | 28.4 | 4.1 | 4.2 |
| LSD 0.10 | 170 | 144 | 1.1 | 1.1 | 1.0 | 0.5 | 0.03 | 0.02 | 2.4 | 1.3 | 0.4 | 0.2 |
| CV % | 8.6 | 8.3 | 2.1 | 2.3 | 0.7 | 0.5 | 1.54 | 1.27 | 4.4 | 3.8 | 6.5 | 4.1 |

1. Micro-Gin quality samples are from total seed cotton harvested from each plot.
2. A random quality sample was taken on the picker during cotton harvest.

**Bolding** indicates entries not significantly different from highest yielding entry based on Fisher's protected LSD (P = 0.10).

Planted: April 29, 2009.
Harvested: September 24, 2009.
Soil Type: Tifton loamy sand.
Fertilization: 78 lb N, 54 lb $P_2O_5$, and 174 lb $K_2O$/acre.
Management: Temik applied 5 lb/acre.

| | May | June | July | Aug. | Sept. |
|---|---|---|---|---|---|
| Irrigation (in): | 0.0 | 1.8 | 1.8 | 0.0 | 0.0 |

Trials conducted by L. Thompson, D. Day and A. Knowlton.

# COTTON IRRIGATION AND MEPIQUAT CHLORIDE MANAGEMENT USING REMOTE SENSING

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## Introduction

Water is the most common environmental factor that limits crop productivity. Water is the primary component of actively growing crop plants, ranging from 70-90% of the crop plant fresh mass, and is essential to nutrient transport, chemical reactions, cell enlargement, transpiration, and most other plant processes. All plants are affected by soil moisture deficit. Moisture deficit inhibits cellular growth, changes enzyme concentrations, and eventually affects respiration, photosynthesis, and assimilate translocation, changing plant growth and development (Gardner et al. 1984). Water depletion affects cotton grown throughout the United States, particularly non-irrigated cotton. The costs of water application and the competitive demands for water further enhance the attractiveness of water-efficient cotton in production settings.

Cotton is an indeterminate crop with a fruiting habit that allows vegetative growth to continue above the fruiting branches after reproductive growth has been initiated. Left unchecked, cotton can exhibit rank growth (Cathey and Luckett 1980). This excess vegetative growth can cause fruit shed, difficulty in picking the cotton, boll rot, increased insect and disease pressure, decreased lint quality, and potentially impact yield (Nichols et al. 2003).

Mepiquat chloride (1,1-dimethylpiperidinium chloride) has been recognized as a useful cotton growth regulator since the late 1970s (Kerby 1985), due to its control of cotton height. Mepiquat chloride is an ammonium-containing compound that blocks the early steps of gibberellic acid (GA) metabolism, decreasing production of GA and resulting in shorter cotton.

Because both irrigation and mepiquat chloride application have associated application costs, the benefits of these amendments might be increased by imagery-based application. Not only may input costs be mitigated with more oversight over water and chemical application, but yield and quality may also be positively affected. Our objectives were to compare four levels of irrigation with multiple rates of mepiquat chloride application and compare the growth habits, yield, and quality of cotton under these regimes.

## Materials and Methods

This study was a split plot experiment conducted on a variable rate center pivot at the Stripling Irrigation Research Park in Camilla, Georgia. The pivot is designed to allow variable application of water in a randomized complete block design, so irrigation was the main plot. DP161B2RF cotton was planned at a rate of three plants per foot with 36

inch row spacing on May 20, 2009. All pesticide and herbicide applications were based on University of Georgia extension guidelines. Nitrogen was applied in a split application, with 20 lb N applied on April 28 in the form of 3-9-18, and follow-up applications of 45 lb each were made on June 17 and June 24, 2009. The irrigation component of this study formed the main plot. One irrigation was applied prior to planting, at a rate of 0.3 inches to all plots. Irrigation treatments were begun on June 26, 2009, and the last irrigation was conducted on July 23, 2009. The irrigation treatments consisted of a 100% irrigation treatment, a 75% irrigation treatment, a 50% irrigation treatment, and a nonirrigated control. Irrigation scheduling and rates were based on the 100% irrigation treatment. In the 100% irrigation treatment, watermark sensors were placed at depths of 8, 16, and 24 inches. Irrigation was commenced when watermark sensors measured -40 centibar soil tension.

The split plot consisted of four mepiquat treatments: a nonapplied control, a mepiquat regime based on a single aerial image prior to the first mepiquat application, a mepiquat regime based on aerial images collected prior to each mepiquat chloride (MC) application, and a standard MC application based on standard practice. Mepiquat chloride was applied on June 22 and July 6, 2007. Each treatment was replicated four times for a total of 64 plots. Measurements included NDVI using a GreenSeeker spectrometer, green/red ratio using images from the aerial blimp, and in-the-field measurements of plant height, nodes, and nodes above first square or uppermost white flower. At the end of the season, subsamples were cut out of each plot and analyzed using box mapping. Plots were harvested with a two-row picker with a bagging attachment, and individual bags were ginned at the University of Georgia Microgin in Tifton. Fiber samples were sent to the Macon classing office and analyzed using HVI.

## Results and Discussion

Plant height was related to irrigation rate, with the full irrigation rate yielding the tallest plants, followed by the 75% irrigation, 50% irrigation, and dryland treatments (Figure 6). The 0 mepiquat application resulted in taller plants than the treated plots, but none of the treated plots showed a significant difference in crop height on any of the sampling dates. This matched the results from the previous two years of this study. In all three study years, the “no MC” treatments were consistently taller than the other mepiquat chloride treatments. The intermediate mepiquat chloride treatments resulted in virtually identical two remote sensing treatments were similar in height to each other and taller than the standard mepiquat treatment at the lower levels of irrigation, but were not different in the full irrigation treatment. The remote sensing mepiquat chloride rates were similar to the standard rate at both the 75% and 100% irrigation rate. Nodes above first square (NAFS) and nodes above white flower (NAWF) measurements give estimates of crop maturity. First bloom occurred at 50 days after planting, but the measurements are combined, since the first squares become the first white flowers. Irrigation rate had the most impact on these ratings in 2009, as shown in Figure 2. The full irrigation plots had delayed maturity compared to the two intermediate irrigation treatments, and the dryland treatment had the lowest NAFS and NAWF throughout the season.

## NDVI and Green:Red Ratio

NDVI and Green:Red ratio are both vegetation indices that estimate crop growth. As with the height and maturity measurements, these indices showed increased vegetative growth for the full irrigation treatment compared to the other irrigation treatments (Figure 2). The Green:Red ratio showed more pronounced differences between the full irrigation and the other two irrigated treatments than the NDVI. One potential reason for this difference is that the NDVI was measured near the ground using a GreenSeeker, and they tended to reach a maximum measurement early in the growing season. The Green:Red ratio was sensitive to higher ground cover fractions. The NDVI measurements did not indicate any differences between MC treatments on any dates, and the Green:Red ratio only indicated significant differences on one date, in which the untreated plots had significantly higher Green:Red values, indicating more vegetative growth (Figure 2).

## Box Mapping, Yield, and Quality

Box mapping data are still being analyzed, but preliminary data is shown in Table 2. Table 2 shows the gains and losses of lint yield based on differences in boll mass during mapping by fruiting zone, compared to the fully irrigated treatment. There were no significant differences ($P<0.05$) for the MC treatments, so the data is not shown. Zone 1 is nodes 5-8, zone 2 is nodes 9-12, zone 3 is nodes 13-17, and zone 4 is nodes 18 and above. The 75%, 50%, and dryland treatments all had higher yields at the lower three zones than the fully irrigated treatment, but lower yields at zone 4. This suggests significantly higher early boll retention, and may explain at leas part of the increased height and vegetative growth of the full irrigation treatment compared to the other treatments. This phenomenon has been observed in other studies we have conducted. The final yield and quality of the plots are shown in Table 2. DP161 does not have the yield capabilities of DP555, which was the original variety planned for this study. Therefore, some of the decreases in yield probably would not have been observed with 555, since it tends to compensate well for loss of early fruiting sites on the plant. However, DP161 has impressive fiber quality parameters, as shown in Table 3. The highest yielding plots were the 50% and 75% irrigation treatments, suggesting that even a little over-watering can have a large impact on yield.

## Acknowledgments

The authors would like to thank the Georgia Cotton Commission, who funded this research.

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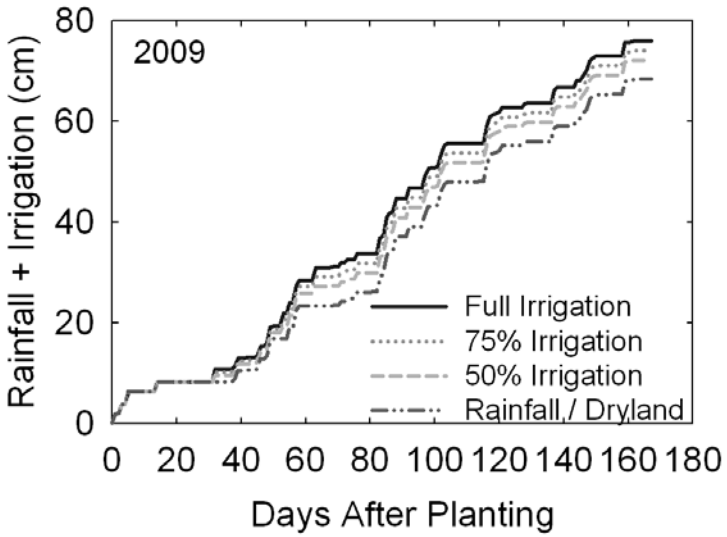


Figure 5. Cumulative rainfall and irrigation amounts for 2009.

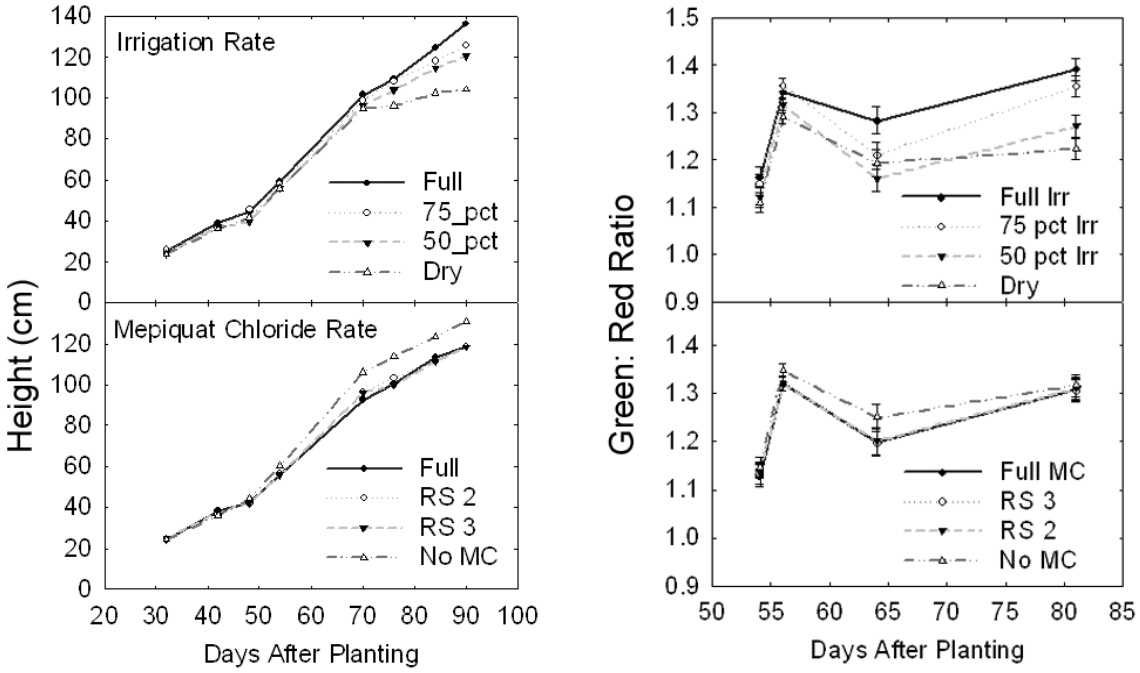


Figure 6. Height and Green:Red ratio by irrigation and mepiquat chloride treatment in 2009.

Table 2. Yield and quality of all irrigation and mepiquat chloride treatments in 2009.

| Irr | Pix | Micronaire | Strength | Length | Uniformity | Yield (lb/acre) | Staple |
|---|---|---|---|---|---|---|---|
| Full | Full | 3.69±0.16 fgh[a] | 31.89±0.41 de | 1.204±0.009 ab | 83.48±0.36 abcd | 905±68 de | 38.6±0.3 ab |
| Full | RS 3 | 3.56±0.19 gh | 32.83±0.48 abcd | 1.201±0.010 ab | 82.56±0.42 cd | 906±68 de | 38.4±0.4 ab |
| Full | RS 2 | 3.79±0.16 efgh | 31.44±0.41 e | 1.201±0.009 b | 82.76±0.36 bcd | 999±68 cd | 38.3±0.3 b |
| Full | No MC | 3.54±0.16 h | 31.92±0.41 cde | 1.201±0.009 b | 82.56±0.36 d | 809±68 e | 38.3±0.3 b |
| 75_pct | Full | 4.04±0.16 cdef | 33.37±0.41 a | 1.219±0.009 ab | 83.63±0.36 ab | 1033±68 cd | 38.8±0.3 ab |
| 75_pct | RS 3 | 4.04±0.16 cdef | 32.17±0.41 bcde | 1.211±0.009 ab | 83.61±0.36 ab | 1057±68 bcd | 38.8±0.3 ab |
| 75_pct | RS 2 | 4.01±0.16 defg | 33.02±0.41 ab | 1.211±0.009 ab | 83.41±0.36 abcd | 1131±68 abc | 38.6±0.3 ab |
| 75_pct | No MC | 4.09±0.16 bcdef | 32.49±0.41 abcde | 1.214±0.009 ab | 83.41±0.36 abcd | 1086±68 abc | 39.1±0.3 ab |
| 50_pct | Full | 4.04±0.16 cdef | 32.49±0.41 abcde | 1.219±0.009 ab | 83.78±0.36 a | 1238±68 a | 38.8±0.3 ab |
| 50_pct | RS 3 | 4.16±0.16 bcde | 33.04±0.41 ab | 1.219±0.009 ab | 83.46±0.36 abcd | 1237±68 a | 39.1±0.3 ab |
| 50_pct | RS 2 | 4.11±0.16 bcde | 32.54±0.41 abcd | 1.224±0.009 ab | 83.93±0.36 a | 1209±68 ab | 39.3±0.3 a |
| 50_pct | No MC | 4.14±0.16 bcde | 32.44±0.41 abcde | 1.211±0.009 ab | 83.36±0.36 abcd | 1238±68 a | 38.8±0.3 ab |
| Dry | Full | 4.59±0.16 a | 32.54±0.41 abcd | 1.226±0.009 a | 83.71±0.36 ab | 1118±68 abc | 39.3±0.3 a |
| Dry | RS 3 | 4.44±0.16 abc | 32.67±0.41 abcd | 1.211±0.009 ab | 83.36±0.36 abcd | 1030±68 cd | 38.8±0.3 ab |
| Dry | RS 2 | 4.34±0.16 abcd | 32.97±0.41 abc | 1.206±0.009 ab | 83.11±0.36 abcd | 1048±68 bcd | 38.6±0.3 ab |
| Dry | No MC | 4.46±0.16 ab | 33.04±0.41 ab | 1.209±0.009 ab | 83.56±0.36 abc | 1059±68 bcd | 38.6±0.3 ab |

[a]Letters in columns indicate significant differences between treatments.

# SCREENING WATER STRESS IN MULTIPLE COTTON VARIETIES

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## Abstract

One of the challenges with genetic selection of cotton for yield and fiber quality is the assessment of phenological changes in the plant that impart improved yield and quality. Understanding in-season growth will help determine beneficial water application schedules for yield and quality. We propose a method for screening large numbers of plots using multiple remote sensing technologies to identify factors that can be identified as contributors to final yield and quality in irrigated and non-irrigated situations. The plot study consisted of fifteen varieties grown in randomized complete block planted in two-row, 40-ft. plots in irrigated and nonirrigated conditions. All of the in-season measurement parameters, as well as final yield and quality, were variety-related.

## Introduction

Water is the most common environmental factor that limits crop productivity. Many of the exotic relatives of domestic cotton (genus *Gossypium*) are well-adapted to heat and drought stress, but domestication and selection for crop yield have narrowed the genetic variability for drought resistance in modern cultivars. In addition, new varieties have limited in-season growth comparisons with other competing varieties, due to the large amounts of time required to make growth measurements.

Drought tolerance is attractive both for dryland growing conditions and during times of water shortage. Identification of stress mechanisms can also help in the selection for attributes that will improve yield stability under water limiting conditions. This work will improve our knowledge of physiological parameters that may identify adaptations to water deficit and improved drought tolerance.

Several types of adaptations to water stress have been observed in cotton, including shifts in fruiting patterns (including leaf or fruit abscission), osmotic regulation, changes in leaf expansion, decreased transpiration rates, and changes in partitioning of carbohydrates (Dumka et al., 2004; Gerik, 1996; Guinn and Mauney, 1984; Ritchie, 2007). Identifying the specific adaptation(s) that are operational in particular genotypes, together with their influence (if any) on other aspects of plant productivity and quality, facilitates selection for those adaptations that are most likely to result in more water efficient but still commercially acceptable cotton. We seek to characterize the mechanism(s) used by cotton varieties in adaptation to or tolerance of drought stress and associated temperature stress.

Some specific outcomes that we expect to result from this research are the identification of plant stress response mechanisms that can be used as screening tools to select cotton for improved drought tolerance, the addition of in-season physiological

parameters to the cotton breeding equation, and cost analysis of the yield and quality parameters in each variety.

## Materials and Methods

This was the continuation of a project that was begun in 2008, but began its funding cycle in 2009. In 2008, 12 varieties were planted in randomized complete block designs with 4 replicates in irrigated and non-irrigated fields. The tillage was conventional to allow consistent germination, and production practices were standard for Tifton with preventative weed and insect sprays. In 2008, a height-adjustable research cart was used as a platform to carry a GreenSeeker portable spectrometer, a DataQ DI-710 datalogger, Apogee Instruments SI-111 IRT sensor, Trossen Robotics distance sensor, Apogee Instruments Quantum sensor, and Apogee Instruments Line Quantum sensor. In 2009, the instrumentation was mounted on a Spider research sprayer, and the measurements were conducted on-the-fly. Because of the increased speed of the system, it was possible to collect all of the samples for both the irrigated and dryland plots quickly (<30 minutes per location).

Each instrument was chosen because of its ability to measure a specific plant growth parameter. The GreenSeeker measures NDVI, a vegetative index based on crop reflectance commonly used to estimate crop growth and leaf area. The distance sensor measures the distance from the cart platform to the cotton canopy, allowing the calculation of crop height without having to pause for ruler measurement. The IRT sensor measures plant temperature (temperature is an indicator of crop stress, particularly water stress). The light sensors allow the measurement of light capture by the plant canopy (light capture is related to plant size and health). The Apogee Instruments Quantum sensor and the Apogee Instruments Quantum Line sensor collected radiation capture using the equation ($1-\text{radiation}_{\text{transmitted}}/\text{radiation}_{\text{incoming}}$). Calibration and additional ground-truthing methods were used to verify remote sensing measurements.

Measurements were collected near noon during both growing seasons by either pushing the research cart or driving the sprayer down each row center and collecting data on the DI-710 datalogger ported into Excel. Each plot had twenty measurements at 0.2 second intervals, which were averaged for the plot mean. In the irrigated study, a $5^{th}$ rep was used for destructive sampling in 3-ft sections. Leaves and fruit were removed from the stems, and the plant parts were dried and weighed to determine the relative fraction of these above-ground components at each sampling date. At the end of the season, an additional destructive sample was collected from each plot for box mapping.

In 2008, the relationships between all parameters measured were examined in this study. Several interesting results were seen in-season. First, NDVI tended to plateau or reach a maximum at about 56 cm in height. NDVI has been criticized in the past for not being sensitive to higher levels of vegetative cover, but it is a widely used standard.

Radiation capture appeared to be sensitive to a wider range of plant height, suggesting that this measurement may give a more accurate full-season view of crop growth than simple overhead NDVI ratings. In 2009, radiation capture did not reach a maximum until about 75 cm plant height or higher, depending on the variety (Figure 7). The relationship between radiation and plant height was also variety-specific, as shown in Table 3. The slope of the relationship between height and radiation capture was almost twice as high for some of the varieties as others, and the equation fit, as determined by the $r^2$ values, was high for each individual variety (0.690 to 0.888).

Slopes for the dryland test were also variety-specific (Table 3), although the goodness of fit based on the $r^2$ values was lower overall ($r^2$ = 0.38 – 0.78). Two of the varieties had similar radiation capture:height slopes for both the irrigated and dryland treatments, and we were curious about whether this seeming resistance to changes in morphology due to water stress might result in more yield stability for these varieties. The relationship between the radiation capture:height slopes was compared with the ratio of yield between dryland and irrigated locations in Figure 8. The varieties with the most similar radiation capture:height relationships actually had the poorest yield stability. This suggests that adaptive responses made by the plants, such as a more erectophile phenology or smaller leaves, may improve yield stability in response to water stress. This will be analyzed for the 2008 data to test this trend.

Crop temperature was of added interest, because it was less closely tied to either crop height or radiation capture, but followed the same general pattern. This suggests that temperature may allow the detection of stress even in tall or lush canopies, even in the humid climate of South Georgia.

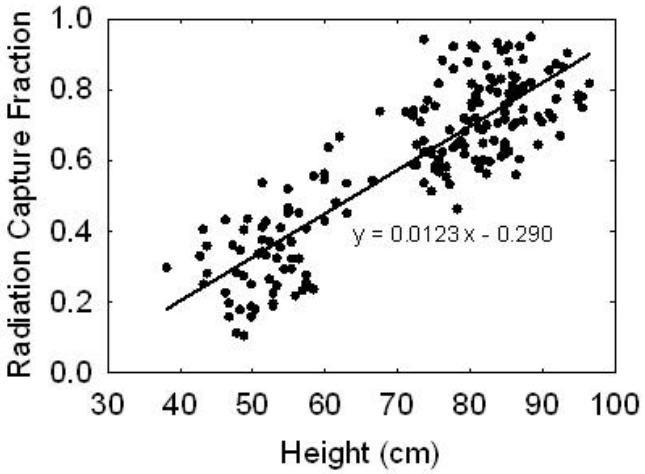

Figure 7. Pooled relationship between radiation capture fraction and plant height (cm) for the irrigated plots in 2009.

Table 3. Relationship between height (x) and radiation capture (y) over the 2009 growing season for both irrigated and non-irrigated pots.

| | Irrigated Rad'n Capture vs. height (cm) | | | Non-Irrigated Rad'n Capture vs. height (cm) | | |
|---|---|---|---|---|---|---|
| Variety | Slope | Intercept | $r^2$ | Slope | Intercept | $r^2$ |
| ST 5327 B2RF | 0.0088 | -0.029 | 0.69 | 0.0078 | 0.224 | 0.66 |
| PHY 565 WRF | 0.0099 | -0.115 | 0.714 | 0.0053 | 0.407 | 0.531 |
| 09R621 B2R2 | 0.011 | -0.2 | 0.888 | 0.0058 | 0.305 | 0.432 |
| DP 555 BG/RR | 0.011 | -0.183 | 0.857 | 0.0068 | 0.308 | 0.699 |
| BCSX 1010 B2F | 0.011 | -0.186 | 0.803 | 0.0112 | 0.02 | 0.765 |
| PHY 375 WRF | 0.012 | -0.255 | 0.836 | 0.0061 | 0.358 | 0.58 |
| DP 174 RF | 0.012 | -0.231 | 0.699 | 0.0069 | 0.301 | 0.62 |
| DP 0949 B2RF | 0.012 | -0.363 | 0.756 | 0.006 | 0.333 | 0.38 |
| DP 161 B2RF | 0.013 | -0.342 | 0.807 | 0.0067 | 0.302 | 0.559 |
| PHY 480 WR | 0.013 | -0.329 | 0.776 | 0.0089 | 0.153 | 0.778 |
| ST 5288 B2F | 0.015 | -0.533 | 0.789 | 0.0082 | 0.187 | 0.555 |
| DP 0935 B2RF | 0.016 | -0.493 | 0.71 | 0.0067 | 0.333 | 0.662 |
| ST 5458 B2RF | 0.017 | -0.536 | 0.751 | 0.0096 | 0.181 | 0.628 |
| DP 164 B2RF | 0.017 | -0.623 | 0.846 | 0.0039 | 0.453 | 0.473 |

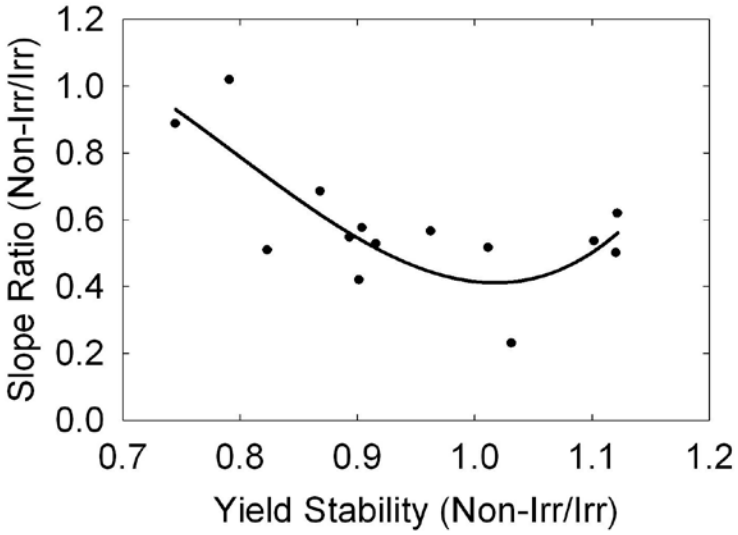


Figure 8. Comparison of the ratio of radiation capture:height slope to the ratio of yield between non-irrigated and irrigated varieties.

## Yield Distribution

Yield distribution is a complex factor and difficult to summarize. Table 2 shows the relative yield distribution of all of the varieties to DP555. DP555 was chosen for the comparison, since it is currently the most commonly grown variety in Georgia, and it has a very distinct yield distribution. DP555 produces less cotton on the lower nodes and more cotton at the upper nodes than other commercial varieties, so the relative

distribution of the other varieties to DP555 is of some interest. Relative distribution was calculated as the 1st position boll number at each node of DP555 minus the 1st position boll number of the other variety listed in the table. As shown in Table 2, some of the varieties (most notably 09R621) produced substantially more fruit near the base of the plant than DP555. Conversely, all of the varieties produced less fruit at the top of the plant than DP555, with 11 of the varieties significantly different from DP555 from node 19 to node 21.

Table 4. Relative 1st position yield distribution by node for 2009 varieties compared to DP555BG/RR under irrigated conditions.

| | Relative 1st Position Yield Distribution by Node (DP555-Variety in Column) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| node | PHY 480 | DP 09R621 | BCS 1010 | DP 0935 | DP 0949 | DP 161 | DP 164 | DP 174 | PHY 375 | PHY 565 | ST 5288 | ST 5327 | ST 5458 |
| 5 | -0.25 | -5.25** | -0.25 | -0.50 | -0.50 | -2.00* | -0.25 | -0.50 | -1.00 | -1.00 | -1.75† | -1.75† | -1.25 |
| 6 | -1.00 | -5.25** | 0.00 | -2.50† | 0.25 | -1.50 | 0.50 | -1.25 | 0.00 | 0.50 | -2.75† | -1.50 | -1.25 |
| 7 | -0.75 | -3.00* | -1.00 | -2.75† | 0.00 | -2.50† | 0.25 | -2.75† | -2.25 | -1.00 | -1.75 | -3.00* | -2.00 |
| 8 | -1.50 | -1.75 | 0.75 | -1.25 | -0.25 | -3.75** | -1.75 | 1.00 | -0.75 | -0.25 | -2.75* | -3.50** | -2.00† |
| 9 | -0.75 | 3.50±* | 2.00 | -0.50 | 0.75 | 1.25 | 0.25 | 3.50** | -0.75 | 1.50 | 1.00 | 0.25 | 1.75 |
| 10 | 1.00 | -0.50 | 1.50 | -0.50 | -0.75 | -1.00 | -1.25 | 1.75 | -1.25 | 0.25 | 0.25 | -1.00 | -0.75 |
| 11 | 1.25 | -0.50 | 0.25 | 0.00 | -1.00 | -2.00 | -2.25† | 1.50 | 0.25 | -0.50 | 0.75 | -0.50 | -0.50 |
| 12 | 0.75 | -1.50 | 1.75 | -0.25 | -0.50 | -0.75 | -1.50 | 1.00 | 0.00 | 0.75 | -1.75 | -1.00 | 0.50 |
| 13 | -0.75 | -0.25 | 0.75 | 0.75 | -2.00 | -0.75 | -1.25 | 1.00 | 0.25 | 1.00 | -1.00 | 0.25 | -0.50 |
| 14 | 2.00* | 2.00* | 2.00* | 2.25* | 0.75 | 1.25 | 0.00 | 2.00* | 0.00 | 0.75 | 1.25 | 1.25 | 2.50* |
| 15 | 0.00 | 0.25 | 0.75 | 2.25* | -0.75 | 1.00 | -1.00 | 0.75 | 1.00 | 0.75 | 0.50 | 1.75 | 1.75 |
| 16 | 1.00 | 3.50** | 2.00† | 3.25** | 0.75 | 1.25 | 1.75 | 3.00** | 3.50** | 1.25 | 1.50 | 2.75* | 3.50** |
| 17 | 1.50 | 2.00† | 1.25 | 1.75 | 1.00 | 1.25 | 1.00 | 1.25 | 1.75 | -0.50 | 0.25 | 1.75 | 2.75* |
| 18 | 1.50 | 1.50 | 1.50 | 0.75 | 1.25 | 1.75† | 1.25 | 1.00 | 2.50* | 0.75 | 1.00 | 2.50* | 2.25* |
| 19 | 1.75* | 1.75* | 1.75* | 1.50* | 2.50** | 1.25† | 1.25† | 2.00** | 1.75* | 1.00 | 1.00 | 2.25** | 1.50* |
| 20 | 2.25** | 2.75** | 2.25** | 2.75** | 2.25** | 2.00** | 1.25* | 2.50** | 2.25** | 2.00** | 1.50* | 2.50** | 2.50** |
| 21 | 4.25** | 4.50** | 4.25** | 4.50** | 4.50** | 3.50** | 3.75** | 4.50** | 4.25** | 4.00** | 3.50** | 4.25** | 4.25** |

** Significantly different at P<0.01
* Significantly different at P<0.05
† Significantly different at P<0.10

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# NUTRIENT CYCLING AND COVER CROP DECOMPOSITION IN STRIP-TILL AND CONVENTIONAL COTTON TILLAGE SYSTEMS

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## Introduction

Cover crops and conservation tillage have important roles in agriculture because of their ability to reduce soil erosion, conserve soil moisture, potentially increase soil organic matter, and suppress numerous pests (Gallaher and Hawf, 1997; Siri-Prieto et al., 2007). However, there has been concern of cover crops tying up too much N and the timing of its release to the next crop (Vyn et al., 1999). A study in Ontario comparing legume and non-legume covers found improved N availability only following a legume (Vyn et al., 2000). However, Weinert et al. (2002) reported accumulation of 55-115 lb N/ac in overwintering rye on an irrigated sandy soil, which could be returned to the soil and a following crop.

In the hot and humid climate of the southeast, along with the sandy soils of the Coastal Plains, cover crops may deteriorate at different rates compared to more temperate environments and the heavy textured soils of the north, from where most decomposition data comes. Therefore, it is important to study the decomposition rates and nutrient cycling capabilities of various cover crops in southeastern crop production. These climates also alter activity of insect populations and feeding patterns. Since there is considerable acreage in both conventional and reduced tillage management in this region, and the incorporation of residues should drastically alter the rate of residue breakdown and thrips behavior, it is important to study decomposition effects and thrips populations in various cover crops common to the region under both tillage management scenarios. Therefore, the objectives of this experiment were to compare decomposition rates of cover crop residues and thrips activity in conventional and strip-till cropping systems, including 'AU Robin' crimson clover (*Trifolium incarnatum* L.), 'Wrens Abruzzi' rye (*Secale cereale* L.), and 'AGS 2026' wheat (*Triticum aestivum* L.) as winter cover crops.

## Materials and Methods

Cover crops were planted 19 November 2008 in appropriate plots over the 0.75 acre experimental site in Tifton, GA. Recommended seeding rates (Sustainable Agriculture Network, 2007) were followed for planting crimson clover (15 lb/ac), rye (90 lb/ac), and wheat (120 lb/ac) with a Tye Pasture Pleaser no-till grain drill (AGCO Corp., Duluth, GA). Treatments were organized as a 2 x 4 factorial in a randomized complete block design with four replications. Independent variables consist of two tillage systems (conventional and strip-till) and four cover crop treatments (crimson clover, rye, wheat,

and bare soil). Individual plots were 0.037 ac (36 ft x 45 ft). Statistical analyses were conducted with parametric statistical tests such as ANOVA and regression.

Cover crops received a burn-down herbicide application of glyphosate (1.25 lb a.i./ac) on 9 April 2009, and tillage treatments were established on 4 May 2009. All plots were planted with 'DP 164' cotton seed with Avicta Complete Pack seed treatment on 12 May 2009 at an in-row seed spacing of 4.0 in. Plots were fertilized with 50 lb N/ac + 9 lb S/ac in the form of 28-0-0-5 fertilizer on 7 July 2009. Other management practices were consistent with UGA Extension recommendations (Collins et al., 2010).

To evaluate the fate of cover crop residue, samples were removed over the course of the season. The initial cover crop biomass sampling occurred on 13 April 2009 and another sampling was made on 1 May 2009, just prior to tillage treatment establishment. To assess cover crop residue in strip-till plots, all aboveground cover crop material was removed from a 5.4 $ft^2$ (3 ft. x 1.8 ft.) area in corresponding plots. Since cover crop tissue is buried in conventional tillage plots, a mesh litterbag made from fiberglass screen with 0.04 in. x 0.04 in. holes (Phifer, Inc., Tuscaloosa, AL) were constructed and filled with a residue amount equivalent to the measured residue values from the 1 May biomass sample. Dimensions of each bag cover 6.0 in x 7.9 in (Wang et al., 2004). Bags were buried in the conventional-till plots on 15 May 2009 at a depth of 6 in. to simulate decomposition of incorporated residue. Cover crop residue samples were then subsequently removed throughout the season on each field sampling date, which consisted of 10 June, 9 July, 5 August, 27 August, and 29 September 2009, with a different residue bag available for each sample date per plot. On each of these sample dates, aboveground biomass of the cotton plants residing within the 5.4 $ft^2$ sample area were also removed. All plant tissue samples were dried and sieved to remove residual soil, rocks, and other contaminants, and dry matter (DM) was determined.

A comprehensive thrips sampling scheme was also implemented. Adult and nymphal thrips populations were sampled at 14, 21, and 28 days after planting by randomly selecting five plants in each plot. Plants were manually removed from the soil and immediately inverted into a 16 oz. glass jar filled with 8 oz. of 70% ethyl alcohol. After vigorous agitation while submersed, the plants were discarded and the jars containing dislodged thrips were sealed. Jars of alcohol and thrips were transported to the laboratory where they were sieved through a fine mesh sieve ($3.9 \times 10^{-5}$ in. openings) and transferred to lined Petri dishes where individuals were enumerated under a dissecting microscope. Adults were sexed and identified to species using the key of Reed et al. (2006) while nymphs were only enumerated because species determination was nebulous.

## Results

Cover crops decomposed at a relatively similar and consistent rate in the conventional tillage plots (Fig. 1). This contrasts with the decomposition rate in strip-till management, where rye residue did not break down as rapidly as either crimson clover or wheat for

the majority of the season (Fig. 2). The differences between rye and wheat in strip-till were significant for the final four sample dates (9 July – 29 September 2009), and between rye and crimson clover were significant for the final three sample dates (5 August – 29 September 2009). There are varied reports on the typical C:N ratio of rye (grass), wheat (grass), and crimson clover (legume), but grasses regularly result in higher C:N ratios (> 20 and sometimes > 100+) than legumes (usually < 20). This would explain the much slower decomposition of rye compared to crimson clover, but does not account for the rate of wheat which very closely mirrored crimson clover's rate of decomposition. It is anticipated that since wheat matures more slowly than other grass crops like rye, it was still at a much lower C:N ratio than rye was upon termination in this trial. Immature grass crops are reported to have C:N ratios < 20 (Sarrantonio, 1994), which would put it in range with crimson clover (McLeod, 1982).

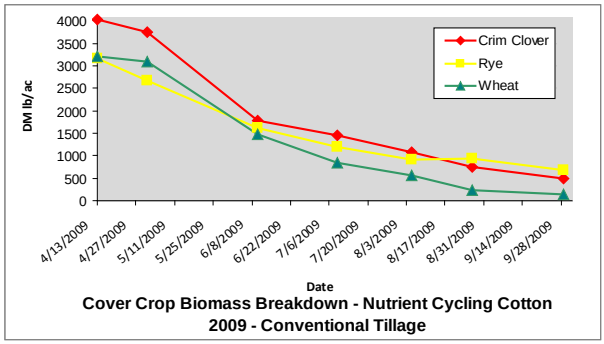


Figure 1.

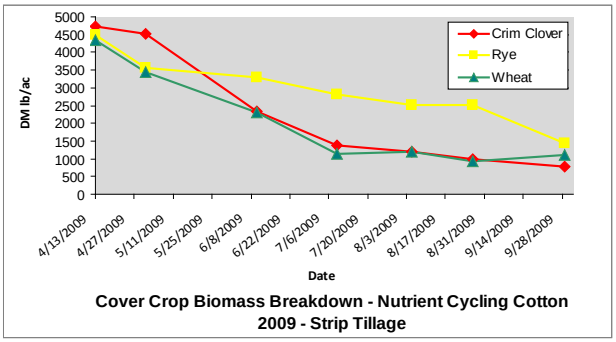


Figure 2.

The accumulation of DM in the cotton vegetation was not as substantial in the conventional tillage plots (Fig. 3) as in the strip-till plots (Fig. 4). On the last two sample dates when statistical differences occurred (an interaction between tillage and cover crop effects on 27 August and a tillage only difference on 29 September – 28,550 lb DM/ac in strip-till, 22,695 lb DM/ac in conventional averaged over reps and cover crops; LSD = 4219 lb DM/ac), cotton biomass in strip-till was larger than in conventional tillage plots. This is inclusive of plots where no cover crop was planted. Thus, this phenomenon is not merely related to rate of decomposition of cover crops; additional benefits are being obtained from the difference in tillage type even where there was no cover crop present.

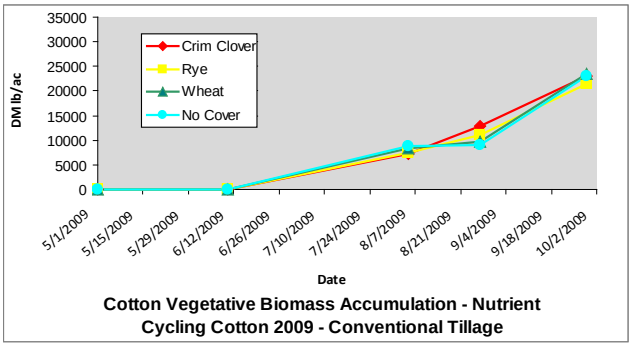


Figure 3.

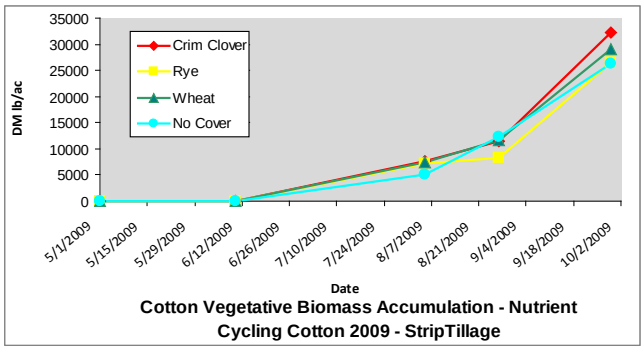


Figure 4.

Thrips populations were also larger in conventional tillage compared to strip-till management (Figs. 5 and 6). The presence of cover crop residues on the soil surface has been shown to reduce thrips populations (All and Vencill, 2008; Manley et al., 2002; Olson et al., 2006), which agrees with the data observed in this study. A difference in cotton plant height was also noted during early sample dates (2 June – Fig. 7; 9 June – Fig. 8) among the cover crop treatment effects, and also between tillage effects on 2 June (strip-till = 3.0 in.; conventional = 2.7 in.; LSD = 0.16 in.). Cotton plants were usually taller with a grass cover crop than with no cover crop, while cotton following crimson clover was not different than any other treatment at the earlier date (Fig. 7), but was shorter than cotton following the grass covers at the later date (Fig. 8).

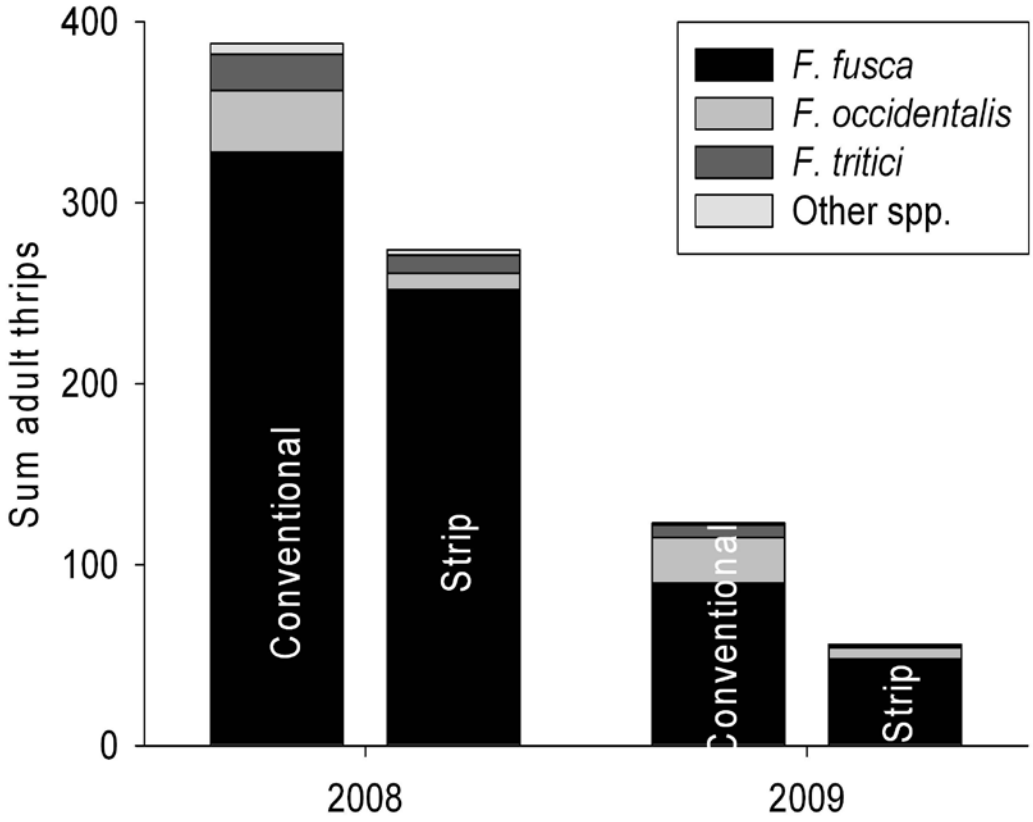


Figure 5. Principle adult thrips species composition by year and tillage type.

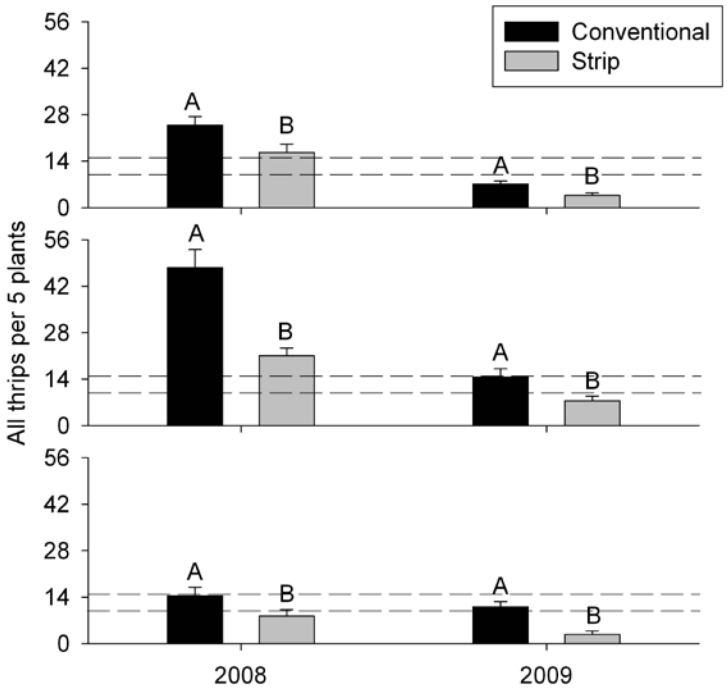


Figure 6. Mean (± SEM) number of thrips (adults plus nymphs) per 5 plants by year and tillage type at 14 (top), 21 (middle) and 28 (bottom) days after planting. Different letters within year and planting date signify statistical differences ($P < 0.05$). Dotted lines designate the Extension based foliar treatment threshold of 2 to 3 thrips per plant.

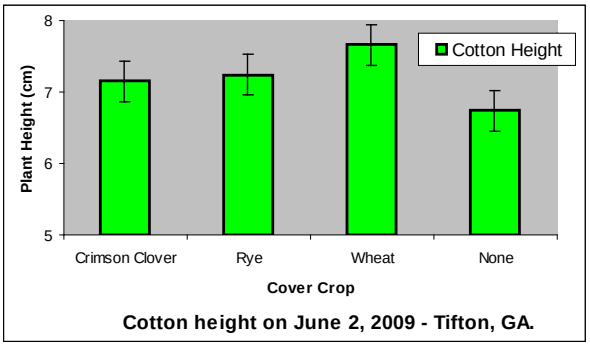


Figure 7.

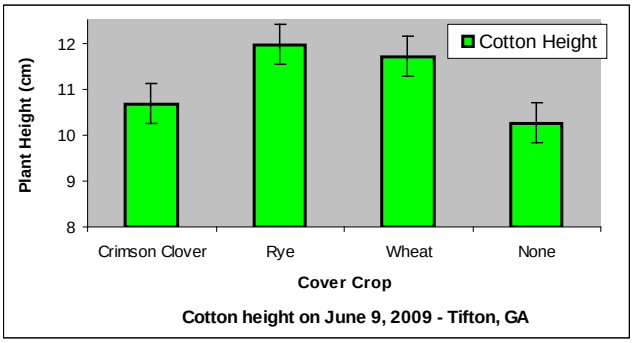


Figure 8.

By the end of the season, cotton plant height differed by both tillage and cover crop factors (Fig. 9). Cotton following crimson clover eventually was taller than following any of the other cover crop treatments. Since crimson clover is a legume, it has higher N concentration than grass crops, which means less N is tied up by the residue and more is subsequently available to a following crop. There were also taller plants under conventional tillage management for cotton following crimson clover. This may be due to a more complete decomposition in conventional tillage (Fig. 1) supplying more nutrients to the crop by the end of the season compared to strip-till (Fig. 2), which still has more residue lying on the soil surface. After all comparisons and differences between tillage systems and cover crops, there were no differences in either factor

when it comes to yield (Fig. 10). Strip-till resulted in a final lint yield of 1657 lb/ac while conventional tillage had 1619 lb/ac.

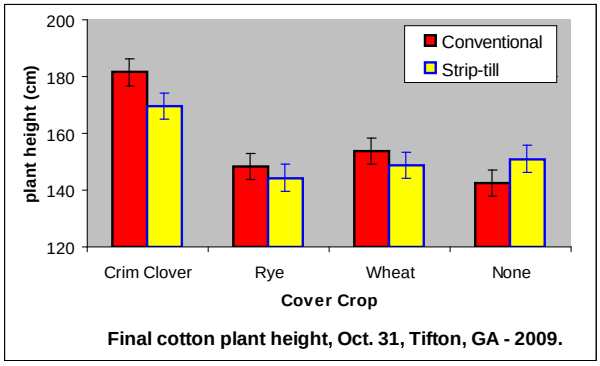


Figure 9.

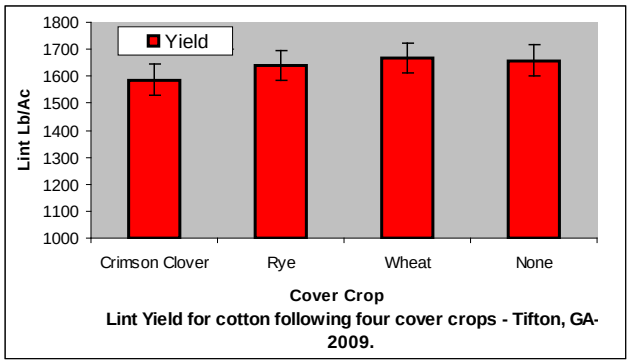


Figure 10.

## Economics

Despite no differences in yields, there were some economic differences in terms of total costs and adjusted revenue (which included fixed costs on equipment in the analyses). Adjusted revenue is defined as revenue adjusted for cover crop, tillage, and ginning/storage/warehousing costs + a credit for cottonseed. Total costs were higher for conventional tillage ($141.32 vs. strip-till = $116.81; LSD = $4.22), primarily due to costs associated with additional trips through the field (more fuel and labor costs) and fixed costs associated with additional equipment inventory. Total costs are significantly higher for the various cover crops (Table 1), mostly related to cost of the seed. Since there were no major differences in yield, the adjusted revenue favored the treatments with low seed costs, including the no cover crop treatment. There was also marginally no statistical difference in adjusted revenue for tillage (conventional = $951.76, strip-till = $1001.30; LSD = 49.81).

Table 1. Total cost and adjusted revenue for four cover crop treatments averaged over four reps and two tillage treatments – Nutrient Cycling Cotton Trial, Tifton, GA, 2009.

| Cover Crop | Total Cost ($/Acre) | | Adjusted Revenue ($/Acre) | |
|---|---|---|---|---|
| Crimson Clover | 153.46 | A | 917.57 | B |
| Rye | 119.05 | C | 988.46 | A |
| Wheat | 137.11 | B | 987.29 | AB |
| No Cover | 106.64 | D | 1012.86 | A |
| LSD | 5.97 | | 70.44 | |

## Discussion and Summary

It is believed that supplemental fertilizer may have masked the effects of the cover crops, not allowing for as much separation among the treatments for biomass accumulation, yield, and other variables. The decision to add fertilizer was made in order to represent practices similar to what a grower might do. Since it is not realistic

for a grower to forego N application, we opted to apply fertilizer, which was likely at the expense of learning the full comparative benefits of cover crops and their potential to reduce fertilizer inputs.

Cover crops decomposed at a greater rate in conventional tillage than in strip-till (especially for rye). Since residues are incorporated into the soil in conventional tillage, there is more surface area contacted by soil micro-organisms, and is therefore more rapidly decomposed than when residues remain on the soil surface and only a fraction of the material is exposed to the soil. The C:N ratio plays a large role in how rapidly plant tissue will breakdown. Legumes and immature plants have lower C:N ratios than mature grasses. In the results of this experiment, rye, a grass with a high C:N ratio, decomposed slower than the other cover crops in strip-till management.

There was more cotton vegetation produced under strip-till management as well. Since vegetative plant growth was not related to any specific cover crop, these results mean benefits are being obtained merely from the tillage difference, since they also occurred in the treatment where no cover crop was planted. Populations of thrips were likewise reduced in strip-till management compared to conventional tillage.

There were no yield differences between tillage management nor among cover crop treatments. However, costs were reduced in strip-till management. The cost of the cover crop seed caused adjusted revenues to drop, especially for crimson clover. However, crimson clover has benefits not associated with grass cover crops, such as increased N availability, which will usually reduce fertilizer requirements for the next crop. Despite no yield differences, there were several positive results using strip-till management over conventional tillage. Although there were no economic advantages to using cover crops over having no cover crop in place, there are many documented benefits of growing cover crops which often have no inherent monetary worth, but can have long-term value. Reduced losses from the highly erodible soils of the southeast are of great importance, since a large rainfall can wash volumes of soil out of a field, and leach nutrients out of the soil profile. Cover crops will hold soil and nutrients in place for subsequent crops.

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# BREEDING CULTIVARS AND GERMPLASM WITH ENHANCED YIELD AND QUALITY, 2009

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## Introduction

The classical breeding component of the University of Georgia cotton improvement program works to develop germplasm with traits that can be used to meet the requirements of both producers and consumers. Higher and more stable yields combined with the fiber properties requested by the yarn and textile manufacturers are the goals for profitable production and processing to support the Georgia Cotton Industry. The objective of this report is to update progress made toward meeting these goals during the 2009 production season.

## Materials and Methods

Our crosses mate elite University of Georgia breeding lines with promising germplasm and non-transgenic commercial cultivars to produce 10 sets of half-sib families. Fifty $F_2$-bulk populations from crosses made in 2008 and advanced at the counter-seasonal nursery in Tecoman, MX were evaluated for lint yield in 2-replicate, randomized complete block designs, with each set of half-sib $F_2$ families, the GA breeding line parent, and the check cultivar, GA 2004230, constituting a trial. Of the $F_2$-bulk populations evaluated in 2008, 22 were advanced in 2009 to $F_3$ for single plant selection. The first level of selection of the $F_3$ plants were decided by visual determination with more individuals selected from the better populations and none from the worst populations. In other years, individual plants were selected from even the worst populations as a segregation of a desirable and non-desirable class was evident. Original $F_3$ plants with lint fractions less than 39% were discarded and then further selected on the basis of HVI fiber properties. Seven hundred and forty $F_3$ plants selected in 2009 were advanced to $F_4$ progeny rows in Plains, GA, in 2010 for evaluation in an un-replicated grid design, with the middle row of each 7 row set of the trial assigned to Deltapine DP 147RF. The trial was machine harvested and the seed-cotton yield of each $F_4$ progeny row was compared with the seed-cotton yield of the nearest row of DP 147RF. Separate, late-planted seed increase plots that are grown in isolation near Tifton, GA allow additional visual selection and hand harvest of seed-cotton to maintain genetic purity of the $F_4$, $F_5$, $F_6$, and elite generation experimental lines. A small number of additional increases are planted at the University of Arizona's Maricopa Agriculture Center, Maricopa, AZ to provide excellent quality seed for the later generation field tests. Further selections of the $F_4$ are based mainly on the fiber quality measures of length, strength, and fineness and on lint percentage for promotion for testing in the $F_5$ preliminary yield trials (PTs) in 2010. The 2009 PTs were conducted at the William Gibbs Research Farm, UGA–Tifton campus, Tifton, GA in fields 04210, 04211, 04212, and 04213. Each PT had 18 $F_5$ breeding lines and 2 commercial conventional checks (GA 2004230 and Deltapine DP 147RF) in a three replicate,

randomized complete block designs for a total of 124 experimental entries. The $F_6$ Advanced Trials (ATs) were conducted at the University of Georgia – Tifton campus, Tifton, GA (AT1 at the William Gibbs Research Farm, fields 04241, 04242, and 04243) and Southwest Georgia Research and Education Center, Plains, GA (AT 1 and AT 2 in fields 39/40). The AT1 consisted of 30 experimental entries and AT2 had 16 entries. Two checks (GA 2004230 and Monsanto Deltapine DP 147RF) were planted in a three replicate, randomized complete block design for a total of 46 $F_6$ breeding lines tested. Prior to machine harvest of all trials except the $F_2$ and $F_4$ generations, 25 unweathered, open bolls from the middle of the fruiting zone were harvested from each plot, and subsequently ginned on a 10-saw laboratory model gin to determine lint percentage. Fiber samples of the PTs and ATs were submitted to Cotton Incorporated in Cary, NC for HVI fiber analysis. The elite (material > $F_7$) germplasm lines with high potential were tested in the 2009 Georgia Official Strains Trial (OST) and Official Variety Trials (OVTs) (Day and Thompson, 2010)

## Results and Discussion

Six lines GA 2004143, GA 2004230, GA 2004303, GA 2006053, GA 2006127, and GA 2006168 were tested in the 2009 GA OVTs (Day and Thompson, 2010). The following is a general synopsis of these lines with further details found in the Georgia 2009 Peanut, Cotton, and Tobacco Performance Tests (Day et al., 2010). GA 2004230 and GA 2004303 have proven their value over the past years and have been accepted last year as cultivars by the University of Georgia Germplasm Release Committee. They will be retested in 2010. GA 2004143 was ranked 6$^{th}$ over all the locations for lint yield (not significantly different from the top yielder) with an excellent fiber quality package. It did not yield as well in the dryland trial, ranking 21$^{st}$, but it retained its excellent fiber quality package. GA 2004143 will be retested in 2010. In lint yield, the elite line GA 2006053 ranked 2$^{nd}$ in the 2009 Dryland, Earlier Maturity Cotton Varieties OVTs and 9$^{th}$ in the Irrigated, Earlier Maturity Cotton Varieties OVTs (neither value significantly different from the best yielding variety). Its fiber qualities were very good and will be retested in 2010. Neither GA 2006127 nor GA 2006168 performed adequately in either of the dryland or the irrigated trials and were eliminated from the program.

GA 2007095 was advanced from the 2008 ATs to the 2009 Georgia Strains Trials while three lines GA 2006128, GA 2006106, and GA 2006109 were retested from 2008 Georgia Strains Trials (Day and Thompson, 2010). Between lint yield, lint %, and fiber quality, GA 2006128 did not yield well in 2009 and did not have any levels of lint % or fiber quality that stood out from the others, so it was eliminated. GA 2007095 was selected to advance to the 2010 GA OVTs because it yielded best (significantly better than GA 2006106). The yields, lint %, uniformity index, strength, and micronaire of GA 2006106 and GA 2006109 were not significantly different, but GA 2006106 had significantly longer fiber; so it was selected for advancement to the GA OVTs as well. None of the 2009 AT entries yielded better than the check GA 2004230 in the pooled AT1 (Table 2) and in the AT2 (Table 3). Although there was significant location by entry interaction for some of the traits in AT1, which means that locations should not be pooled for those traits, selecting all of the lines that were not significantly different in

yield from the best gave too many to advance to the GA OST. The top three experimental lines of the pooled AT1 plus the top four of the AT2 were advanced to the GA Strains Trials based on comparisons with the check GA 2004230. All of them had a very good to excellent fiber quality; for example, all had UHM lengths better than 1.20 (Table 2 & 3).

Thirty three lines were selected from the 2009 PTs (Tables 4, 5, and 6) for testing in the 2009 ATs based primarily on lint yield as compared to checks and also potential outstanding lint % or fiber qualities.

For the past 3 years the research material was divided into the two AT tests by putting the lines that were elite yielders with acceptable fiber quality into AT1 and the lines that had enhanced fiber quality with adequate yield into AT2. This was mandated by the fact that we could not select for fiber quality until after the cotton increases were picked. We now have a set of increases grown in AZ through the assistance of Cotton Incorporated that we hope to gain better seed quality for the PTs, ATs, OSTs, and the OVTs and to be able to have the ability to gin and get fiber quality data before we harvest the AZ increases.

Based chiefly on lint yield comparisons, 123 $F_4$ progenies will be further selected for placement in the 2009 PTs. About 500 single plants were selected in the $F_3$ populations to be placed in the $F_4$ plant-to-row yield test.

Fifty $F_1$ crosses that were made in the summer of 2008 were sent to the USDA-ARS Cotton Winter Nursery in Mexico for selfing to the $F_2$ generation. These will be placed in replicated yield tests to determine the suitability of the germplasm populations to be further tested.

## Acknowledgments

The authors thank the Georgia Commodity Commission for Cotton for funding this research (Project Number 00-860GA CY 2003), Cotton Incorporated for providing HVI fiber analysis and seed production in Arizona under Core Funded Project 03-404, Don Day, Larry Thompson, and staff for conducting the University of Georgia Official Variety Trials, Stan Jones and Ronnie Pines at Southwest Georgia Branch Experiment Station, Plains, GA, and Gordon Sephus Willis at the William Gibbs Research Farm, Tifton, GA for providing technical support in the conduct of trials at their respective locations.

Table 1. Results of 2009 Advanced ($F_6$) Trial 1.

| 2009 AT 1 Tifton | | | | | | | 2009 AT 1 Plains | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ENTRY | Lint Yield | Lint % | UHM in. | UI % | mic | Str g/tex | ENTRY | Lint Yield | Lint % | UHM in. | UI % | mic | Str g/tex |
| GA 2008001 | **1309** | 42.44 | 1.21 | 84.75 | 4.44 | 32.35 | GA 2004230 | **1651** | 43.73 | 1.24 | 84.00 | 4.60 | 31.15 |
| GA 2008037 | **1249** | 45.51 | 1.18 | 84.80 | 5.13 | 30.65 | GA 2008005 | 1451 | 44.27 | 1.22 | 85.50 | 4.69 | 30.85 |
| GA 2006101 | **1243** | 41.97 | 1.18 | 84.75 | 4.76 | 31.85 | GA 2008057 | 1364 | 44.04 | 1.23 | 85.50 | 4.73 | 31.40 |
| GA 2008040 | **1242** | 41.52 | 1.15 | 84.90 | 4.89 | 32.30 | GA 2008001 | 1353 | 40.64 | 1.25 | 85.00 | 4.16 | 31.30 |
| GA 2008005 | **1233** | 41.89 | 1.18 | 84.55 | 4.86 | 33.70 | GA 2006099 | 1277 | 42.69 | 1.21 | 84.00 | 4.59 | 29.95 |
| GA 2008057 | **1208** | 42.40 | 1.22 | 85.30 | 4.75 | 33.90 | GA 2008040 | 1245 | 41.81 | 1.20 | 85.50 | 4.49 | 30.35 |
| GA 2008025 | **1204** | 43.94 | 1.20 | 84.00 | 5.01 | 30.30 | GA 2008035 | 1229 | 42.79 | 1.24 | 86.00 | 4.07 | 30.55 |
| GA 2008058 | **1197** | 40.32 | 1.24 | 85.30 | 4.24 | 35.05 | GA 2008060 | 1216 | 43.40 | 1.22 | 85.50 | 4.65 | 31.25 |
| GA 2008011 | **1147** | 40.62 | 1.24 | 85.70 | 4.50 | 34.65 | GA 2008058 | 1206 | 43.29 | 1.28 | 86.00 | 4.30 | 32.55 |
| GA 2006010 | **1143** | 40.67 | 1.16 | 83.85 | 4.63 | 31.30 | GA 2008098 | 1203 | 43.76 | 1.24 | 86.00 | 4.45 | 32.00 |
| GA 2008035 | 1128 | 40.33 | 1.25 | 85.00 | 3.99 | 32.10 | GA 2006033 | 1173 | 40.89 | 1.23 | 84.50 | 4.33 | 32.30 |
| GA 2006099 | 1126 | 41.35 | 1.19 | 84.95 | 4.69 | 32.60 | GA 2006095 | 1152 | 42.12 | 1.25 | 85.50 | 4.14 | 33.40 |
| GA 2006095 | 1118 | 42.04 | 1.22 | 84.00 | 4.40 | 35.00 | GA 2008077 | 1099 | 43.42 | 1.18 | 86.00 | 4.40 | 32.45 |
| DP 147RF | 1105 | 40.08 | 1.24 | 84.65 | 4.48 | 32.75 | GA 2008043 | 1098 | 39.20 | 1.26 | 84.50 | 4.55 | 33.55 |
| GA 2008007 | 1082 | 39.99 | 1.19 | 83.80 | 4.71 | 34.00 | GA 2008023 | 1081 | 41.39 | 1.29 | 85.00 | 4.26 | 30.75 |
| GA 2008077 | 1081 | 41.88 | 1.16 | 85.90 | 4.71 | 32.30 | GA 2006101 | 1078 | 42.37 | 1.21 | 85.50 | 4.67 | 31.50 |
| GA 2008054 | 1048 | 40.33 | 1.21 | 84.00 | 4.36 | 33.10 | GA 2008107 | 1034 | 42.39 | 1.23 | 86.00 | 4.57 | 30.15 |
| GA 2008023 | 1044 | 40.80 | 1.24 | 85.90 | 4.64 | 35.35 | GA 2008039 | 1027 | 43.18 | 1.23 | 84.00 | 4.24 | 31.50 |
| GA 2004230 | 1036 | 39.70 | 1.26 | 84.05 | 4.13 | 32.15 | GA 2008037 | 1014 | 45.27 | 1.19 | 84.00 | 4.63 | 30.65 |
| GA 2006091 | 1029 | 40.40 | 1.18 | 83.95 | 4.42 | 32.05 | GA 2008025 | 992 | 45.30 | 1.23 | 85.00 | 4.53 | 30.30 |
| GA 2008030 | 988 | 40.64 | 1.22 | 83.50 | 4.17 | 33.40 | GA 2006091 | 992 | 42.41 | 1.20 | 84.00 | 4.33 | 30.25 |
| GA 2008018 | 977 | 39.69 | 1.21 | 83.85 | 4.58 | 33.95 | GA 2008054 | 982 | 42.62 | 1.26 | 85.50 | 4.27 | 30.95 |
| GA 2008107 | 973 | 41.58 | 1.21 | 85.55 | 4.63 | 31.70 | DP 147RF | 975 | 39.41 | 1.29 | 84.00 | 3.89 | 29.35 |
| GA 2008042 | 932 | 37.29 | 1.19 | 85.15 | 4.43 | 35.10 | GA 2006010 | 966 | 39.29 | 1.21 | 83.50 | 4.22 | 31.15 |
| GA 2006033 | 905 | 41.06 | 1.20 | 84.65 | 4.97 | 33.60 | GA 2008042 | 965 | 37.18 | 1.24 | 85.00 | 4.04 | 32.30 |
| GA 2008048 | 872 | 39.74 | 1.19 | 85.30 | 4.41 | 33.40 | GA 2008048 | 931 | 40.54 | 1.22 | 85.00 | 4.34 | 32.10 |
| GA 2008098 | 842 | 43.35 | 1.18 | 84.50 | 4.59 | 31.85 | GA 2008018 | 816 | 41.62 | 1.27 | 85.50 | 4.36 | 33.25 |
| GA 2008039 | 787 | 40.07 | 1.18 | 84.40 | 4.33 | 33.05 | GA 2008007 | 816 | 39.18 | 1.25 | 86.00 | 4.19 | 31.05 |
| GA 2008060 | 766 | 40.24 | 1.19 | 85.60 | 4.51 | 30.80 | GA 2008011 | 806 | 42.63 | 1.27 | 85.50 | 4.37 | 32.85 |
| GA 2008043 | 732 | 40.46 | 1.19 | 85.05 | 5.01 | 34.65 | GA 2008030 | 0 | 44.70 | 1.20 | 84.00 | 4.43 | 30.75 |
| **$LSD_{0.10}$** | **168** | **1.21** | **0.02** | **0.97** | **0.34** | **1.57** | **$LSD_{0.10}$** | **117** | **1.05** | **0.03** | **0.84** | **0.20** | **1.37** |

The bold type indicates the lint yields that are not significantly different from the top yielder. DP147RF and GA 2004230 are check varieties for comparison purposes.

Table 2. Results of 2009 Advanced ($F_6$) Trial 1 over Tifton and Plains, GA

| ENTRY | Lint Yield | Lint % | UHM in. | UI % | mic | Str g/tex |
|---|---|---|---|---|---|---|
| GA 2004230 | 1344 | 41.72 | **1.25** | 84.03 | 4.36 | 31.65 |
| GA 2008005 | 1342 | 43.08 | 1.20 | 85.03 | 4.77 | 32.28 |
| GA 2008001 | 1331 | 41.54 | 1.23 | 84.88 | 4.30 | 31.83 |
| GA 2008057 | 1286 | 43.22 | 1.22 | **85.40** | 4.74 | 32.65 |
| GA 2008040 | 1243 | 41.66 | 1.17 | 85.20 | 4.69 | 31.33 |
| GA 2006099 | 1201 | 42.02 | 1.20 | 84.48 | 4.64 | 31.28 |
| GA 2008058 | 1201 | 41.80 | **1.26** | **85.65** | 4.27 | **33.80** |
| GA 2008035 | 1178 | 41.56 | **1.24** | **85.50** | 4.03 | 31.33 |
| GA 2006101 | 1161 | 42.17 | 1.19 | 85.13 | 4.71 | 31.68 |
| GA 2006095 | 1135 | 42.08 | 1.23 | 84.75 | 4.27 | **34.20** |
| GA 2008037 | 1131 | 45.39 | 1.18 | 84.40 | 4.88 | 30.65 |
| GA 2008025 | 1098 | 44.62 | 1.21 | 84.50 | 4.77 | 30.30 |
| GA 2008077 | 1090 | 42.65 | 1.17 | **85.95** | 4.55 | 32.38 |
| GA 2008023 | 1063 | 41.09 | **1.26** | **85.45** | 4.45 | 33.05 |
| GA 2006010 | 1054 | 39.98 | 1.18 | 83.68 | 4.42 | 31.23 |
| DP 147RF | 1040 | 39.75 | **1.26** | 84.33 | 4.19 | 31.05 |
| GA 2006033 | 1039 | 40.97 | 1.22 | 84.58 | 4.65 | 32.95 |
| GA 2008098 | 1022 | 43.55 | 1.21 | 85.25 | 4.52 | 31.93 |
| GA 2008054 | 1015 | 41.47 | **1.24** | 84.75 | 4.31 | 32.03 |
| GA 2006091 | 1010 | 41.41 | 1.19 | 83.98 | 4.37 | 31.15 |
| GA 2008107 | 1003 | 41.98 | 1.22 | **85.78** | 4.60 | 30.93 |
| GA 2008060 | 991 | 41.82 | 1.20 | **85.55** | 4.58 | 31.03 |
| GA 2008011 | 977 | 41.62 | **1.25** | **85.60** | 4.43 | **33.75** |
| GA 2008007 | 949 | 39.58 | 1.22 | 84.90 | 4.45 | 32.53 |
| GA 2008042 | 948 | 37.23 | 1.21 | 85.08 | 4.23 | **33.70** |
| GA 2008043 | 915 | 39.83 | 1.22 | 84.78 | 4.78 | **34.10** |
| GA 2008039 | 907 | 41.63 | 1.21 | 84.20 | 4.28 | 32.28 |
| GA 2008048 | 901 | 40.14 | 1.20 | 85.15 | 4.37 | 32.75 |
| GA 2008018 | 897 | 40.65 | **1.24** | 84.68 | 4.47 | **33.60** |
| GA 2008030 | - | 42.67 | 1.21 | 83.75 | 4.30 | 32.08 |
| **location by entry interaction** | *** | *** | **NS** | **NS** | **NS** | **NS** |
| **$LSD_{0.10}$** | **-** | **-** | **0.02** | **0.64** | **0.19** | **1.03** |

When location by entry interaction is significant, the locations should not be combined to compare for significant differences; **NS (not significant), † (10%), * (5%), ** (1%), & *** (0.1%).**
The bold type indicates the measures that are not significantly different from the best when the location data is properly pooled.
Acceptable micronaire (mic) is a range so significant differences are not highlighted.
DP 147RF and GA 2004230 are check varieties for comparison purposes.

Table 3. Results of 2009 Advanced ($F_6$) Trial 2, Plains, GA.

| ENTRY | Lint Yield | Lint % | UHM (in) | UI (%) | mic | Strength (g $tex^{-1}$) |
|---|---|---|---|---|---|---|
| GA 2004230 | 1371 | 44.17 | 1.26 | 84.2 | 4.49 | 31.35 |
| GA 2008083 | 1359 | 44.33 | 1.21 | 84.85 | 4.63 | 31.3 |
| GA 2008016 | 1295 | 43.32 | 1.24 | 86 | 4.64 | 32.25 |
| GA 2006046 | 1276 | 41.27 | 1.21 | 83.65 | 4.45 | 32.05 |
| GA 2008052 | 1235 | 42.55 | 1.24 | 86.7 | 4.28 | 31.5 |
| GA 2006052 | 1188 | 41.41 | 1.22 | 84.3 | 4.22 | 31.75 |
| GA 2008063 | 1136 | 46.32 | 1.2 | 84.4 | 4.42 | 30.15 |
| GA 2008038 | 1121 | 44.76 | 1.26 | 84.8 | 4.53 | 30.25 |
| GA 2008062 | 1102 | 45.3 | 1.2 | 84.3 | 4.58 | 32.8 |
| GA 2006039 | 1100 | 44.49 | 1.21 | 83.15 | 4.44 | 31.1 |
| DP 147RF | 1078 | 40.62 | 1.26 | 83.3 | 3.85 | 30.85 |
| GA 2008055 | 1036 | 41.92 | 1.25 | 85.25 | 4.41 | 31.3 |
| GA 2008067 | 1027 | 43.17 | 1.25 | 84.7 | 4.3 | 30.25 |
| GA 2008071 | 958 | 43.89 | 1.17 | 84.65 | 4.58 | 31.3 |
| GA 2008073 | 957 | 44.58 | 1.24 | 85.05 | 4.52 | 31.3 |
| GA 2008010 | 870 | 43.4 | 1.2 | 84.9 | 4.45 | 32.35 |
| $LSD_{0.10}$ | 111 | 1.16 | 0.03 | 1.31 | 0.2 | 1.49 |

The bold type indicates the lint yields that are not significantly different from the top. DP147RF, DP491, and FiberMax FM 966 are check varieties for comparison purposes.

Table 4. Results of 2009 Preliminary ($F_5$) Trials 1 and 2.

| ENTRY | Lint Yield | Lint % | UHM (in) | UI (%) | mic | Str g/tex | ENTRY | Lint Yield | Lint % | UHM (in) | UI (%) | mic | Str g/tex |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GA 2009001 | 1126 | 39.16 | 1.09 | 83.4 | 28.95 | 4.58 | GA 2009019 | 1215 | 40.32 | 1.21 | 84.75 | 32.8 | 4.8 |
| GA 2009002 | 1174 | 41.39 | 1.15 | 84.55 | 33.65 | 4.44 | GA 2009020 | 968 | 42.24 | 1.11 | 84.65 | 33.35 | 5.21 |
| GA 2009003 | 1082 | 38.66 | 1.15 | 84.1 | 34 | 4.39 | GA 2009021 | 1144 | 41.7 | 1.18 | 84.45 | 32.45 | 4.5 |
| GA 2009004 | 1061 | 38.57 | 1.15 | 84.85 | 33.85 | 4.58 | GA 2009022 | 1063 | 42.07 | 1.13 | 84.35 | 34.45 | 5.11 |
| GA 2009005 | 916 | 40.82 | 1.13 | 84.35 | 30.9 | 4.6 | GA 2009023 | 1063 | 41.78 | 1.14 | 84.1 | 33.5 | 5.02 |
| GA 2009006 | 983 | 41.1 | 1.17 | 84.75 | 32.15 | 4.89 | GA 2009024 | 1262 | 42.46 | 1.2 | 84.85 | 33.55 | 4.49 |
| GA 2004230 | 1146 | 40.62 | 1.25 | 84.9 | 33.85 | 4.36 | GA 2004230 | 1129 | 39.99 | 1.26 | 85.25 | 33.55 | 4.27 |
| GA 2009007 | 983 | 39.13 | 1.19 | 84.75 | 32.8 | 4.56 | GA 2009025 | 1030 | 42.18 | 1.15 | 84 | 32 | 4.78 |
| GA 2009008 | 1021 | 39.19 | 1.15 | 84.1 | 32.25 | 4.12 | GA 2009026 | 1205 | 42.46 | 1.19 | 84.05 | 34.05 | 4.81 |
| GA 2009009 | 1083 | 40.43 | 1.12 | 84.2 | 29.4 | 4.5 | GA 2009027 | 1201 | 41.25 | 1.15 | 84.7 | 32.6 | 4.83 |
| GA 2009010 | 1189 | 42.71 | 1.11 | 84.55 | 30.75 | 4.79 | GA 2009028 | 1215 | 44.65 | 1.12 | 83.75 | 30.55 | 4.74 |
| GA 2009011 | 999 | 41.39 | 1.12 | 84.7 | 35.7 | 5.23 | GA 2009029 | 1324 | 42.19 | 1.16 | 84.65 | 32.75 | 5.05 |
| GA 2009012 | 1134 | 43.15 | 1.17 | 84.5 | 32.85 | 5.06 | GA 2009031 | 1263 | 41.23 | 1.2 | 84.55 | 32.1 | 4.44 |
| DP 147RF | 1009 | 40.37 | 1.23 | 83.9 | 33.35 | 3.86 | DP 147RF | 1204 | 41.28 | 1.25 | 83.8 | 34.3 | 4.33 |
| GA 2009013 | 1104 | 42.85 | 1.18 | 84.55 | 31.85 | 5.01 | GA 2009032 | 1335 | 41.56 | 1.17 | 84.25 | 32.5 | 4.45 |
| GA 2009014 | 1037 | 41.57 | 1.21 | 85.1 | 34.05 | 5.36 | GA 2009033 | 1143 | 42.8 | 1.15 | 84.8 | 35.6 | 4.85 |
| GA 2009015 | 1081 | 43.9 | 1.16 | 83.65 | 35.35 | 4.66 | GA 2009034 | 1286 | 44.68 | 1.13 | 84.95 | 32.95 | 5.21 |
| GA 2009016 | 1139 | 39.95 | 1.22 | 84.9 | 33.45 | 4.22 | GA 2009035 | 1260 | 43.63 | 1.15 | 85.05 | 31.75 | 4.82 |
| GA 2009017 | 1075 | 40.97 | 1.15 | 85.35 | 32.65 | 4.91 | GA 2009036 | 1234 | 40.91 | 1.21 | 84.45 | 33.25 | 4.97 |
| GA 2009018 | 939 | 41.91 | 1.19 | 85.15 | 33.25 | 4.96 | GA 2009037 | 1306 | 41.36 | 1.19 | 84.3 | 32.8 | 4.68 |
| **$LSD_{0.10}$** | **NS** | **1.73** | **0.02** | **NS** | **1.7** | **0.42** | **$LSD0_{.10}$** | **NS** | **1.39** | **0.03** | **NS** | **1.49** | **NS** |

Lint yields are not significantly different from the top to bottom for either trial, so they are listed in numerical order of the names. DP 147RF and GA 2004230 are check varieties for comparison purposes.

Table 5. Results of 2009 Preliminary ($F_5$) Trials 3 and 4.

| 2009 PT3 | | | | | | | 2009 PT4 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ENTRY | Lint Yield | Lint % | UHM in. | UI % | Str g/tex | mic | ENTRY | Lint Yield | Lint % | UHM in. | UI % | Str g/tex | mic |
| GA 2009039 | **1490** | 41.29 | 1.14 | 83.65 | 32.50 | 5.36 | GA 2009115 | **1414** | 43.01 | 1.19 | 84.85 | 33.10 | 4.54 |
| GA 2009041 | **1430** | 42.93 | 1.13 | 84.50 | 31.85 | 5.09 | GA 2009104 | 1276 | 41.92 | 1.18 | 85.70 | 34.05 | 4.84 |
| GA 2009044 | **1428** | 44.51 | 1.14 | 84.65 | 31.15 | 5.01 | DP 147RF | 1276 | 41.41 | 1.23 | 85.05 | 32.35 | 3.88 |
| GA 2009038 | **1384** | 43.26 | 1.13 | 84.40 | 32.60 | 5.10 | GA 2004230 | 1276 | 39.12 | 1.28 | 84.60 | 33.10 | 3.89 |
| GA 2009045 | 1362 | 42.48 | 1.18 | 84.75 | 32.65 | 4.82 | GA 2009105 | 1208 | 42.92 | 1.11 | 83.80 | 31.00 | 5.14 |
| GA 2009042 | 1359 | 44.78 | 1.18 | 84.25 | 32.45 | 5.08 | GA 2009119 | 1196 | 36.90 | 1.11 | 84.40 | 33.25 | 4.11 |
| GA 2009100 | 1349 | 43.51 | 1.19 | 84.95 | 34.50 | 4.10 | GA 2009120 | 1125 | 36.84 | 1.12 | 85.70 | 32.95 | 5.05 |
| GA 2009102 | 1330 | 43.80 | 1.19 | 84.35 | 34.25 | 4.47 | GA 2009107 | 1124 | 37.57 | 1.18 | 84.80 | 32.15 | 4.31 |
| GA 2009181 | 1319 | 41.19 | 1.19 | 85.50 | 33.75 | 4.15 | GA 2009109 | 1111 | 37.95 | 1.12 | 84.70 | 33.30 | 4.45 |
| GA 2009098 | 1318 | 42.37 | 1.11 | 84.20 | 32.85 | 4.66 | GA 2009122 | 1108 | 41.06 | 1.21 | 84.55 | 33.85 | 4.28 |
| GA 2009093 | 1300 | 41.41 | 1.13 | 85.40 | 29.85 | 4.92 | GA 2009116 | 1107 | 42.33 | 1.16 | 84.85 | 33.65 | 4.84 |
| GA 2009103 | 1285 | 42.77 | 1.17 | 84.35 | 32.35 | 4.69 | GA 2009121 | 1099 | 40.66 | 1.16 | 83.95 | 32.95 | 4.66 |
| GA 2004230 | 1285 | 41.87 | 1.23 | 84.05 | 34.20 | 4.60 | GA 2009118 | 1060 | 39.76 | 1.14 | 84.70 | 31.00 | 4.26 |
| GA 2009046 | 1252 | 40.41 | 1.18 | 84.60 | 33.15 | 5.11 | GA 2009112 | 1051 | 42.42 | 1.17 | 84.35 | 33.85 | 4.29 |
| GA 2009043 | 1176 | 41.25 | 1.18 | 84.75 | 30.80 | 4.18 | GA 2009117 | 1033 | 42.15 | 1.18 | 85.80 | 31.40 | 4.51 |
| GA 2009101 | 1145 | 38.68 | 1.2 | 86.20 | 36.55 | 4.43 | GA 2009106 | 1026 | 36.41 | 1.19 | 85.75 | 35.55 | 4.73 |
| DP 147RF | 1123 | 40.17 | 1.26 | 84.45 | 32.60 | 4.14 | GA 2009110 | 982 | 38.01 | 1.17 | 83.80 | 32.45 | 4.81 |
| GA 2009095 | 1108 | 41.78 | 1.19 | 84.15 | 33.60 | 3.96 | GA 2009111 | 970 | 40.94 | 1.15 | 84.25 | 34.60 | 4.69 |
| GA 2009096 | 1015 | 41.69 | 1.1 | 83.05 | 32.95 | 4.73 | GA 2009123 | 899 | 42.07 | 1.21 | 84.70 | 30.60 | 4.35 |
| GA 2009099 | 997 | 34.12 | 1.16 | 84.20 | 32.60 | 3.65 | GA 2009113 | 884 | 40.98 | 1.12 | 85.05 | 33.30 | 4.63 |
| **$LSD_{0.10}$** | **117** | **1.34** | **0.03** | **NS** | **NS** | **0.38** | **$LSD_{0.10}$** | **98** | **2.19** | **0.03** | **0.69** | **1.38** | **0.42** |

The bold type indicates the lint yields that are not significantly different from the top.
DP 147RF and GA 2004230 are check varieties for comparison purposes.

Table 6. Results of 2009 Preliminary ($F_5$) Trials 5 and 6.

| 2009 PT5 | | | | | | | 2009 PT6 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ENTRY | Lint Yield | Lint % | UHM in. | UI % | Str g/tex | mic | ENTRY | Lint Yield | Lint % | UHM in. | UI % | Str g/tex | mic |
| GA 2009142 | **1327** | 43.23 | 1.17 | 83.65 | 32.95 | 4.72 | GA 2009151 | **1311** | 43.18 | 1.16 | 83.65 | 35.00 | 4.69 |
| GA 2009140 | **1300** | 42.81 | 1.18 | 85.05 | 33.60 | 5.05 | GA 2009147 | **1241** | 40.46 | 1.21 | 85.10 | 34.20 | 5.04 |
| GA 2009141 | **1192** | 41.01 | 1.21 | 85.50 | 34.80 | 4.49 | GA 2009148 | **1229** | 39.58 | 1.18 | 84.70 | 31.60 | 4.67 |
| GA 2009139 | **1190** | 37.96 | 1.08 | 83.30 | 30.40 | 4.31 | ST4664RF | **1190** | 41.35 | 1.14 | 83.65 | 29.50 | 4.41 |
| GA 2009131 | 1183 | 42.01 | 1.18 | 84.40 | 31.30 | 4.65 | GA 2009150 | 1143 | 39.88 | 1.19 | 85.00 | 36.10 | 5.03 |
| GA 2004230 | 1133 | 39.70 | 1.24 | 85.40 | 34.20 | 4.24 | GA 2009160 | 1109 | 42.08 | 1.16 | 83.60 | 30.15 | 4.15 |
| GA 2009126 | 1091 | 41.72 | 1.17 | 84.45 | 32.10 | 4.78 | GA2004230 | 1096 | 40.29 | 1.26 | 85.55 | 33.10 | 4.27 |
| GA 2009138 | 1021 | 41.69 | 1.2 | 83.75 | 31.95 | 4.50 | GA 2009155 | 1091 | 43.06 | 1.18 | 84.20 | 31.05 | 4.38 |
| GA 2009125 | 1015 | 41.46 | 1.21 | 85.70 | 32.20 | 4.24 | GA 2009154 | 1074 | 44.19 | 1.14 | 84.00 | 30.35 | 4.20 |
| GA 2009130 | 1014 | 40.41 | 1.15 | 84.30 | 31.10 | 4.57 | GA 2009144 | 1060 | 42.23 | 1.17 | 85.20 | 33.60 | 5.06 |
| GA 2009124 | 977 | 42.20 | 1.18 | 83.80 | 31.50 | 4.27 | DP147RF | 1049 | 39.99 | 1.26 | 85.40 | 33.85 | 3.90 |
| DP 147RF | 953 | 40.30 | 1.24 | 84.45 | 31.45 | 3.81 | GA 2009145 | 1024 | 41.66 | 1.27 | 85.70 | 33.60 | 4.36 |
| GA 2009133 | 924 | 38.44 | 1.22 | 84.75 | 33.15 | 4.75 | GA 2009143 | 1023 | 40.19 | 1.17 | 83.95 | 34.00 | 4.94 |
| GA 2009127 | 913 | 40.18 | 1.14 | 84.05 | 31.50 | 4.65 | GA 2009157 | 1005 | 42.86 | 1.18 | 84.50 | 33.15 | 4.31 |
| GA 2009129 | 908 | 41.99 | 1.2 | 84.95 | 31.70 | 4.30 | GA 2009152 | 999 | 44.19 | 1.17 | 85.35 | 33.50 | 4.83 |
| GA 2009128 | 889 | 43.95 | 1.16 | 84.55 | 30.50 | 4.75 | GA 2009158 | 978 | 42.94 | 1.18 | 85.35 | 35.65 | 4.60 |
| GA 2009136 | 862 | 41.84 | 1.15 | 84.05 | 31.70 | 4.80 | GA 2009159 | 903 | 42.75 | 1.12 | 82.50 | 32.05 | 4.22 |
| GA 2009134 | 841 | 40.60 | 1.18 | 84.85 | 35.20 | 4.86 | GA 2009153 | 845 | 42.16 | 1.15 | 84.65 | 33.20 | 4.82 |
| GA 2009137 | 830 | 41.03 | 1.12 | 83.65 | 33.50 | 5.04 | GA 2009146 | 836 | 40.19 | 1.12 | 84.10 | 30.70 | 4.84 |
| GA 2009135 | 607 | 40.65 | 1.21 | 83.90 | 32.50 | 4.90 | GA 2009161 | 790 | 43.20 | 1.15 | 84.15 | 31.45 | 4.58 |
| **$LSD_{0.10}$** | **137** | **1.53** | **0.02** | **NS** | **1.54** | **NS** | **$LSD_{0.10}$** | **126** | **1.96** | **0.03** | **0.96** | **2.19** | **0.46** |

The bold type indicates the lint yields that are not significantly different from the top.
DP 147RF and GA 2004230 are check varieties for comparison purposes.

Table 7. Results of 2009 Preliminary ($F_5$) Trial 7.

| | 2009 PT7 | | | | | |
|---|---|---|---|---|---|---|
| ENTRY | Lint Yield | Lint % | UHM in. | UI % | Str g/tex | mic |
| GA 2009172 | **1242** | 40.03 | 1.18 | 85.10 | 33.25 | 5.10 |
| GA 2009167 | **1168** | 41.71 | 1.15 | 84.50 | 30.05 | 4.33 |
| GA 2009176 | **1153** | 44.18 | 1.18 | 84.05 | 35.50 | 4.81 |
| GA 2009165 | **1137** | 45.12 | 1.12 | 83.55 | 35.25 | 5.28 |
| GA 2009173 | **1123** | 41.08 | 1.14 | 83.90 | 32.15 | 4.92 |
| GA 2009162 | 1112 | 42.50 | 1.16 | 83.55 | 34.70 | 4.92 |
| ST4664RF | 1070 | 42.05 | 1.17 | 84.80 | 31.35 | 4.74 |
| GA 2009175 | 992 | 40.81 | 1.19 | 84.10 | 31.25 | 5.09 |
| GA2004230 | 981 | 41.57 | 1.28 | 84.10 | 33.10 | 4.25 |
| GA 2009171 | 938 | 39.09 | 1.16 | 83.40 | 30.10 | 4.38 |
| GA 2009180 | 931 | 41.10 | 1.25 | 85.25 | 34.50 | 4.56 |
| DP147RF | 928 | 39.42 | 1.22 | 82.20 | 32.90 | 3.78 |
| GA 2009174 | 897 | 37.73 | 1.19 | 83.90 | 31.60 | 4.75 |
| GA 2009168 | 888 | 37.76 | 1.17 | 84.25 | 32.25 | 4.87 |
| GA 2009170 | 876 | 39.69 | 1.13 | 85.90 | 32.40 | 4.91 |
| GA 2009166 | 847 | 41.76 | 1.18 | 83.65 | 33.00 | 4.67 |
| GA 2009169 | 834 | 36.71 | 1.22 | 84.75 | 35.10 | 4.32 |
| GA 2009179 | 763 | 40.10 | 1.15 | 83.85 | 31.75 | 4.44 |
| GA 2009177 | 667 | 37.64 | 1.18 | 83.50 | 32.90 | 4.34 |
| GA 2009178 | 614 | 37.04 | 1.22 | 83.85 | 32.95 | 3.54 |
| **$LSD_{0.10}$** | **120** | **1.48** | **0.03** | **0.93** | **1.25** | **0.39** |

The bold type indicates the lint yields that are not significantly different from the top.
DP 147RF and GA 2004230 are check varieties for comparison purposes.

# ADDING ROOT-KNOT NEMATODE RESISTANCE TO GEORGIA-ADAPTED COTTON GERMPLASM, 2009

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## Introduction

State surveys of the densities of nematodes reveal that the major cotton-producing counties in Georgia have damaging levels of nematodes (state loss of 137,423 bales, valued at $53,594,970 in 1998) and is increasing from previous years (National Cotton Council, 1998). From 1991 to 1998, almost 98 thousand bales per year valued at a total of $300 million were lost (National Cotton Council, 1998). It is estimated that Georgia producers specifically lose about 77,000 bales of cotton annually from root-knot nematodes (*Meloidogyne incognita,* RKN) damage (Blasingame and Petal, 2001). Crop rotation, while a recommended cultural practice to lessen soil populations of RKN, is not an option for most Georgia growers because of the lack of suitable non-host crops with which to rotate their cotton acreages. Therefore, inherent genetic resistance provides an attractive alternative to pesticides and crop rotation.

Poor profit potential of cotton production from yield stagnation and high pest management costs impels creation of cultivars with inherent genetic resistance to enhance economic returns for cotton producers. Insect, nematode, and weed pest management costs are among the highest expenditures growers face in cotton production (National Cotton Council, 2001), thus their reduction would enhance profitability of cotton production. Since Georgia is the second ranked cotton producing state with 1.4 million acres (NASS, 2006), cotton cultivars adapted for the unique aspects of the environment of Georgia, such as rainfall patterns, soils types and depth, and presence of root-knot nematodes must be developed to give the best available genetics to the GA producer.

Despite the widespread occurrence of RKN in Georgia and most cotton production areas in the Southeast and that genetic resistance to RKN has existed since 1974 (Shepherd, 1974), private cultivar developers have previously exhibited little interest in fulfilling this need. Commonly cited reasons for the slow progress in developing RKN resistant cultivars is that the current screening process is costly, tedious, time consuming and destructive for identifying resistance genotypes. Further, most breeding stations have neither the facilities nor personnel with expertise in nematology to carry out the screening process to identify resistant material. Of those RKN-resistant (CPCSD Acala NemX) or tolerant cultivars (ST LA887 or PM H1560) that have been distributed by commercial cotton seed companies, none are adapted to the Southeast.
Our objective, to develop Georgia-adapted, value-added cotton germplasm with RKN resistance, will benefit the state's producers by providing increased yield and decreased

production costs whereas the increased availability of RKN-resistant germplasm will benefit the cotton industry across the belt.

## Materials and Methods

In a previous project, Drs. Chee, May, and Davis developed advanced RKN parents from a backcross breeding population using M120RNR and M155RNR root-knot nematode resistant donor parent with the elite breeding line PD94042 (May, 1999). The best resistant BC3F3 lines were crossed with Georgia adapted, value added lines from our UGA Cotton Breeding program. A ten plant sample of the RKN resistant parental material was challenged twice with a very high rate of RKN in a pot-based greenhouse test following Shen et al. (2006). Further samples were then grown at the Gibbs Farm, University of Georgia-Tifton campus in an RKN infested field following the procedure of Davis and May (2005). The resistant lines were verified in an additional pot-based greenhouse test. Resistant lines 103-7, 201-A, 506-5, and 506-11 were selected as parents to introgress the RKN resistance into the Georgia-adapted germplasm GA 98028 and GA 2001078.

DNA markers developed in a companion project with the preliminary work described by Shen et al. (2006) were to be used to select the resistant offspring using marker-assisted selection (MAS). The chromosomal region bearing the RKN resistance that is indicated by these molecular markers was verified independently (Ynturi et al., 2006), although the work in our lab appears to have markers that were closer to the RKN resistance gene. These markers are polymorphic between the parental line and both original parents of the RKN resistance donors that led to the $BC_3F_3$ population. Following marker aided selection (MAS), it is expected that selecting for the closely linked markers would also select for the RKN resistance. Three rounds of backcrossing to the agronomic elite parents while ensuring the presence of the markers and the RKN resistance should give Georgia-adapted, value-added cotton germplasm with RKN resistance.

## Results & Discussion

The following is our approach after using MAS to maintain the resistance and the marker up to the $2^{nd}$ backcross. After single plant selections in the $BC_2F_1$ population of the backcrossing approach along with fiber quality testing, an unreplicated modified augmented design yield test (with every 5th row in the trial assigned to a conventional check cultivar) was to be planted to select for yield and to test/verify the homozygosity of the RKN resistance marker(s). This trial was to be machine harvested and the seed-cotton yield of each F4 progeny row compared with seed-cotton yield of the nearest check row. For the rows that significantly out-yield the nearest check plot, boll samples will be picked for lint %, fiber quality, and for seed in a parallel increase field. Next, the preliminary trial (PT) was to be conducted near Tifton or Plains, GA, depending upon land availability. Advanced generation germplasm lines promoted from the PT were to

be tested in an advanced yield trial (AT) in both Plains and Tifton. Elite germplasm lines from a successful performance in the ATs will be tested in locations throughout the state in both dryland and irrigated fields in the University of Georgia Official Variety Trials. After the preliminary crossing, these most current molecular markers from the companion program mentioned above were to have been used in a three-cycle backcrossing program in the greenhouse to insert the RKN resistance gene during 2007. However, our crossing schedule was disrupted by inviable seed from the second backcross during 2007. $F_1$ seed were sent to the winter nursery in Mexico to obtain seed for the 2008 growing season to test samples of the $F_3$ population with the molecular markers for RKN resistance and then to continue with backcrossing with the plants that tested positive with the DNA markers for the RKN resistance.
During 2008, ten $F_2$ populations of RKN resistance by GA adapted lines from the winter nursery at Tecoman, Mexico were planted at the Gibbs farm, University of Georgia-Tifton campus; one population was lost when no plants emerged. DNA was extracted from ten plants of each $F_2$ population as well as their RKN-resistant and GA-adapted parents. Three additional advanced lines (155-R2-B1, 120-R1-B3, and 120-R1-B1) that are closely related to the original RKN-resistant parents were also sampled. The DNA markers for the RKN resistance were found to not be polymorphic in any of the populations with any of the RKN-resistant markers in our possession. Furthermore, no polymorphisms showed between the immediate parents of these populations. The linkage between the markers and the RKN-resistance gene must have been broken in the development of the PD 94042 RKN-resistant population. Immediate phenotype testing was not possible due to resource constraints. To continue our aggressive approach, new crosses were made immediately in 2008/2009 utilizing the more advanced RKN-resistant lines (155-R2-B1, 120-R1-B3, and 120-R1-B1) with newer GA-adapted lines to renew the effort to develop better GA-adapted, RKN-resistant cultivars via backcrossing utilizing phenotypic testing if needed.

Early in 2009 year, these crosses were destroyed inadvertently in our greenhouse by technicians from another program spraying 2,4D to control broadleaf weeds in grass plots during the winter of 2008/2009. These grass plots were not next to the greenhouse but the damage showed the classical 2,4D symptoms as compared with photos on the internet (www.weedscience.okstate.edu/cotton.htm [no longer linked, they are redoing their site]). The crosses from available remnant seed along with the backcross parents were planted into the 2009 field crossing block for further crossing/backcrossing. Further crosses with newly released cultivars GA 2004303 and GA 2004230 along with additional elite GA 2007 material were made to develop lines with enhanced GA adaptability along with this superior root-knot resistance. We have also made new crosses to M-120-RNR, the original source of resistance, with GA 2004303 and GA 2004230 to utilize the DNA markers that are presently available and any new ones that may be found. The later generation lines and backcrosses are currently being grown to be phenotypically challenged with RKN in our greenhouse during the winter season of 2009/2010 unless new DNA markers are found that were unaffected by the putative linkage breakage.

The two lines 120-R1-B1 and 120-R1-B3 of the three original lines in 2008 were retested at the UGA-Tifton campus Gibbs Farm in Tifton, GA and the UGA Southwest Georgia Research and Education Center in Plains, GA. Agronomic data was gathered for these improved lines to be used in submitting them for release as germplasm lines. The checks for this test were increased to 5 (GA 2004230, DP 147RF, FM 966, ST 4664RF, and DP 5415) along with PD 94042 which was the original elite breeding line. DP 5415 was eliminated from the lint yield analysis of the Gibbs Farm because it had very poor emergence.

The location by entry interaction term for the lint yield was very highly significant at greater than the 0.001 level. Therefore the lint yield data cannot be averaged across Tifton and Plains in 2009; this was also true in 2008. Plains had a better overall growing condition in 2009 shown by the grand mean of 1460 lbs/acre while Tifton was less at 823 lbs/acre. The line 120-R1-B1 was the best yielder in Plains at 1962 lbs/acre but it was 6$^{th}$ of the 7 lines in Tifton (Table 1 & 2). Line 120-R1-B3 ranked 3$^{rd}$ in Tifton at 865 lbs/acre and 5$^{th}$ in Plains (Tables 1 & 2). Lint % didn't have a location by entry interaction. As it did in 2008, 120-R1-B1 had the highest lint % in 2009 (46.4% across locations); 120-R1-B3 was 2$^{nd}$ in 2009 with 44.6% (Table 3). The fiber, tested by Cotton Incorporated HVI fiber testing, did not show location by entry interaction either. Only GA 2004230 and DP 147RF had better length than these RKN-resistant lines (Table 3). The uniformity index and micronaire were excellent values as good as the recurrent parent, PD 94042, and the checks. Their strength values were significantly less than PD 94042, but they still were as good as all the checks but FM 966.

Line 120-R1-B3 is being released as germplasm under the name "GA 120R1B3" based on its stable, very good resistance to RKN and its very good yield performance and fiber quality.

We are expecting our approach to provide a solid performing release of GA-adapted, RKN resistant germplasms/cultivars. Even though MAS is generally considered a reliable procedure, it is a relatively recent innovation and has not been extensively utilized, and there have been technical problems associated with it. Phenotypic analyses of the new populations are likely to present resource allocation difficulties that will decrease the size of the populations that can be tested.

## Acknowledgments

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Table 1. Lint yield, lint %, and fiber quality comparisons of RKN resistant lines 120-R1-B1 and 120-R1-B3 with the original recurrent parent, PD 94042, and 5 check cultivars at the Southwest Research and Education Center, Plains, GA

| ENTRY | Lint Yield[1] | Lint % | UHM[2] in. | UI[3] % | mic[4] | Str[5] g/tex |
|---|---|---|---|---|---|---|
| 120-R1-B1 | 981 | 47.00 | 1.24 | 85.50 | 4.40 | 31.87 |
| ST 4664RF | 866 | 43.22 | 1.20 | 85.13 | 4.71 | 30.30 |
| GA 2004230 | 863 | 44.87 | 1.27 | 85.47 | 4.64 | 30.50 |
| 120-R1-B3 | 849 | 44.88 | 1.25 | 85.60 | 4.46 | 31.23 |
| DP 147RF | 736 | 42.16 | 1.24 | 85.70 | 4.31 | 30.37 |
| DP 5415 | 703 | 41.43 | 1.22 | 85.17 | 4.62 | 31.23 |
| FM 966 | 656 | 42.70 | 1.24 | 84.27 | 4.65 | 38.70 |
| PD 94042 | 524 | 43.79 | 1.19 | 85.07 | 4.75 | 31.17 |
| $LSD_{0.05}$ | 145[6] | -[7] | -[7] | -[7] | -[7] | -[7] |

[1] - lbs/acre
[2] - Length as Upper Half Mean
[3] - Uniformity Index
[4] - Micronaire
[5] - Fiber Strength
[6] - Significant location by entry interaction, no combined analysis
[7] - No location by entry interaction, see Table 3 for the combined analyses.

Table 2. Lint yield, lint %, and fiber quality comparisons of RKN resistant lines 120-R1-B1 and 120-R1-B3 with the original recurrent parent, PD 94042, and 5 check cultivars at the Gibbs Research Farm, UGA-Tifton campus, Tifton, GA

| ENTRY | Lint Yield[1] | Lint % | UHM[2] in. | UI[3] % | mic[4] | Str[5] g/tex |
|---|---|---|---|---|---|---|
| FM 966 | 530 | 41.2 | 1.16 | 85.37 | 4.51 | 33.6 |
| DP 147RF | 441 | 42.1 | 1.25 | 85.23 | 4.09 | 31.9 |
| 120-R1-B3 | 432 | 44.4 | 1.22 | 86.63 | 4.44 | 31.9 |
| PD 94042 | 401 | 44.3 | 1.20 | 85.20 | 4.54 | 33.3 |
| GA 2004230 | 367 | 43.0 | 1.27 | 86.37 | 4.44 | 32.5 |
| 120-R1-B1 | 366 | 45.8 | 1.21 | 85.47 | 4.19 | 31.1 |
| ST 4664RF | 354 | 41.4 | 1.15 | 85.43 | 4.61 | 30.0 |
| DP 5415 | - | 37.5 | 1.14 | 84.67 | 4.58 | 29.5 |
| $LSD_{0.05}$ | 98[6] | -[7] | -[7] | -[7] | -[7] | -[7] |

[1] - lbs/acre
[2] – Length as Upper Half Mean
[3] - Uniformity Index
[4] - Micronaire
[5] - Fiber Strength
[6] - Significant location by entry interaction, no combined analysis
[7] - No location by entry interaction, see Table 3 for the combined analyses.

Table 3. Lint yield, lint %, and fiber quality comparisons of RKN resistant lines 120-R1-B1 and 120-R1-B3 with the original recurrent parent, PD 94042, and 5 check cultivars
across both GA locations shown in Tables 1 and 2.

| ENTRY | Lint Yield[1] | Lint % | UHM[2] in. | UI[3] % | mic[4] | Str[5] g/tex |
|---|---|---|---|---|---|---|
| 120-R1-B1 | 673 | 46.4 | 1.23 | 85.48 | 4.30 | 31.47 |
| 120-R1-B3 | 641 | 44.6 | 1.23 | 86.12 | 4.45 | 31.55 |
| GA 2044230 | 615 | 44.0 | 1.27 | 85.92 | 4.54 | 31.48 |
| ST 4664RF | 606 | 42.3 | 1.18 | 85.28 | 4.66 | 30.13 |
| FM 966 | 593 | 41.9 | 1.20 | 84.82 | 4.58 | 36.17 |
| DP 147RF | 588 | 42.2 | 1.24 | 85.47 | 4.20 | 31.15 |
| PD 94042 | 455 | 44.0 | 1.20 | 85.13 | 4.65 | 32.22 |
| DP 5415 | - | 39.4 | 1.18 | 84.92 | 4.60 | 30.37 |
| $LSD_{0.10}$ | -[1] | 1.3 | 0.04 | NS | 0.18 | 1.62 |

[1] - lbs/acre
[2] - Length
[3] - Uniformity Index
[4] - Micronaire
[5] - Fiber Strength
[6] - Location by entry interaction, see Tables 1 and 2 for correct, individual analyses

# 2009 IRWIN COUNTY COTTON VARIETY TRIAL

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## Introduction

A large-plot county variety trial was initiated in 2009 in Irwin County to address farmer questions about finding a suitable replacement for DP555 BR. Seed was requested from area seed representatives and a farmer in Irwin County agreed to supply land and equipment for the trial. The varieties included DP555 BR, DP0912 B2RF, DP0949 B2RF, DP0935 B2RF, PHY480 WR, PHY485 WRF, PHY370 WR, and PHY375 WRF.

The trial was planted on June 9, 2009 and harvested on January 7-8, 2010. Some of these varieties were duplicated from the previous variety trials in the county dating back to 2005. A large body of information has been gathered on many of these varieties and this replicated trial adds to that base of information.

## Materials and Methods

The trial was a randomized complete block. Four replications were made however only three replications were utilized to collect data. At the harvest of each replication the seed cotton was weighed and samples were pulled. Those samples were ginned at the UGA Micro Gin facility in Tifton and the results are given below.

## Results, Discussion, and Conclusions

Data is shown in several forms. Table 1 shows results by replication number. Table 2 shows results by variety. Table 3 show gin data as well as grade.

The trials were a good success in 2009. The trials allow agents and growers a closer look at these 12 varieties and it comparison to DP555. Although the highest numeric average yield was obtained from the DP555 (1050 lb per acre), other varieties competed well, with yield averages ranging from 900 to 1032 lb per acre.

Table 1. 2009 Irwin County cotton variety trial by replication.

| Plot # | Stand Count | Row Length (ft) | Plot Size (acre) | Variety | Seed Cotton Wgt | Lint Wgt | Plot Weight | % turnout | Yield Per Acre |
|---|---|---|---|---|---|---|---|---|---|
| 101 | 2.1 | 2442 | .67 | PHY 480 WR | 25.6 | 9.33 | 1790 | 36.45% | 969.9 |
| 102 | 2.6 | 2424 | .67 | PHY 485 WRF | 25.03 | 9.22 | 1744 | 36.84% | 962.2 |
| 103 | 2.3 | 2406 | .66 | DP 0912 B2RF | 27.12 | 9.98 | 1850 | 36.80% | 1027.1 |
| 104 | 2.5 | 2341 | .64 | DP 0949 B2RF | 28.01 | 10.31 | 1590 | 36.81% | 907.5 |
| 105 | 2.1 | 2324 | .64 | PHY 370 WR | 26.66 | 10.2 | 1662 | 38.26% | 933.2 |
| 106 | 2.7 | 2352 | .65 | DP 555 BGRR | 23.92 | 9.63 | 1690 | 40.26% | 1050 |
| 107 | 2.3 | 2340 | .64 | DP 0935 B2RF | 29.25 | 11.48 | 1666 | 39.25% | 1014.4 |
| 108 | 2.3 | 2328 | .64 | PHY 375 WRF | 25.83 | 10.01 | 1564 | 38.75% | 945.0 |
| 201 | 2.1 | 2307 | .64 | PHY 480 WR | 23.13 | 8.45 | 1592 | 36.53% | 915.1 |
| 202 | 2.7 | 2284 | .63 | PHY 485 WRF | 26.08 | 9.76 | 1546 | 37.42% | 919.4 |
| 203 | 2.2 | 2272 | .63 | DP 555 BGRR | 17.37 | 7.28 | 1598 | 41.91% | 1070.1 |
| 204 | 2.3 | 2265 | .62 | DP 0949 B2RF | 24.38 | 9.48 | 1636 | 38.88% | 1020.0 |
| 205 | 2.2 | 2250 | .62 | PHY 375 WRF | 16.86 | 6.54 | 1486 | 38.79% | 930.0 |
| 206 | 2.4 | 2250 | .62 | PHY 370 WR | 22.32 | 8.74 | 1558 | 39.16% | 984.3 |
| 207 | 3 | 2242 | .62 | DP 0912 B2RF | 18.41 | 7.06 | 1700 | 38.35% | 1053.9 |
| 208 | 1.7 | 2232 | .62 | DP 0935 B2RF | 19.61 | 7.75 | 1602 | 39.52% | 1029.7 |
| 301 | 2.4 | 2226 | .61 | DP 0912 B2RF | 17.82 | 6.92 | 1624 | 38.83% | 1015.1 |
| 302 | 2.5 | 2217 | .61 | DP 0935 B2RF | 19.61 | 7.81 | 1462 | 39.83% | 953.5 |
| 303 | 2.3 | 2211 | .61 | DP 555 BGRR | 19.3 | 7.96 | 1544 | 41.24% | 1045.5 |
| 304 | 3 | 2208 | .61 | PHY 480 WR | 22.47 | 8.33 | 1332 | 37.07% | 811.8 |
| 305 | 2.3 | 2199 | .61 | PHY 375 WRF | 23.13 | 9.03 | 1468 | 39.04% | 947.1 |
| 306 | 2.4 | 2193 | .61 | PHY 370 WR | 24.22 | 9.49 | 1354 | 39.18% | 878.1 |
| 307 | 2.3 | 2184 | .60 | DP 0949 B2RF | 20.65 | 8.01 | 1242 | 38.79% | 800.8 |
| 308 | 2.8 | 2178 | .60 | PHY 485 WRF | 24.44 | 9.26 | 1412 | 37.89% | 891.6 |

Table 2. 2009 Irwin County cotton variety trial by variety (averages +/- 1 standard deviation).

| Plot | Stand Count | Variety | Plot Weight | % turnout | Yield Per Acre | Average Yield |
|---|---|---|---|---|---|---|
| 101 | 2.1 | PHY 480 WR | 1790 | 36.45% | 969.9 | |
| 201 | 2.1 | PHY 480 WR | 1592 | 36.53% | 915.1 | 899+/-80 |
| 304 | 3 | PHY 480 WR | 1332 | 37.07% | 811.8 | |
| 102 | 2.6 | PHY 485 WRF | 1744 | 36.84% | 962.2 | |
| 202 | 2.7 | PHY 485 WRF | 1546 | 37.42% | 919.4 | 924+/-36 |
| 308 | 2.8 | PHY 485 WRF | 1412 | 37.89% | 891.6 | |
| 108 | 2.3 | PHY 375 WRF | 1564 | 38.75% | 945.0 | |
| 205 | 2.2 | PHY 375 WRF | 1486 | 38.79% | 930.0 | 941+/-9 |
| 305 | 2.3 | PHY 375 WRF | 1468 | 39.04% | 947.1 | |
| 105 | 2.1 | PHY 370 WR | 1662 | 38.26% | 933.2 | |
| 206 | 2.4 | PHY 370 WR | 1558 | 39.16% | 984.3 | 932+/-53 |
| 306 | 2.4 | PHY 370 WR | 1354 | 39.18% | 878.1 | |
| 106 | 2.7 | DP 555 BGRR | 1690 | 40.26% | 1050 | |
| 203 | 2.2 | DP 555 BGRR | 1598 | 41.91% | 1070.1 | 1055+/-13 |
| 303 | 2.3 | DP 555 BGRR | 1544 | 41.24% | 1045.5 | |
| 103 | 2.3 | DP 0912 B2RF | 1850 | 36.80% | 1027.1 | |
| 207 | 3 | DP 0912 B2RF | 1700 | 38.35% | 1053.9 | 1032+/-20 |
| 301 | 2.4 | DP 0912 B2RF | 1624 | 38.83% | 1015.1 | |
| 104 | 2.5 | DP 0949 B2RF | 1590 | 36.81% | 907.5 | |
| 204 | 2.3 | DP 0949 B2RF | 1636 | 38.88% | 1020.0 | 909+/-110 |
| 307 | 2.3 | DP 0949 B2RF | 1242 | 38.79% | 800.8 | |
| 107 | 2.3 | DP 0935 B2RF | 1666 | 39.25% | 1014.4 | |
| 208 | 1.7 | DP 0935 B2RF | 1602 | 39.52% | 1029.7 | 999+/-40 |
| 302 | 2.5 | DP 0935 B2RF | 1462 | 39.83% | 953.5 | |

Table 3. Irwin County gin data including grade.

| Plot # | Variety | Grade | Staple | Mic | Strength | Color Grade | Color | Rd | +B | Trash | Hvi Length | Uniformity |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 101 | PHY 480 WR | 41 | 37 | 4.1 | 28.3 | 3 | 41-2 | 75 | 68 | 0 | 1.1 | 81.9 |
| 102 | PHY 485 WRF | 41 | 37 | 4.3 | 29 | 3 | 41-2 | 75 | 69 | 0 | 1.2 | 83.2 |
| 103 | DP 0912 B2RF | 41 | 35 | 4.1 | 28 | 2 | 41-1 | 76 | 70 | 0 | 1.1 | 81 |
| 104 | DP 0949 B2RF | 41 | 36 | 3.7 | 28.4 | 3 | 41-2 | 75 | 69 | 0 | 1.1 | 81.8 |
| 105 | PHY 370 WR | 41 | 35 | 3.9 | 27.8 | 2 | 41-1 | 77 | 66 | 0 | 1.1 | 82.3 |
| 106 | DP 555 BGRR | 41 | 36 | 4 | 28.3 | 3 | 41-1 | 78 | 62 | 0 | 1.1 | 80.9 |
| 107 | DP 0935 B2RF | 41 | 36 | 3.6 | 27.5 | 2 | 41-1 | 77 | 70 | 0 | 1.1 | 81 |
| 108 | PHY 375 WRF | 41 | 36 | 3.6 | 28.5 | 2 | 41-2 | 76 | 58 | 0 | 1.1 | 80.5 |
| 201 | PHY 480 WR | 41 | 37 | 4.2 | 29.1 | 2 | 41-2 | 75 | 66 | 0 | 1.1 | 83.5 |
| 202 | PHY 485 WRF | 51 | 36 | 4.3 | 29.1 | 3 | 51-1 | 73 | 65 | 0 | 1.1 | 81.7 |
| 203 | DP 555 BGRR | 41 | 36 | 3.8 | 28.2 | 2 | 41-1 | 78 | 58 | 0 | 1.1 | 80.7 |
| 204 | DP 0949 B2RF | 41 | 36 | 4.1 | 28.1 | 3 | 41-1 | 77 | 66 | 0 | 1.1 | 80.9 |
| 205 | PHY 375 WRF | 41 | 35 | 3.7 | 26.7 | 3 | 41-2 | 76 | 58 | 0 | 1.1 | 81.3 |
| 206 | PHY 370 WR | 41 | 35 | 4.2 | 28.8 | 2 | 41-2 | 76 | 62 | 0 | 1.1 | 81.4 |
| 207 | DP 0912 B2RF | 51 | 35 | 4.4 | 28 | 2 | 51-1 | 75 | 57 | 0 | 1.1 | 81 |
| 208 | DP 0935 B2RF | 41 | 36 | 3.9 | 28.8 | 3 | 41-1 | 76 | 72 | 0 | 1.1 | 79.9 |
| 301 | DP 0912 B2RF | 51 | 36 | 4.3 | 27 | 2 | 51-1 | 76 | 55 | 0 | 1.1 | 81.8 |
| 302 | DP 0935 B2RF | 41 | 35 | 3.8 | 26.5 | 2 | 41-1 | 77 | 71 | 0 | 1.1 | 79.7 |
| 303 | DP 555 BGRR | 41 | 36 | 4 | 28.3 | 2 | 41-2 | 78 | 57 | 0 | 1.1 | 79.9 |
| 304 | PHY 480 WR | 41 | 37 | 4.3 | 29.3 | 2 | 41-2 | 76 | 61 | 0 | 1.2 | 83.5 |
| 305 | PHY 375 WRF | 41 | 36 | 3.9 | 28.1 | 2 | 41-2 | 77 | 58 | 0 | 1.1 | 81.9 |
| 306 | PHY 370 WR | 41 | 35 | 4.2 | 27.6 | 2 | 41-2 | 76 | 63 | 0 | 1.1 | 82.9 |
| 307 | DP 0949 B2RF | 41 | 37 | 3.8 | 29.8 | 3 | 41-2 | 77 | 61 | 0 | 1.2 | 81.5 |
| 308 | PHY 485 WRF | 51 | 36 | 4.3 | 28.8 | 2 | 51-1 | 73 | 67 | 0 | 1.1 | 82 |

# EXCESSIVE THRIPS INJURY IMPACTS ROOT GROWTH IN SEEDLING COTTON

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## Introduction

Thrips are a consistent and predictable insect pest of seedling cotton in Georgia and the southeast. In general, thrips infestations are higher on early planted cotton compared with late May and June plantings. Thrips feed on cotyledon leaves initially and then move to the growing point to feed on newly forming leaves. Thrips injury results in crinkled distorted true leaves, stunted or reduced seedling growth, delays in maturity, reduced yield potential, and in severe cases loss of apical dominance or stand loss. Thrips injury is also compounded by slow seedling growth resulting from other plant stresses such as cool temperatures. Most growers choose to use a preventive systemic insecticide at planting in the form of granules applied in the seed furrow or a commercial seed treatment to aid in management and control of early season thrips. Preventive treatments vary in efficacy and residual activity, and it is important that growers understand treatment performance and attributes.

Research has demonstrated a consistent yield response when preventive systemic insecticides are used. However, supplemental treatment with a foliar insecticide is sometimes needed. The threshold for foliar application of an insecticide for early season thrips is 2-3 thrips per plant and immatures present. The presence of immature thrips suggests that the preventive insecticide used at planting is no longer active or not providing control. Foliar treatments for thrips are rarely necessary once plants reach the 4-5 leaf stage and are growing vigorously.

Plant stunting resulting from excessive thrips injury has been well documented in many studies. However, relatively few studies have investigated the impact of thrips injury on root development. Rapid and robust root development is a desired objective in cotton production systems. A strong root system improves the plants ability to endure periods of stress resulting from poor growing conditions or debilitating pests such as nematodes. Recently Roberts and Toews reported on the impact of thrips injury on root growth (2008 Cotton Research and Extension Report, found online at ugacotton.com). However, in these studies plants were dug with shovels from field plots and more precise collection and quantification of root biomass is desired. Thus the objective of this study was to more precisely quantify the impact of seedling thrips infestations on early season root growth in a more controlled environment (i.e. potted cotton seedlings).

## Materials and Methods

Treatments were selected with the objective of creating three levels of thrips infestation and injury and included an untreated check, Cruiser seed treatment, and Cruiser seed

treatment plus foliar applications of Orthene 97 at 3 ozs/acre applied 10, 17, and 24 days after planting (DAP). Two seeds (DP 0935 B2RF) were planted in 1 gallon pots filled with soil amendment and fertilizer. Pots were uniformly watered to ensure rapid and uniform seedling emergence. Each treatment (pot) was replicated 45 times. Pots were arranged in a randomized complete block design and placed in the row middles of a recently tilled and planted field in Tift County, GA. Pots were partially buried in the soil so that 0.5-1 inch of the pot was visible. Seedlings were thinned to one plant per pot upon emergence. Pots were uniformly hand watered as needed during the trial period. Foliar insecticide treatments were applied on May 8, 15, and 23 with a CO2 backpack sprayer and TXVS 6 nozzles calibrated to deliver 13.8 gpa in a 12 inch band.

Thrips infestation levels and plant injury and growth measurements were collected on May 12, 19, and 26 (14, 21, and 28 DAP). Data was collected from 15 of the 45 replicates on each sample date. Subjective thrips injury ratings were assigned to individual plants on a scale of 1-5 where 1=no damage, 3=moderate (acceptable damage), and 5=severe damage. To quantify thrips infestation, plants were excised at the soil surface and immediately immersed in a container filled with 70% ETOH. Thrips samples were returned to the laboratory and immature and adult thrips were enumerated. The above ground portions of plants were individually bagged and also transported to the laboratory for additional processing. Plant height was determined by measuring the distance from the base to the terminal bud. Plant nodes or true leaves were also quantified; the uppermost node was determined by the presence of an expanded leaf at least the diameter of a quarter and the cotyledon node was defined as zero. Individual plant (above ground plant parts) dry weights were quantified after drying plants for 48 hours at 60 C in a forced air oven. Roots (below ground plant parts) were collected by removing the soil and root ball from individual pots and carefully washing soil from the root mass. Root dry weights were quantified for individual plants as described above. Root and shoot growth data were subjected to analysis of variance and means were separated using LSD, p=0.05.

## Results and Discussion

Thrips infestations were high during the trial period, exceeding 50 thrips per plant in some pots. Infestations of individual seedlings were much higher than cotton which had been planted in rows in the trial area. Perhaps this was due to the fact that cotton in the pots (placed in row middles) emerged approximately 2 days prior to the field planted cotton. Thrips infestations varied from low to moderate to high in respective treatments (Table 1); thus achieving the goal of having varying degrees of thrips damage. Plant height and node development were all influenced as expected by the varying levels of thrips infestation and injury. Plant height and node development were decreased as thrips injury increased.

No significant differences in above ground plant biomass (shoots) were observed at 14 DAP (Figure 1). However, at 21 DAP the shoot dry weights for the Cruiser+Orthene

treatment were significantly greater than the Cruiser and the untreated; no significant difference was observed between the Cruiser and untreated on this date. At 28 DAP significant differences were observed among all treatments; shoot dry weights were greatest in the Cruiser+Orthene > Cruiser > untreated.

Table 1. Thrips damage rating, number of immature and adult thrips per plant, plant height, and total nodes at 14, 21, and 28 days after planting. Tift County GA, 2009.

| Evaluation Date Treatments | Thrips Damage Rating | Thrips per Plant | | Plant Height (cm) | Nodes (True Leaves) |
|---|---|---|---|---|---|
| | | Immatures | Adults | | |
| 14 DAP (May 12) | | | | | |
| Untreated | 3.87 | 26.73 | 11.67 | 5.73 | 0 |
| Cruiser | 3.39 | 15.79 | 10.43 | 6.43 | 0 |
| Cruiser+Orthene[a] | 2.32 | 5.50 | 2.43 | 6.50 | 0 |
| 21 DAP (May 19) | | | | | |
| Untreated | 4.14 | 48.29 | 3.29 | 7.64 | 0.93 |
| Cruiser | 3.77 | 50.00 | 7.73 | 8.47 | 1.73 |
| Cruiser+Orthene[a] | 2.17 | 6.87 | 1.07 | 9.53 | 2.67 |
| 28 DAP (May 26) | | | | | |
| Untreated | 4.47 | 11.53 | 1.73 | 7.90 | 0.47 |
| Cruiser | 3.63 | 15.00 | 2.53 | 11.10 | 2.93 |
| Cruiser+Orthene[a] | 2.30 | 5.07 | 0.67 | 13.20 | 4.13 |

[a]Orthene 97 applied at 3 ozs/acre on May 12, 19, and 26 (10, 17, and 24 days after planting)

Root (below ground plant parts) dry weights followed a similar trend as shoots except at 14 DAP. At 14 DAP the Cruiser+Orthene and Cruiser treatments had significantly greater root dry weights compared with the untreated (Figure 2). At 21 DAP Cruiser+Orthene had significantly greater root dry weights compared with Cruiser and the untreated. At 28 DAP significant differences were again observed among all treatments; root dry weights were greatest in the Cruiser+Orthene > Cruiser > untreated. Figure 3 illustrates the correlation of above-ground and below-ground plant growth at 28 DAP. An R-squared value of 0.81 suggests there is a strong correlation of above-ground to below-ground plant growth.

Data from this trial which was conducted in a manner to more precisely collect root data are consistent with results reported by Roberts and Toews in the 2008 Cotton Research and Extension Report. Reduced plant growth resulting from thrips injury is directly

correlated with root growth. When you observe above-ground plant stunting resulting from excessive thrips injury, root development has also been deterred to a similar degree. These data suggests that failure to adequately control thrips will delay root development. These data do not suggest that we need to make wholesale foliar thrips treatments. Unneeded early season foliar insecticides may create additional problems such as flaring or increasing the risk of aphid and spider mite outbreaks. The primary point is that thrips impact root development and appropriate thrips management programs are an important part of the overall production system.

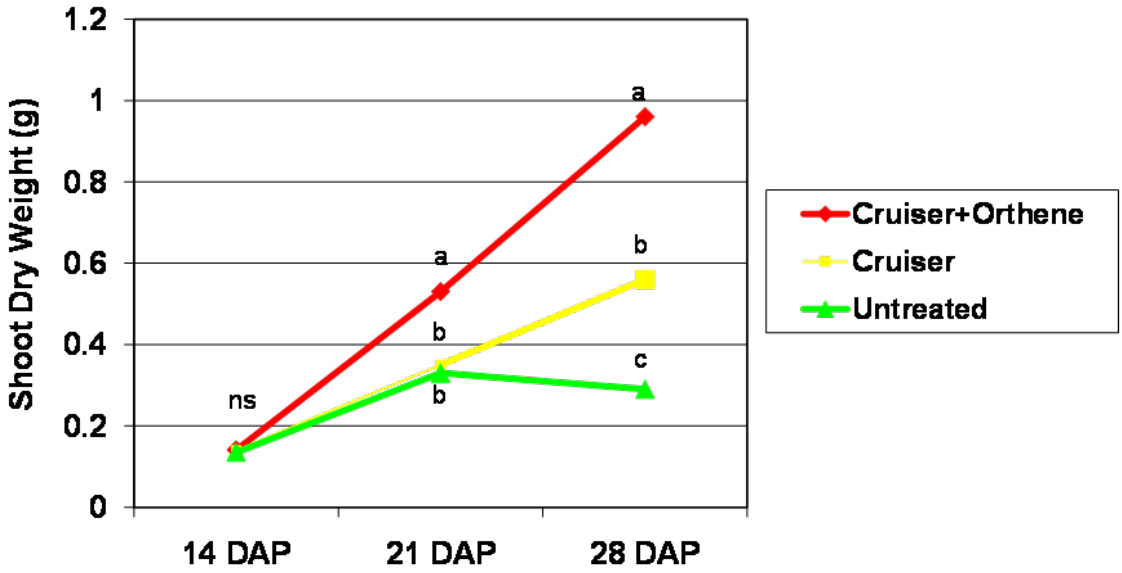


Figure 1. Root dry weights in selected treatments at 14, 21, and 28 days after planting. Tift County GA, 2009. Means followed by the same letter on a sample date are not significantly different.

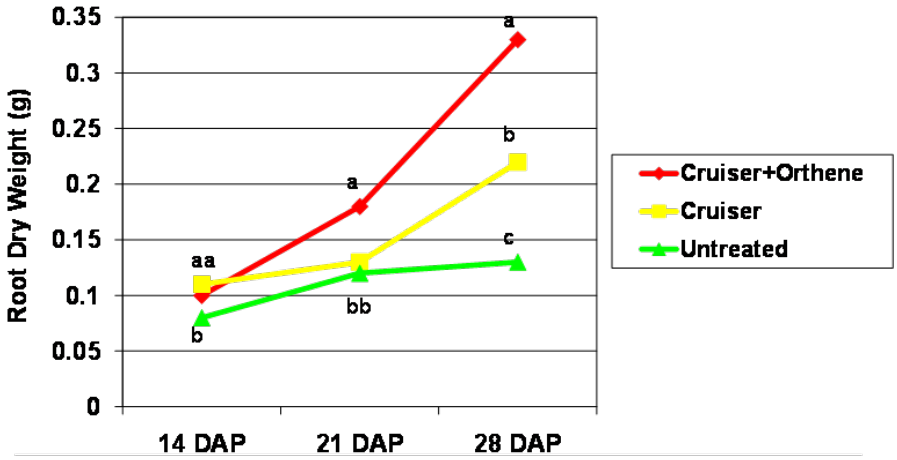


Figure 2. Root dry weights in selected treatments at 14, 21, and 28 days after planting. Tift County GA, 2009. Means followed by the same letter on a sample date are not significantly different.

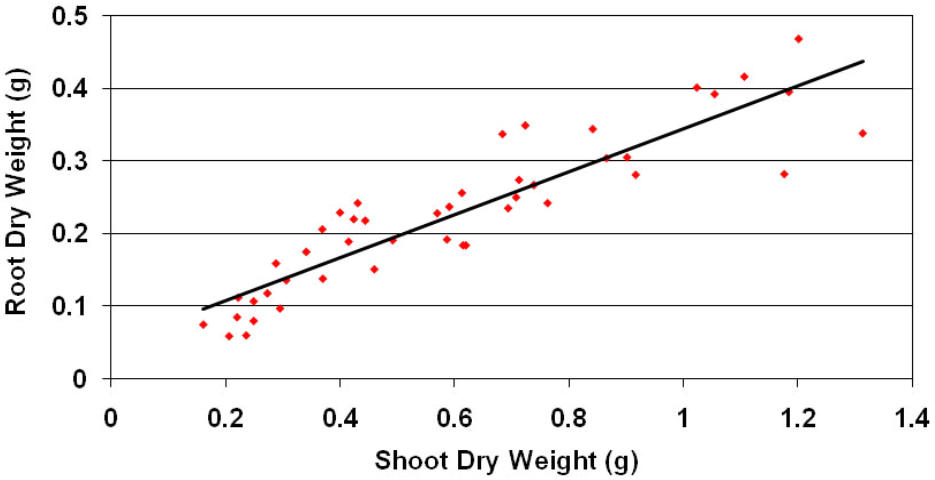


Figure 3. Correlation of root dry weights and shoot dry weights at 28 days after planting. Tift County GA, 2009.

## References

Roberts, Phillip, and Mike Toews. 2009. Evaluation of thrips management programs and the effect of thrips damage on early season root growth. In: Cotton Research-Extension Report 2008 (Toews, M., G. Ritchie, and A. Smith, Eds.) UGA/CPES Research – Extension Publication No. 6, pp. 108-113. Found online at http://ugacotton.com.

# LABORATORY EVALUATION OF SELECTED INSECTICIDES ON FIELD-COLLECTED POPULATIONS OF BOLLWORM AND TOBACCO BUDWORM LARVAE

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## Abstract

Bollworm (CEW) and tobacco budworm (TBW) larvae and adults were collected from a variety of host crops and evaluated for susceptibility to MVP II®, cypermethrin, and spinosad (Tracer®) insecticides during the 2009 season. Results were compared to historical data collected throughout a fifteen-year period beginning in 1995. As expected, CEW larvae were less susceptible to MVP II® than TBW larvae. However, the susceptibilities of both CEW and TBW to MVP II® have remained relatively stable throughout the study period with annual average fluctuations in $LC_{50}$ values of 2-3-fold. Although cypermethrin remains effective in controlling CEW larvae, average $LC_{50}$ values were highest during 2009; approximately 6-fold higher than $LC_{50}$ values recorded in the mid-1990s. The effectiveness of cypermethrin for the control of TBW larvae has also declined. The average $LC_{50}$ values for cypermethrin against TBW larvae collected during the 2009 season were approximately 37-fold higher than the $LC_{50}$ value obtained for a pyrethroid-susceptible laboratory strain. Furthermore, they were approximately 13-fold higher than the average $LC_{50}$ values obtained during the mid-1990s. Decreases in the susceptibilities of CEW and TBW populations were confirmed by the use of topical application bioassays and adult vial tests. Spinosad (Tracer®) has remained highly effective against CEW and TBW larvae throughout the study period. However, the highest average $LC_{50}$ values to date were obtained during 2009.

## Introduction

The bollworm (CEW; *Helicoverpa zea*) and the tobacco budworm (TBW; *Heliothis virescens*) are two of the more economically important cotton pests in the United States. CEW and TBW populations have developed resistance to many of the insecticides used for their control. As a result, it is essential that research efforts and agricultural practices be devoted to the preservation of effective insecticides and to the development of new compounds and technologies. Programs to monitor insecticide susceptibilities of field-collected populations of CEW and TBW are critical to the development of effective management strategies. Samples of CEW and TBW populations were collected from cotton, tobacco, peanut and corn fields throughout Georgia during the summer of 2009. Larvae from those field-collected samples were assayed for susceptibility to a variety of insecticides using treated-diet and topical application bioassays. Adults were evaluated using an adult vial test bioassay. Results were compared to baseline data collected between 1995-1999 and 2003-2005.

## Materials and Methods

During 2009, CEW and TBW were collected from Burke, Colquitt, Decatur, Dooly, Early, Miller, Mitchell, Sumter, Taylor, Terrell, and Tift counties (Figure 1). Field-collected CEW and TBW moths or larvae were transported to facilities at the University of West Georgia. Larvae were transferred to a pinto bean/wheat germ, agar-based diet. Adults were placed in mating cages to produce adequate numbers of larvae for testing. Larvae and adults were maintained at 27˚C, LD 14:10 and approximately 40% RH. The insecticides used were MVP II® (19.1% A.I., Monsanto Corporation, St. Louis, MO); cypermethrin (94.3% A.I., FMC Corporation, Princeton, NJ); and spinosad (91.3% A.I., Dow AgroSciences, Indianapolis, IN).

Larvae were evaluated using a modified insecticide-treated diet bioassay or by topical application. Adults were evaluated using an adult vial test (AVT) protocol. For the insecticide-treated diet assay, an insecticide test solution (100 µl) was added to 50 ml of liquefied pinto bean/wheat germ, agar-based diet at approximately 57˚C while mixing with a variable speed stirrer. The insecticide-treated diet (approximately 2.5 ml) was distributed into 1 oz. clear plastic medicine cups. The treated diets were allowed to cool and gel. One neonate or one late 2$^{nd}$ instar larva (depending upon the insecticide being evaluated) was added to each cup, and mortality was monitored over a 4 day period. For the topical application bioassay, a 1 µl droplet, an insecticide solution or acetone (control) was applied to the dorsal thorax of a 4$^{th}$ instar larva (approximately 35 mg). Mortality was assessed after a 48 h exposure period. For the adult vial test, a single moth was placed in an insecticide-treated or acetone-treated (control) vial. Mortality was assessed after a 24 h exposure period. Mortality was defined as the inability of the larva to move across the diet surface when probed or for a moth to fly a distance of 1 meter when dropped from a 2 meter height. During the treatment period, the larvae and adults were held in an environmental chamber at 27˚C, LD 14:10 and approximately 40% RH.

## Results and Discussion

As expected, MVP II® was less effective against CEW larvae as compared to TBW larvae (Tables 1-4; Figures 2-3). The average CEW $LC_{50}$ values were approximately 20-fold greater than the average TBW $LC_{50}$ values. Although isolated CEW and TBW populations exhibited high levels of survival following exposure to MVP II ®, the average CEW and TBW $LC_{50}$ values for the 2009 season were comparable to the average CEW and TBW $LC_{50}$ values obtained during the mid-1990s. Additionally, TBW $LC_{50}$ values for the field-collected strains have remained comparable to the $LC_{50}$ values obtained for the laboratory-maintained HRV, OPS, OPR and PYR reference strains. The highest CEW $LC_{50}$ values (> 250 ppm) were recorded during the 2004-2005 seasons and were more than 75-fold higher than the $LC_{50}$ values obtained for the most susceptible CEW field-strain.

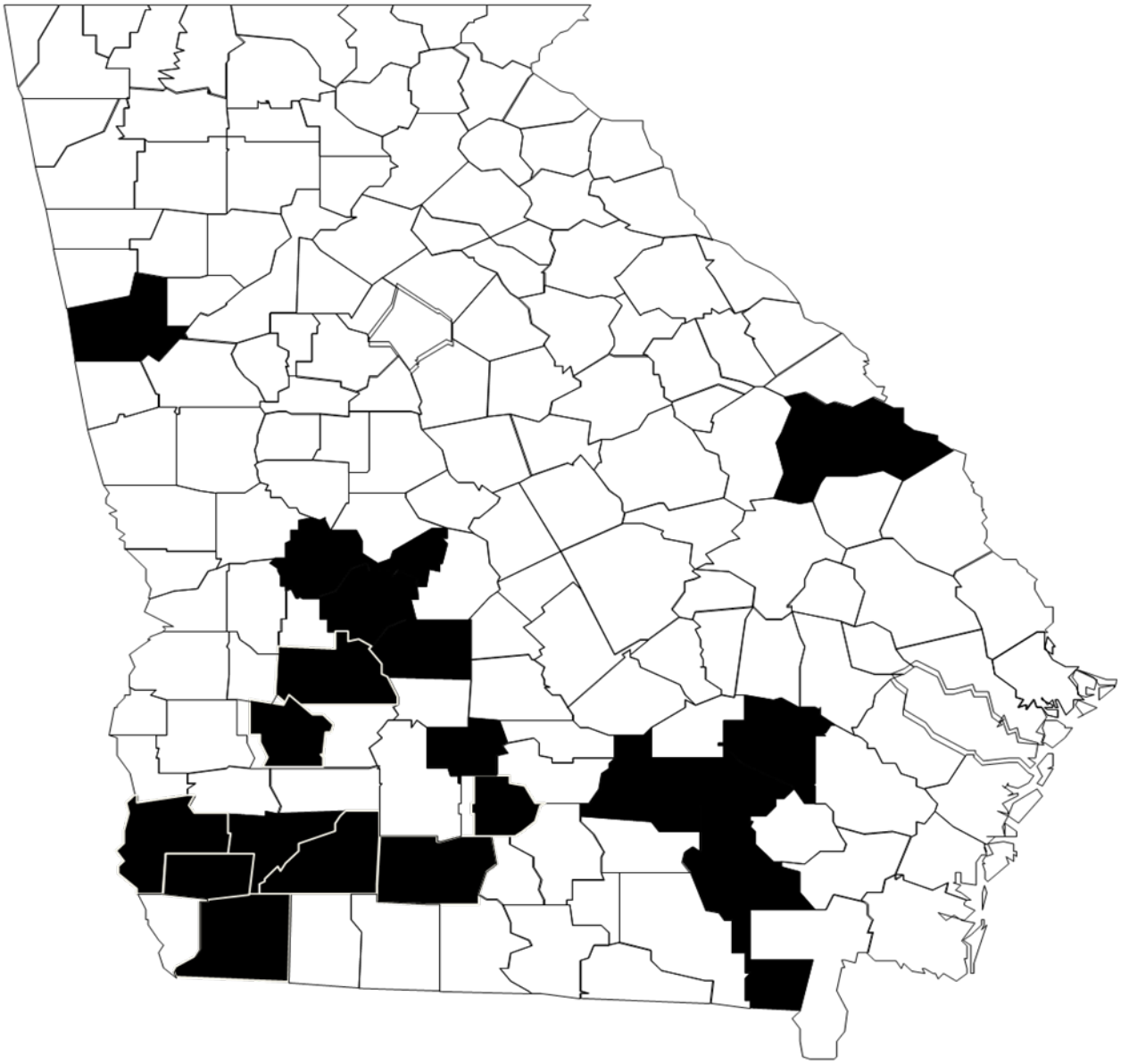

Figure 1. Bollworm and tobacco budworm collection sites.

Although decreases in the susceptibilities of CEW populations to pyrethroid insecticides were noted throughout the study, data indicated that CEW populations in Georgia remained relatively susceptible to cypermethrin. $LC_{50}$ values for field populations collected during the 2003-2005 seasons were only two- to three-fold greater than $LC_{50}$ values obtained for field populations collected during the 1996 and 1997 seasons (Table 3; Figure 2). However, 2009 $LC_{50}$ values (for both CEW and TBW) were the highest $LC_{50}$s recorded to date (Tables 1-4). The average 2009 CEW $LC_{50}$ value was approximately 6-fold higher than the average 1996-1997 CEW $LC_{50}$ value. The data also indicated that pyrethroid resistance remains an issue for the control of TBW

populations in Georgia. The average 2009 TBW $LC_{50}$ value was approximately 13-fold higher than the average 1995-1996 TBW $LC_{50}$ value. Furthermore, it was more than 37-fold higher than the $LC_{50}$ value obtained for the pyrethroid-susceptible HRV laboratory strain and 1.5-fold higher than the $LC_{50}$ value obtained for a laboratory-selected, pyrethroid-resistant strain (PYR) (Table 4).

Topical application (Tables 1 and 2) and AVT (Tables 1 and 2; Figure 4) data also indicate decreases in the susceptibilities of CEW and TBW populations to cypermethrin over time. Compared to a pyrethroid-susceptible laboratory strain, topical $LD_{50}$ values for the 2009 CEW populations were 3- to 12-fold higher. Plus, the percent survival of CEW adults using the AVT has steadily risen since 1998. In field-collected TBW populations, pyrethroid resistance was confirmed by topical application in the Tay2 05 strain ($LD_{50}$ = 49.3 µg/g larva; RR = 31.4; data not shown), the Cam 09 strain ($LD_{50}$ = 93.8 µg/g larva; RR = 59.7) and the Tif C 09 strain ($LD_{50}$ = 80.5 µg/g larva; RR = 51.3) (Tables 2). Furthermore, an evaluation of $LC_{95}$ values for cypermethrin against TBW larvae have indicated an annual and sharp increase since the monitoring project began (Figure 5).

To date, spinosad (Tracer®) has remained effective against all strains tested (Tables 1-4; Figures 2-3). Mean $LC_{50}$ values for CEW larvae (0.49 ± 0.07) and TBW larvae (0.46 ± 0.05 ppm) were comparable and have remained stable throughout the fifteen-year study period.

## Summary

Throughout the fifteen-year study period, bollworm (CEW) and tobacco budworm (TBW) populations in Georgia have remained relatively susceptible to MVP II®. As expected, the data indicate that CEW larvae were more tolerant to the effects of MVP II® than TBW larvae. CEW and TBW populations have become more resistant to cypermethrin. In 2009, CEW populations were 6 times more resistant to cypermethrin than CEW populations sampled during the mid-1990s and 3 times more resistant to cypermethrin than CEW populations sampled during the mid-2000s. On average, TBW populations collected during the 2009 season were 12 times more resistant than TBW populations sampled during the mid-1990s, 5 times more resistant than TBW populations sampled during the late 1990s, and approximately 1.5 times more resistant than TBW populations sampled during the mid-2000s. The data indicate that spinosad (Tracer®) has remained effective in the control of CEW and TBW populations in Georgia. There have been no substantial fluctuations in the activity of spinosad against CEW and TBW larvae throughout the study period. In general, the treated diet-96 h activity spectrums for the insecticides tested were as follows:

For CEW: Spinosad (Tracer®) > Cypermethrin > MVP II®; and for
TBW: Spinosad (Tracer®) > MVP II® > Cypermethrin.

## Acknowledgments

This work has been supported by grants from the Georgia Cotton Commission, Cotton Incorporated, IRAC-US, USDA-ARS SIMRU, Monsanto Corporation, and the University of West Georgia Faculty Research and Undergraduate Research Assistant Programs. Special thanks is extended to the numerous growers and consultants that have allowed me to collect from their fields and to Dr. Phillip Roberts (University of Georgia-Tifton) and Dr. John Ruberson (University of Georgia-Tifton) for their unfailing support and expertise.

Table 1. Susceptibilities of field-collected tobacco budworm populations to MVPII®, spinosad (Tracer®), and cypermethrin using treated diet, topical application, and adult vial test (AVT) bioassays--2009.

| Colony | Treatment | Diet $LC_{50}$ (C.I.; Slope) ppm | Topical* $LC_{50}$ (C.I.; Slope) µg/g | AVT** $LC_{50}$ (C.I.; Slope) µg/vial |
|---|---|---|---|---|
| BUR 09 | MVPII® | 15.4 (10.7-21.8; 0.89) | | |
| COL A 09 | | 87.1 (61.2-127; 1.23) | | |
| COL B 09 | | 19.5 (9.03-41.9; 0.84) | | |
| DEC 09 | | 5.01 (3.18-7.72; 0.72) | | |
| MIL 09 | | 3.33 (1.66-6.30); 1.51 | | |
| SUM 09 | | 161 (75.5-498; 0.63) | | |
| TAY 09 | | 25.0 (14.4-44.5); 0.77 | | |
| TIF 09 | | 4.50(2.35-8.73; 1.03) | | |
| BUR 09 | Spinosad | 0.38 (0.23-0.64; 2.75) | | |
| COL B 09 | | 0.46 (0.34-0.65; 4.54) | | |
| DEC 09 | | 0.55 (0.34-0.89;3.52) | | |
| EAR 09 | | 0.80 (0.47-1.32; 2.75) | | |
| BUR 09 | Cypermethrin | 9.11 (7.91-10.5; 3.61) | | 3.10 (2.29-4.03; 3.46) |
| COL A 09 | | 7.10 (5.74-8.79; 2.13) | 1.25 (0.85-1.75; 4.17) | 2.68 (1.60-3.84; 1.83) |
| COL B 09 | | | | 2.42 (1.70-3.18; 4.40) |
| DEC 09 | | 4.70 (3.27-6.77; 3.08) | | 3.81 (2.73-5.37; 5.03) |
| EAR 09 | | 11.7 (9.04-15.9; 4.43) | | 4.06 (2.39-8.25; 2.55) |
| SUM 09 | | 10.9 (8.65-13.6; 3.27) | | 3.22 (2.09-4.74; 2.84) |
| TIF 09 | | | 4.93 (0.58-24.7; 0.66) | |

* larval weight: ~ 35 mg/larva

** Adult Vial Test(males and females evaluated)

Table 2. Mean susceptibilities of bollworm larvae to MVPII®, spinosad (Tracer®), and cypermethrin following a 96 h exposure period using an insecticide-treated diet bioassay—1996-2009.

| Year | $LC_{50}$, ppm (Slope) | | |
|---|---|---|---|
| | MVPII® | Spinosad | Cypermethrin |
| 1996 | 38.9 (1.7) | 0.30 (1.6) | 1.40 (2.1) |
| 1997 | 68.3 (1.6) | ND[b] | 1.31 (2.2) |
| 2003 | 110 (0.6)[a] | 0.51 (1.5) | 4.49 (1.8) |
| 2004 | 128 (1.1)[a] | 0.30 (2.1) | 2.63 (3.4) |
| 2005 | 122 (0.3)[a] | ND[b] | 1.13 (0.8) |
| 2009 | 40.1 (0.9)[a] | 0.54 (3.4) | 8.72 (3.3) |

[a] data based on tests using neonate larvae
[b] Not Determined

Table 3. Susceptibilities of field-collected tobacco budworm populations to MVPII®, spinosad (Tracer®), and cypermethrin using treated diet, topical application, and adult vial test (AVT) bioassays--2009.

| Strain | Year | $LC_{50}$, ppm (Slope) | | |
|---|---|---|---|---|
| | | MVPII® | Spinosad | Cypermethrin |
| HRV | | ND[b] | 0.38 (1.4) | 1.42 (5.2) |
| OPS | | 0.75 (0.7) | 0.14 (3.3) | 5.01 (3.2) |
| OPR | | ND[b] | 0.37 (2.2) | 5.48 (2.7) |
| PYR | | 1.23 (1.9) | 0.40 (3.4) | 36.5 (2.1) |
| | 1995 | 0.95 (1.0) | 0.84 (1.7) | 0.46 (1.1) |
| | 1996 | 9.63 (1.0) | 0.48 (3.1) | 4.32 (3.0) |
| | 1997 | 8.68 (1.2) | 0.35 (1.8) | 7.55 (2.5) |
| | 1998 | ND[b] | ND[b] | 12.1 (1.7) |
| | 1999 | ND[b] | 0.20 (1.9) | 11.5 (0.9) |
| | 2003 | 1.00 (0.5)[a] | 0.52 (1.1) | 33.1 (1.4) |
| | 2004 | 1.20 (1.6)[a] | 0.40 (1.6) | 33.1 (1.3) |
| | 2005 | 3.33 (0.5)[a] | 0.32 (1.2) | 27.6 (1.2) |
| | 2009 | 2.66 (1.2)[a] | 0.61 (1.8) | 52.7 (2.2) |

[a] data based on tests using neonate larvae
[b] Not Determined

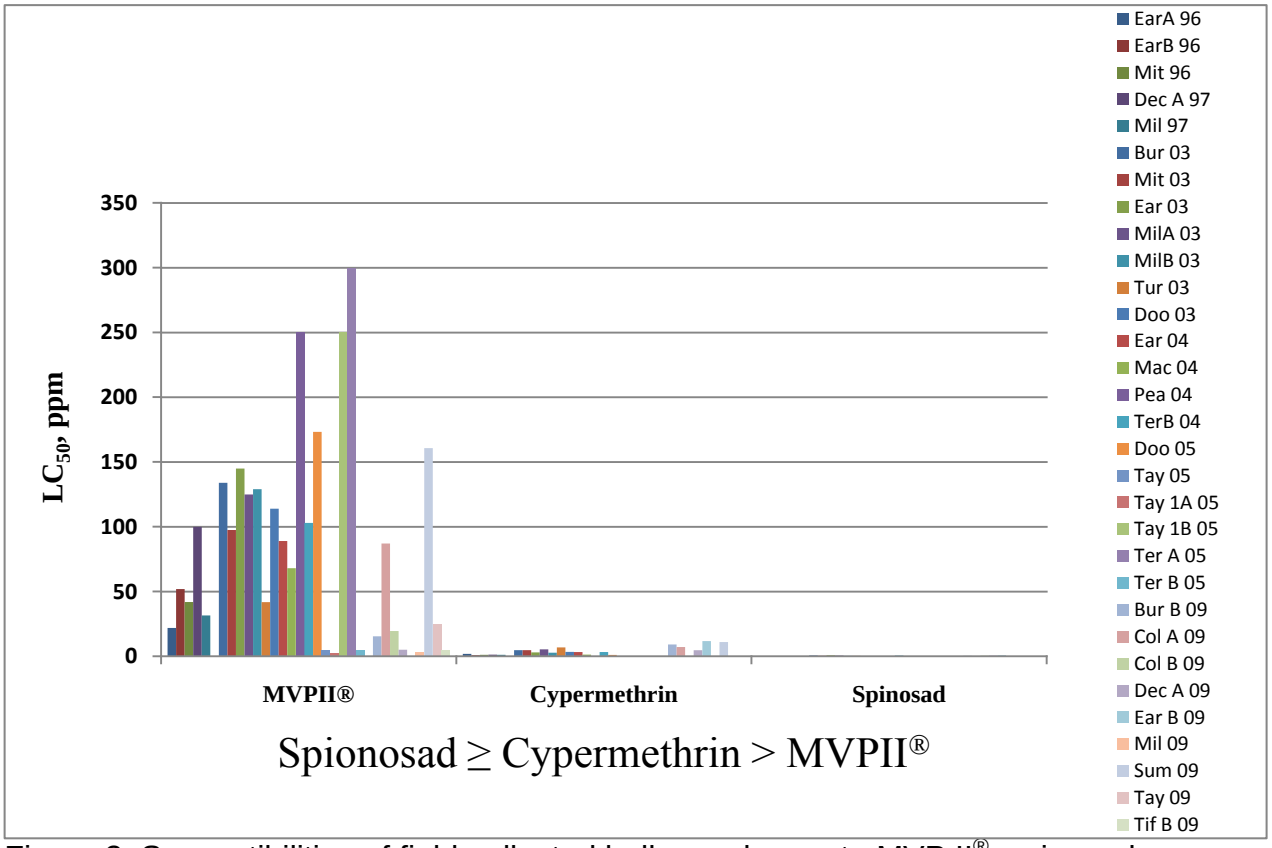


Figure 2. Susceptibilities of field-collected bollworm larvae to MVP II®, spinosad (Tracer®), and cypermethrin using a treated diet bioassay—1996-2009.

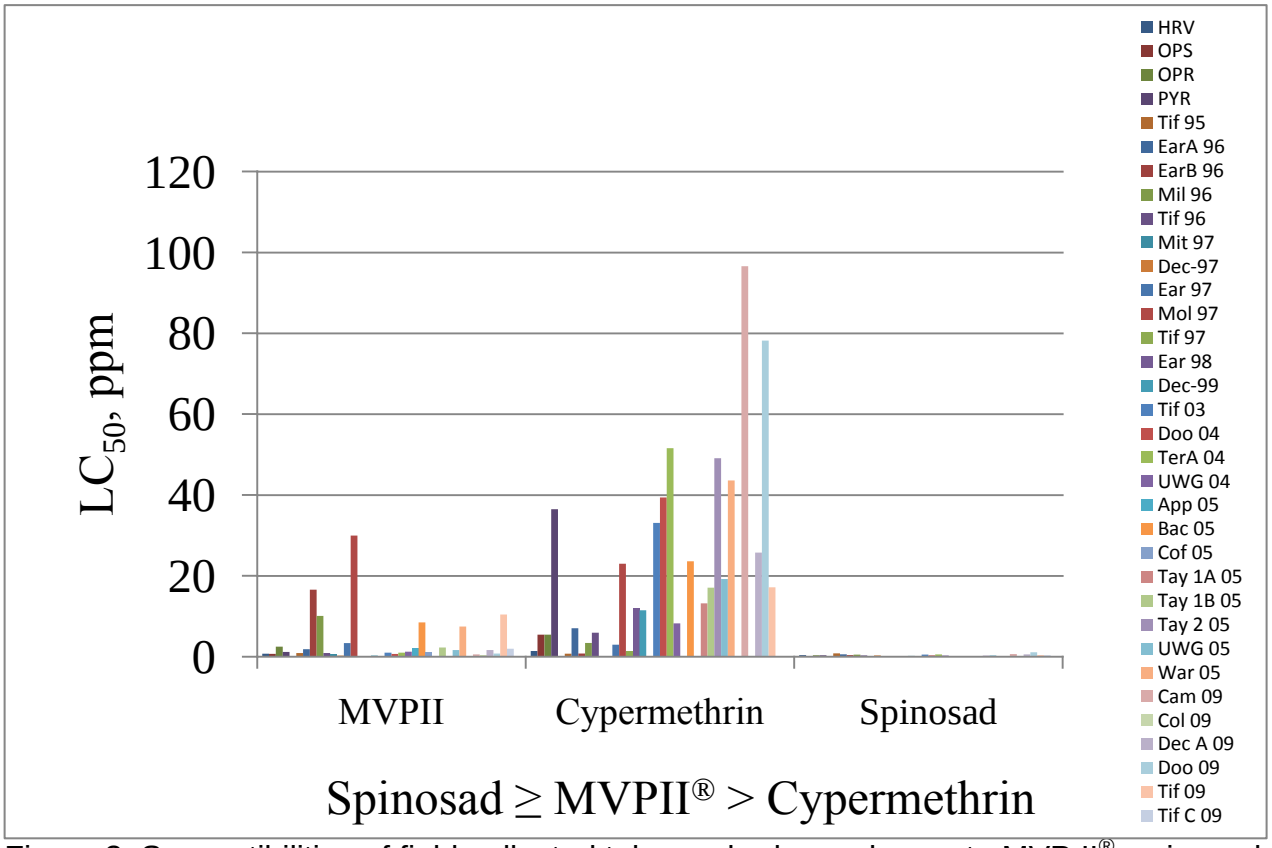


Figure 3. Susceptibilities of field-collected tobacco budworm larvae to MVP II®, spinosad (Tracer®), and cypermethrin using a treated diet bioassay—1996-2009.

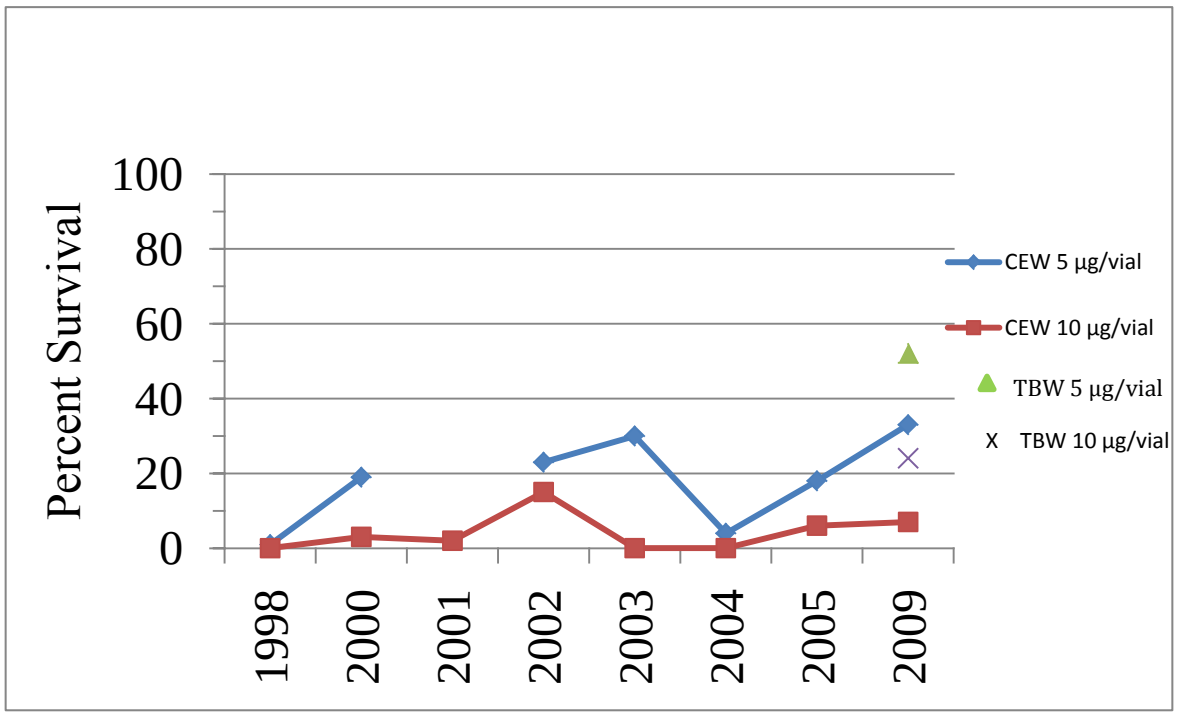


Figure 4. Susceptibilities of bollworm and tobacco budworm adults to cypermethrin using an adult vial test (AVT) bioassay—1998-2009.

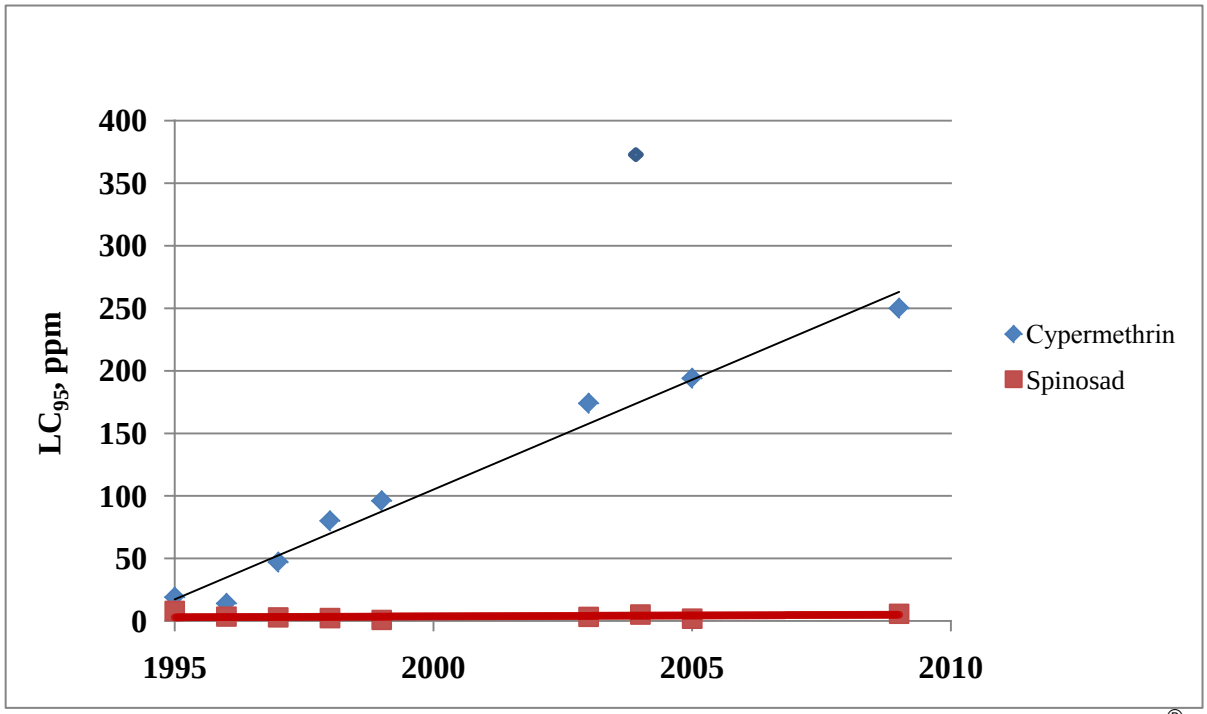


Figure 5. Susceptibilities of bollworm larvae to cypermethrin and spinosad (Tracer®) expressed as the $LC_{95}$ using a treated diet bioassay—1995-2009.

# IMPORTANCE OF NATURAL ENEMIES FOR STINK BUG CONTROL

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## Introduction

A complex of stink bug species has become a very serious problem in Georgia cotton production. The problem is exacerbated by the widespread distribution of stink bugs across the landscape, the numerous host plants available to them for feeding and reproduction, and the difficulties associated with finding them in cotton and characterizing their damage. The dominant stink bug species in Georgia are the southern green stink bug, *Nezara viridula*, the green stink bug, *Acrosternum hilare*, and the brown stink bug, *Euschistus servus*, with the southern green stink bug generally dominating by a significant margin. In addition to these species, several other species have become increasingly abundant including the red banded stink bug, *Piezodorus guildinii*, and *Euschistus quadrator*, both of which seem to be more abundant in the southernmost portions of the state (pers. observ.).

Various natural enemies have been reported attacking stink bugs in various regions of the world (e.g., Yeargan 1979, Jones 1988, Ehler 2002), but the natural enemy complex in the southeastern United States has been poorly defined. This project was initiated in 2007 to characterize the suite of stink bug natural enemies present in Georgia and to determine their efficacy. We found that the parasitoid complex attacking stink bugs was primarily active against adult stink bugs, and had little impact on immatures. However, we obtained a few specimens of an exotic braconid wasp (*Aridelus rufotestaceus*) from nymphs of the southern green stink bug and an adult brown stink bug, *Euschistus servus*, in 2007 and 2008. These studies were continued in 2009 to obtain further information on the role and diversity of stink bug natural enemies.

## Materials and Methods

Parasitoid and Pathogen Survey. Cotton (Bollgard II, DPL924RF), Group 5 soybeans (Asgrow 5905R), and Group 7 (Pioneer 97M50R) soybeans were planted in Sumter County (2 June) and Decatur County (8 June), Georgia. These crops were sampled for stink bug populations, and all stink bugs collected in the samples were returned to the laboratory and held for parasitoid emergence. In addition, bugs were collected in soybean and cotton fields in Mitchell and Coffee Counties (6 fields per county) at approximately weekly intervals from mid-July until 7 October. The fields in these two counties were commercial and managed with insecticides, which limited the numbers of

stink bugs and likely the activity of natural enemies, as well. Collected bugs were held in 50 mL sample cups and provided with pieces of green bean pods and sunflower kernels as food. Bugs were checked daily for survival and parasitoid emergence. Bugs were held in an environmentally controlled rearing room at 25 ± 1°C with a photoperiod of L:D 14:10. Dead bugs were dissected to evaluate the presence of pathogens and parasitoids. Bugs were considered to be parasitized if they met one or more of the following four criteria: (1) parasitoid egg(s) present on the bug cuticle, (2) parasitoid emerged from the bug, (3) parasitoid immatures present in bug at the time of host death, and/or (4) the presence of a tracheal funnel in the stink bug, signifying that a parasitoid fly larva had completed development in the host and departed (bugs can live up to two weeks after a parasitoid has emerged).

## Predation of Stink Bug Egg Masses

Fire ants appear to be one of the more significant predators of stink bug eggs, so we evaluated the impact of fire ant presence on stink bug egg loss. Egg masses of the southern green stink bug, *Nezara viridula*, were placed in a set of eight 0.5-acre experimental cotton plots (DPL935B2/RF; planted 20 May) to evaluate egg predation and parasitism. Four of the plots were treated with Amdro to exclude fire ants. Egg masses were placed on plants in the center of the plot, with 2 m between placement sites, in a 2x3 or 2x4 layout (with 2-3 egg masses placed on each of the two rows, depending on date and egg availability). Plots were separated from one another by open gaps of 3 m of bare soil tilled at regular intervals. The plots were arranged in 4 blocks, each containing one fire ant inclusion plot and one fire ant exclusion plot. Plots were approximately square, and a 10x10m area in the center of each plot was designated for sampling. Fire ant exclusion plots were treated with hydramethylnon ant bait (Amdro®) at a rate of 1.1 kg of formulated bait per ha on 20 July, 7 and 14 August, and 4 September 2009 to eliminate fire ants. To assess the exclusion treatment, ant detection tests were conducted on 12 August and 18 September. This test consisted of placing six 33-ml test tubes containing a small piece (5 gm) of hotdog in each plot. After 1 hour all tubes were recovered and sealed, and transported back to the lab where the tubes were emptied and the number of ants was recorded.

Predation trials were conducted using egg masses of the southern green stink bug, *Nezara viridula*. Eggs of *N. viridula* were obtained from a lab colony maintained on green bean pods and shelled sunflower seeds. Eggs were placed in the field on multiple occasions. Each egg mass was stapled to the lower surface of the uppermost expanded leaf. Three to four egg masses were placed on plants in each of two rows of cotton, which were separated from one another by six rows. All egg masses were collected after 72 hours of exposure to enemies. Egg counts were then made at 2, 6, 12, 18, 24, 48, and 72 hours after all eggs had been deployed by digitally photographing each egg mass, although not all intervals were represented in all evaluation dates due to rain. Photographing minimized disturbance of the egg mass and allowed us to make more accurate counts of egg loss and empty eggs on the computer. The presence of

specific predators at each observation period also was recorded on the digital images of the egg masses. Predators were identified to species in the field or from the images and were recorded either preying upon or simply occupying egg masses.

Host and Temperature Relationships of the Parasitoid *Aridelus rufotestaceus*.

We evaluated the development of the recently discovered parasitoid *Aridelus rufotestaceus* in laboratory trials. For the temperature studies, wasps were exposed to nymphs of the Southern green stink bug of various life stages (Instars 2, 3, 4, and 5). After stinging was visually verified, stung bugs were separated and placed in equivalent numbers into three temperatures: 20, 25, and 30± 1°C with a photoperiod of L:D 14:10. The bugs were fed daily and checked for emergence of parasitoid larvae and formation of cocoons. After cocoon formation, cocoons were held and monitored for wasp emergence.

Data Analyses. Survey results reported here are incomplete because we are still dissecting stink bugs that were sampled. Egg mortality was evaluated by comparing survival (transformed as arcsin$\sqrt{x}$) at sample intervals for the respective sample dates. We used repeated measures one-way analysis of variance (PROC GLM in SAS) to compare the results between the plots with and without ants. Developmental data for *A. rufotestaceus* was evaluated among temperatures using analysis of variance (after conversion of raw data to reciprocals to normalize the distribution), and was modeled using regression. Untransformed data on percent emergence and developmental times are presented for the host range studies with *A. rufotestaceus*.

## Results and Discussion

Parasitoid and Pathogen Survey

We are still processing specimens, but the results thus far are presented in Table 1. The complex was once again dominated by the Southern green stink bug, *Nezara viridula*, with the brown stink bug, *Euschistus servus*, being second most abundant. Parasitism rates also were highest in *N. viridula* (27.2%) and *E. servus* experienced very little parasitism (1.7%), in accordance with our observations from previous years that this species experiences little parasitism. Parasitism of the Green stink bug, *Acrosternum hilare*, was intermediate (13.8%), although this species was considerably less abundant than *E. servus.* The Red-banded stink bug, *Piezodorus guildinii*, experienced no parasitism at all.

Table 1. Numbers of stink bugs collected, and number parasitized (in parentheses), by location. Numbers are pooled across sample dates and host plants (cotton, soybeans, and millet).

| Species | Life stage | Location | | | | Totals |
|---|---|---|---|---|---|---|
| | | Attapulgus | Plains | Coffee Co. | Mitchell Co. | |
| Nezara viridula | 2nd instar | 0 | 0 | 15 (0) | 46 (0) | 61 (0) |
| | 3rd instar | 5 (0) | 2 (0) | 3 (0) | 57 (0) | 67 (0) |
| | 4th instar | 13 (0) | 12 (1) | 4 (0) | 37 (0) | 66 (1) |
| | 5th instar | 61 (1) | 31 (0) | 6 (0) | 79 (0) | 177 (1) |
| | Adult | 242 (24) | 425 (173) | 28 (1) | 62 (8) | 757 (206) |
| Euschistus servus | 2nd instar | 0 | 0 | 4 (0) | 7 (0) | 11 (0) |
| | 3rd instar | 2 (0) | 1 (0) | 3 (0) | 21 (0) | 27 (0) |
| | 4th instar | 1 (1) | 1 (0) | 3 (0) | 24 (0) | 29 (1) |
| | 5th instar | 7 (0) | 19 (1) | 10 (0) | 62 (1) | 98 (2) |
| | Adult | 55 (1) | 53 (3) | 111 (1) | 126 (1) | 345 (6) |
| Acrosternum hilare | 3rd instar | 0 | 0 | 11 (0) | 0 | 11 (0) |
| | 4th instar | 0 | 0 | 2 (0) | | 2 (0) |
| | 5th instar | 1 (0) | 2 (0) | 7 (0) | 4 (0) | 14 (0) |
| | Adult | 45 (6) | 26 (4) | 32 (5) | 6 (0) | 109 (15) |
| Piezodorus guildinii | 5th instar | 0 | 0 | 0 | 1 (0) | 1 (0) |
| | Adult | 6 (0) | 0 | 2 (0) | 27 (0) | 35 (0) |
| | | | | | Totals | 1810 (232) |

Parasitism of stink bug adults and nymphs was heavily dominated by a single species, the tachinid fly *Trichopoda pennipes*, as has been the case in previous years. This fly lays external eggs on the bugs (from 1 to 54 eggs per host in the present survey), from which fly larvae bore into the host to become internal parasites. The probability of successful parasitism increased somewhat with the number of eggs placed on a host, although the majority of bugs had only a single egg placed on them (Fig. 1). Higher numbers of eggs were found on stink bugs in 2009 than was the case in 2007 or 2008, with one bug having 54 eggs on its body. In addition, 66 of the 183 bugs successfully parasitized by flies had no external eggs at all. This high rate of successful parasitism without external eggs (36.1%) is approximately double the rate observed in previous years, and the rate reported in the literature (Harris and Todd 1980). This may reflect higher fly activity against late-instar stink bug nymphs.

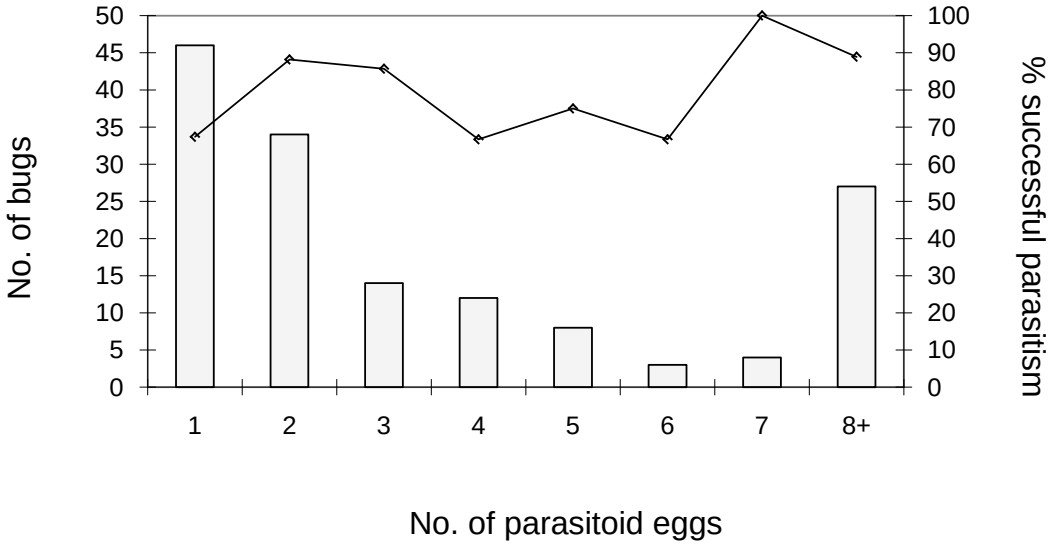


Figure 1. Number of parasitoid eggs oviposited on individual stink bug hosts, and the relationship between number of eggs oviposited and the success of the parasitoid in completing development in the host.

In addition to bugs parasitized by *T. pennipes*, five collected bugs were parasitized by the braconid wasp *Aridelus rufotestaceus*. The wasps were obtained from one stink bug in corn in Mitchell County (*Euschistus servus* 5th instar collected on 30 June), three from soybeans in Attapulgus (*Euschistus* sp. 5th instar collected on 17 September; two from *Nezara viridula* 5th instar, collected on 9 September and 7 October), and one from soybeans in Plains (*Nezara viridula* 4th instar; 29 September). As was previously the case, all of the collected parasitoids were female, and all successfully produced offspring in the lab without mates. The collection from Mitchell County represents the first collection from that county, and also the earliest that the wasps have been collected. We had not found the wasps prior to September in our 2007 and 2008 collections. Thus, we now have recorded the presence of the parasitoid in Decatur, Mitchell, Sumter, and Tift Counties in Georgia, and have reared it from two species in the field (*E. servus* and *N. viridula*) collected from corn, cotton, and soybeans. The parasitoid is obviously established over a fairly large portion of Georgia, and is active across various habitats. The parasitism rate appears to be consistently low, suggesting that there are some limiting factors for the parasitoid's success (see below).

## Predation of Stink Bug Egg Masses

The Amdro treatments were moderately effective in suppressing fire ant populations, but overall ant activity was relatively low and localized compared to prior years. Fire

ants were found in 50 (3.5 ants per tube) and 45.8% (39 ants per tube) of the tubes placed in the ant inclusion plots on 12 August and 18 September, respectively. In contrast, ants were obtained in 50 (3.3 ants per tube) and 8.3% (17.4 ants per tube) of tubes on 12 August and 18 September, respectively, in the ant exclusion plots. These low ant numbers and low activity values were reflected in overall predation of eggs (Table 2), supporting the notion that fire ants are important predators. Predation of stink bug eggs by chewing predators after 72 hours ranged from 1.7 to 23.7% of all eggs in cotton plants with fire ants present (overall mean of 11.8%). In contrast, predation by chewing predators in plots without ants ranged from 0.1 to 14.7% after 72 hours (overall mean of 4.5%). Sucking predators had very little impact on stink bug egg mortality, accounting for less than 1% of all mortality. Ant presence had no apparent effect on sucking predation.

Predation on stink bug eggs by fire ants varied considerably among treatment blocks (Table 2), but was never as high as in previous years. Ehler (2002) observed that although predators readily fed upon nymphs of *Nezara viridula*, they rarely fed upon *N. viridula* eggs. In the current study we observed predation on eggs of *N. viridula* by *S. invicta*, long-horned grasshoppers (Family Tettigoniidae), the big-eyed bug *G. punctipes*, the snowy tree cricket *Oecanthus fultoni*, a nymph of the spined soldier bug *Podisus maculiventris*, as well as some cannibalism by nymphs of brown and Southern green stink bugs. Egg loss was quite variable, but it is obvious that fire ants are the most important predators of stink bug eggs. The growth of conservation tillage in cotton may contribute to increased fire ant populations, and enhanced predation of stink bug eggs in cotton.

Table 2. Loss of Southern green stink bug eggs (%) in relation to presence ("Ants+") or absence of ants ("Ants-"). Note that some sample periods are omitted due to weather conditions. There are 4 replicates per treatment per date (with 6 egg masses per replicate).

| Start date | Treatment | Time of exposure | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 2 hr | 6 hr | 12 hr | 18 hr | 24 hr | 48 hr | 72 hr |
| 31 Jul | Ants+ | --- | --- | --- | 97.2 | 97.0 | 97.0 | 97.0 |
| | Ants- | --- | --- | --- | 100 | 99.8 | 99.8 | 93.1 |
| 7 Aug | Ants+ | --- | 99.3 | --- | 87.0 | 86.7 | 79.3 | 76.6* |
| | Ants- | --- | 100 | --- | 100 | 100 | 99.1 | 97.8* |
| 13 Aug | Ants+ | 100 | 96.1 | --- | 93.9 | --- | --- | 76.3† |
| | Ants- | 100 | 100 | --- | 96.4 | --- | --- | 96.1† |
| 25 Aug | Ants+ | --- | 99.9 | 99.7 | 97.7 | 97.2 | 96.9 | 96.9 |
| | Ants- | --- | 100 | 99.9 | 99.9 | 99.9 | 99.9 | 99.9 |
| 2 Sep | Ants+ | 99.4 | 98.6 | 98.6 | 98.6 | 88.0 | 87.0 | 87.0 |
| | Ants- | 100 | 100 | 97.4 | 97.4 | 97.1 | 97.1 | 97.0 |
| 8 Sep | Ants+ | 100 | 100 | 100 | 99.3 | 99.3 | 99.0 | 98.3 |
| | Ants- | 100 | 100 | 100 | 100 | 100 | 100 | 98.5 |
| 15 Sep | Ants+ | 100 | 99.5 | 99.0 | --- | 92.9 | 90.2 | 85.9 |
| | Ants- | 100 | 100 | 100 | --- | 99.0 | 97.9 | 96.6 |
| 23 Sep | Ants+ | 100 | 100 | --- | 97.8 | --- | 88.9 | 88.7 |
| | Ants- | 96.6 | 95.8 | --- | 94.8 | --- | 86.3 | 85.3 |

*Marginal statistical difference: P=0.0501; df=1.30, F=4.17
†Statistically significant difference: P=0.0462; df=1,30, F=4.33

## Host and temperature relationships of *Aridelus rufotestaceus*.

Developmental rate of the parasitoid was directly related to temperature, as is typical of arthropods (Table 3). There were numerical effects of host instar at time of parasitization on parasitoid development, but only in the 20C treatment, so the instars were pooled for regression analysis. A linear model ($y = 675.86x + 9.08$) fitted the data reasonably well ($df=1,176$; $F=1696.58$; $p<0.0001$; $r^2=0.9060$), but a nonlinear regression model provided the best fit to the developmental data ($df =2, 175$; $F=1735.32$; $p<0.0001$; $r^2=0.9514$), with the equation:

$$y = 30.098 -1423.83x + 49542x^2$$

where y is temperature in ºC, and x is the developmental rate (1/days required to become an adult). The linear model yielded a lower developmental threshold of 9C, but the curvilinear model suggests that the lower developmental threshold is higher than the linear estimate. In any case, the developmental threshold is relatively low compared to other insects in the warm Temperate Zone, suggesting that the parasitoid may be adapted to cool climates.

Parasitoid developmental times were slow by comparison with other parasitoids that often require no more than 10-20 days to complete development. The prolonged development of *A. rufotestaceus* does, however, synchronize the wasp with the developmental pattern of its hosts so that the parasitoid females are emerging about the time that their hosts are in a stage susceptible for parasitism.

Table 3. Developmental times (egg to adult, in days) of *Aridelus rufotestaceus* after oviposition into various host instars, and at three temperatures (photoperiod L:D 14:10). Host species used was the Southern green stink bug, *Nezara viridula*. No significant differences were noted between instars within temperatures.

| Host instar | Temperature (ºC) | | |
|---|---|---|---|
| | 20 | 25 | 30 |
| 2 | 63.6 ± 4.70 | 40.2 ± 1.84 | 36.0 |
| | 15 | 17 | 1 |
| 3 | 59.2 ± 2.37 | 40.7 ± 0.91 | 35.2 ± 1.11 |
| | 18 | 21 | 12 |
| 4 | 63.5 ± 2.25 | 40.0 ± 0.73 | 35.7 ± 1.27 |
| | 24 | 20 | 11 |
| 5 | 65.3 ± 3.20 | 41.1 ± 1.33 | 36.3 ± 0.58 |
| | 16 | 20 | 3 |

Host range testing, revealed that the parasitoid is capable of successfully developing in the Southern green stink bug (*Nezara viridula*), brown stink bugs (*Euschistus servus* and *E. quadrator*), Green stink bug (*Acrosternum hilare*), and red-banded stink bug (*Piezodorus guildinii*), although the rates of successful parasitism were quite variable among species and life stages (Table 4). Developmental times did not differ among host species or instars (Table 3), indicating that suitability among species may be comparable once the parasitoid has successfully colonized the host. The sample sizes, however, are rather limited. Developmental times were several days shorter in *Nezara viridula* than in the other species, suggesting that there may be slight suitability advantages in Southern green stink bugs compared to the other species.

It should be noted that the highly variable success rates of parasitism shown in Table 4 may be partly due to the source of the stink bugs. All of the bugs used in the host range

tests were collected in the field, and some died prematurely in the lab due to parasitism or other factors in the field. Therefore, these results likely underestimate the true suitability of the respective hosts for the parasitoid. The ideal situation would be to use lab-reared bugs for the tests, but rearing of these species is difficult and very time consuming. Therefore, we chose to use field bugs and accept the lack of control over the quality of the tested bugs.

Table 4. Percent successful development and developmental times (in days) of the parasitoid *Aridelus rufotestaceus* in various stink bug species and life stages (temperature 25 ± 1°C, photoperiod L:D 14:10)

| Species | Stage | N | % emergence | Developmental time |
|---|---|---|---|---|
| *Piezodorus guildinii* – | N4 | 2 | 50 | 44 |
| Red-banded stink bug | N5 | 7 | 14.3 | 44 |
| | Adult male | 5 | 0 | --- |
| | Adult female | 10 | 30 | 44.7 ± 0.58 |
| Acrosternum hilare – | N2 | 9 | 11.1 | 45 |
| Green stink bug | N3 | 2 | 0 | --- |
| | N4 | 5 | 40 | 43 |
| | N5 | 24 | 12.5 | 43 |
| | Adult male | 8 | 0 | --- |
| | Adult female | 5 | 0 | --- |
| Euschistus quadrator | 3 | 1 | 100 | 42 |
| | 4 | 3 | 100 | 44.3 ± 1.53 |
| | 5 | 1 | 0 | --- |
| | Adult male | 1 | 0 | --- |
| Euschistus servus | 2 | 1 | 0 | --- |
| | 3 | 8 | 0 | --- |
| | 4 | 6 | 16.7 | 23 to cocoon |
| | 5 | 23 | 4.3 | 43 |
| | Adult male | 8 | 0 | --- |
| | Adult female | 6 | 0 | --- |

## Parasitoid Propagation and Release

*Aridelus rufotestaceus* was propagated in the laboratory to produce wasps to supplement field populations. Due to the challenges associated with producing large numbers of stink bug hosts, limited parasitism success (about 50-60% of stung hosts produce parasitoids. Most of the remainder of the stink bugs die from unsuccessful parasitism), and the long developmental times of the parasitoids, we were only able to

release 280 wasps into stink bug-infested soybeans in Tifton. We released 150 on 22 August and 130 more on 12 September. In addition, 60 wasps were distributed to producers at the Cotton and Peanut Research Field Day (in Tifton) on 9 September.

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# BIOLOGICAL NEMATICIDES FOR COTTON PRODUCTION

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## Introduction

The goal of this project was to conduct an extensive evaluation of a newly-developed bionematicide for control of root-knot nematodes on cotton. Nematodes are the number one cotton disease problem in Georgia. In 2008, according to Georgia Cooperative Extension Service estimates, plant-parasitic nematodes caused cotton losses equal to 10% of the crop, for a total of $50 million in direct economic losses, and incurred 82% ($9.5 million) of the cost of pesticides used for disease control (Langston, D , et. al., 2009). Approximately 69% of the cotton fields in Georgia have root-knot nematodes (Kemerait, R., 2005). Plant-parasitic nematodes typically have a scattered, or patchy, distribution across farms and production areas, so the actual losses experienced by growers vary widely from the overall estimates.

Available control methods for nematodes are limited, and current management practices rely heavily on one or two nematicides that were developed in the 1960's. These older products present serious challenges in terms of cost and issues with human and environmental health concerns. There is a critical need for new nematicides with entirely new chemistries for control of plant-parasitic nematodes. Several new nematode-killing products have been derived in my lab from a group of soil-inhabiting microbes called fungi. This project was designed to demonstrate efficacy of one of the new products on a more extensive basis, using replicated field trials across the major cotton producing areas in Georgia.

## Materials and Methods

As part of our ongoing effort to develop new nematicidal chemistries, fermentation products from selected fungal cultures have been tested for the presence of nematicidal compounds through a series of lab, greenhouse, and field trials. In this process, fungal cultures were isolated from various environments by dilution-plating and use of selective growth media. Using this procedure, thousands of isolates of fungi have been obtained from different fields and environments. The resulting fungi were then evaluated for production of nematicidal compounds. To obtain the products for testing, each fungal isolate was placed in flasks containing nutrient agar and fermented with aeration on platform shakers for 21 days. To test for evidence of nematicidal activity, the liquid cultures were micro-filtered (0.22 µm) and pipetted into sterile microwell plates with freshly-hatched Southern root-knot nematode (*Meloidogyne incognita*) juveniles. The micro-filtering removed all viable stages of the fungus, and left only the products of the fermentation. Sterile water was used as a control treatment. Nematode survival rates

were determined at 2, 4, 24, and 48 hours after suspension, with 6 replications per isolate. During the same time the in-vitro assay was performed, liquid fungal-culture filtrates were also applied to a sterile soil mix in 6" greenhouse pots. Control treatments of sterile water, and a filtrate of the nutrient agar used for fermentation were also applied. Southern root-knot nematode (*M. incognita*) eggs were added to the pots, and cotton cv. DP555 was planted in each pot to serve as a susceptible host. Each treatment was applied to 6 replications. Plants were grown on greenhouse benches for 45 days. Plant roots were then removed from the pots and washed, and the nematode eggs were collected and counted. Total numbers of nematode eggs were compared using ANOVA followed by mean separation (LSD) for each fungal-isolate treatment and the controls. After mass screening of the fungal collection, a few isolates were selected for further evaluation using additional research protocols. The methods used to prepare products for field trials were similar to the methods used for greenhouse screening, but with much larger quantities required. Using these methods, we identified a group of promising fungal products for nematode control.

During the 2009 growing season, an advanced-stage bionematicide (GA534) from our lab was selected for an extensive field evaluation in four different locations across Georgia. Research sites were located at UGA research facilities in Decatur, Tift, Burke, and Oconee counties (Fig.1). These sites were chosen to be broadly representative of soils and production areas for cotton in Georgia. Identical research designs were implemented at all of the sites, with 10 replications per treatment at each of the sites. More than 250 plots were used in the studies. The large extent of the research design required large inputs of the experimental fermentation product. The rates applied to the field plots were upscaled from rates that were shown to be effective in greenhouse pot studies. In excess of 300 gallons of the experimental product were fermented in our limited lab facilities during the first 3 months of 2009 in order to complete the project as planned. At the beginning of the experiment, the research plots were inoculated with root-knot nematodes and planted with cotton DP555 B/RR. The experimental treatments, consisting of the experimental bionematicide (GA534), a media control that was fermented with a fungus that does not produce any nematicidal compounds, and a water control, were applied to 10 replicate plots for each treatment at each site. Root-knot nematodes (juveniles+eggs) were assayed 5 times during the growing season, including a pre-planting assay to determine existing levels of nematode infestation. At each nematode assay date, 10-15 soil cores were removed from the root zones of cotton plants in each plot. Individual soil cores from each plot were mixed before processing. Nematodes were collected from the soil samples by elutriation and centrifugation. Nematodes were then counted under a stereomicroscope. Root fragments from each of the soil samples were caught on a sieve during elutriation. Root-knot nematode eggs were collected from the root fragments using a sodium hypochlorite extraction method. Data were reported as combined juvenile + egg counts. Nematode counts from each assay date were also averaged across dates for a growing season estimate of root-knot nematode population densities in each plot. All of the research plots were managed as appropriate for the growing area and were irrigated as

needed. Cotton was harvested from individual plots at maturity. Total numbers of nematodes at each assay date and cotton yields were compared using ANOVA followed by mean separation (LSD, $p=0.05$) for each treatment and the controls.

## Results and Discussion

There were no significant interactions between experiment location and treatments during the 2009 growing season, so data from all 4 sites were combined for analysis. In combined data, the experimental bionematicide from fungal isolate GA534 significantly ($p<0.05$) decreased the numbers of root-knot nematodes in soil assays over a time period that extended from approximately 40 days after planting (mid to late June) until 100 days after planting (late August to early September) (Table 1). In the first reading, taken 40 days after planting, root-knot numbers were reduced by 55% in the plots treated with GA534, as compared to the water controls. By 60 days after planting, plots treated with GA534 had 40% lower root-knot nematode counts than the controls. At 100 days after planting, the reduction was still significant at 25%. Control of root-knot nematodes is most important during the early phase of cotton growth, and that is when the product was most effective. However, the extended control of root-knot nematodes late into the growing season was a bonus for this experimental product. Long-term reductions in nematode population densities from an at-plant application are historically not typical of nematicides currently on the market. Often, nematode counts drop soon after application of a nematicide then resurge to numbers higher than the untreated controls by the end of the season. At harvest, there were no treatment differences in the nematode population densities. This lack of treatment effects at harvest is often observed after the cotton plants have been defoliated and the nematodes have ceased feeding. The root-knot nematode population densities averaged across all assay dates were significantly reduced by 24% after application of GA534, as compared to water controls. Cotton yields were increased by 8% (approximately 55 lbs lint/acre) in plots treated with the experimental bionematicide GA534. The results of the 2009 growing season were very encouraging for commercial development of GA534 as a new bionematicide for cotton. The product was effective across all four of the research sites in Georgia, which had different soils and weather conditions. The long-term nematode control and increased yields observed in this research after application of a relatively unimproved fungal culture derivative demonstrated a high potential for this product. Increased efficacy can be anticipated when production is further refined in a commercial environment.

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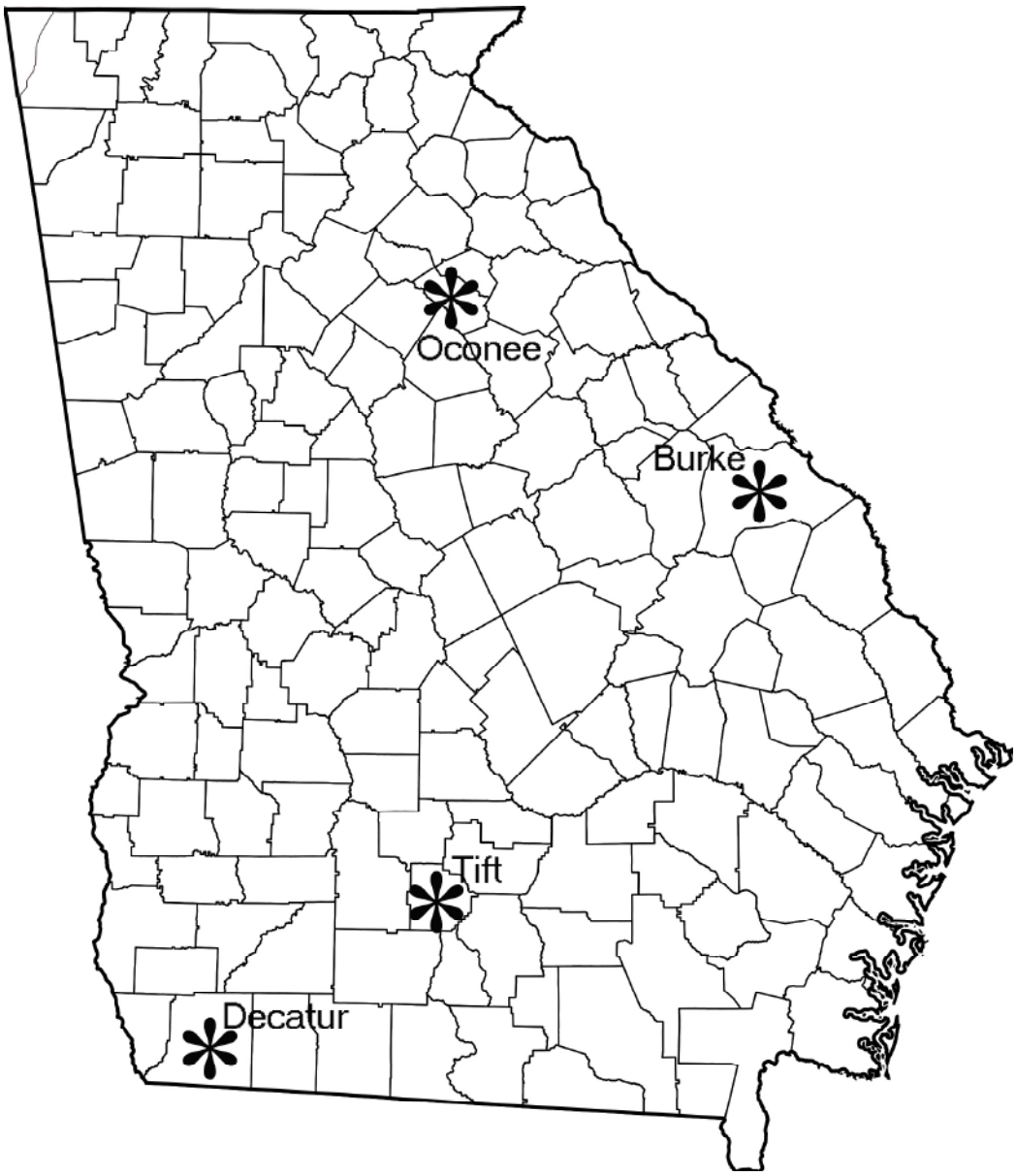


Figure 1. Location of research sites for 2009 evaluation of GA534 bionematicide. Research plots were located at the Attapulgus Research & Education Center in Decatur County, on a research facility operated by the Tifton campus, CAES-UGA, in Tift County, at the Southeast Georgia Research & Education Center in Burke County, and at the CAES Plant Sciences Farm in Oconee County. These sites were chosen to be broadly representative of soils and production areas for cotton in Georgia.

*Table 1*. Evaluation of an experimental bionematicide (GA534) for control of root-knot nematodes (*Meloidogyne incognita*) on Cotton DP 555 B/RR using plots combined across four research sites in Georgia. Research sites were located at UGA research stations in Decatur, Tift, Burke, and Oconee counties.

| | Number of root-knot nematodes (juveniles+eggs)/ 100 $cm^3$ soil Nematode assay date | | | | | |
|---|---|---|---|---|---|---|
| Treatment | 40 DAP** | 60 DAP | 100 DAP | Harvest | 2009 Season average | Cotton yield lbs lint/acre |
| GA534 | 534 b* | 1,110 b | 2,636 b | 827 a | 1,650 b | 732 a |
| Media*** control | 1,106 a | 1,436 ab | 3,878 a | 822 a | 2,277 a | 695 ab |
| Water control | 1,185 a | 1,856 a | 3,530 a | 822 a | 2,162 a | 677 b |

* Means of 40 replicate plots combined for 4 research sites. Rows with different letters are significantly different (P=0.05). Nematode count data were transformed log10(x+1) for analysis.
** Days after planting.
*** Fungal fermentation media control. A fungal isolate that does not produce nematicidal compounds incubated in the same fermentation media as GA534.

## Literature Cited

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# ASSESSMENT OF FOLIAR APPLICATIONS OF PYRACLOSTROBIN, AZOXYSTROBIN, AND THIOPHANATE METHYL FOR IMPROVED YIELD IN COTTON

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## Abstract

Two field studies were conducted in 2009 to assess the impact of foliar-applied fungicides on cotton. A study conducted at the Attapulgus Research and Education Center included 10 DP B2RF varieties that received 0, 6.14 or 12.28 fl oz/A of pyraclostrobin (Headline) four weeks after first-bloom. A second study was conducted at the RDC Pivot on the Coastal Plain Experiment Station. The variety PHY 375 WRF was treated at two weeks and/or four weeks after first bloom with pyraclostrobin (Headline, 6.0 fl oz/A), azoxystrobin (Quadris 2.08SC, 6 .0 fl oz/A) or thiophanate methyl (Topsin M, 16 fl oz/A) at both timings. Diseases observed in Attapulgus included Stemphylium leaf spot and Corynespora leaf spot. Diseases at the RDC Pivot in Tifton were primarily Cercospora leaf spot and Stemphylium leaf spot. Disease pressure was considered low-to-moderate at each location. Treatment with fungicides did not improve yields or reduce defoliation or disease severity when compared against the untreated control in Attapulgus or in Tifton.

## Introduction

Cotton that is grown in Georgia can be affected by a number of fungal pathogens that cause spotting and damage to the foliage. Some of the more common diseases include Ascochyta “wet weather blight” caused by *Ascochyta gossypii*, Stemphylium leaf spot caused by *Stemphylium solani*, areolate or “false” mildew caused by *Ramularia gossyppii*, Cercospora leaf spot caused by *Cercospora gossypina*, and Alternaria leaf spot caused by *Alternaria macrospora* and *A. alternata*. Typically these diseases are incidental in nature and causes little yield loss. In extreme cases, for example during periods of excessive rainfall (Ascochyta blight and areolate mildew) and when cotton plants are deficient in a nutrient such as potassium (Stemphlium and Cercospora leaf spot diseases), severe premature defoliation can occur that can adversely affect yields. In fact, a deficiency of potassium, either due to insufficient levels in the soil or insufficient uptake into the plant during periods of drought, has been one of the most common causes of losses to foliar diseases of cotton in Georgia in recent years.

Beginning in about 2003, Extension agents and consultants working in southwestern Georgia began to report a foliar disease of cotton that seemed to cause damage not only to the leaves, but to the bolls, the bracts, and even the blooms. Despite repeated suggestions that the disease was likely Stemphylium leaf spot or Cercospora leaf spot, the agents and consultants were adamant that the observed symptoms were not obviously related to a nutrient deficiency. In 2009, severe mid-season defoliation was observed in a number of different cotton fields across the Coastal Plain. For example, in a field in Decatur County, cotton plants with 21 nodes and approximately 5 weeks away from planned defoliation were completely from nodes 11 and below. In this situation, and in many others across the state, a new disease of cotton was observed for Georgia. This disease, Corynespora leaf spot, appears to be caused by the fungal pathogen *Corynespora cassiicola* and was first reported in Florida in the early 1960's. The disease is also reported to cause boll rots and other damage to cotton in Southwest Asia. Corynespora leaf spot appears unrelated to nutrient deficiencies and more related to the abundant rainfall in 2009.

The objectives of the following studies were to determine if the application of fungicides to cotton plants would a) reduce the severity of foliar diseases and b) affect yield.

## Materials and Methods

A field trial was established in at the Attapulgus Research and Education Center in early May of 2009. The plots were maintained according to recommendations from the University of Georgia Cooperative Extension. The experimental design was a factorial randomized complete block design where main effects included variety and fungicide application. Varieties of cotton included DP 09R549 B2RF, DP 09R999 B2RF, DP 09R550 B2RF, DP 09R605 B2RF, DP 09R621 B2RF, DP 0912 B2RF, DP 0920 B2RF, DP 0924 B2RF, DP 0935 B2RF, and DP 0949 B2RF. Fungicide treatments included 0 fl oz/A, 6.14 fl oz/A and 12.28 fl oz/A of Headline (pyraclostrobin) applied 4 weeks after first bloom. Plots were 2 rows wide (36 in. centers) by 25 ft long. Each treatment combination (variety by fungicide rate) was replicated 4 times. Fungicides were applied in 15 gal/A on 1 Jul. On 18 Aug and 8 Sep, 10 leaves were randomly sampled from each plot and the severity of foliar damage (% leaf area) was calculated using the ASSESS program from the American Phytopathological Society. Percent defoliation was estimated on 1 Oct and plots were harvested on 21 Oct.

A second field trial was established at the RDC Pivot on the Coastal Plain Experiment Station on 28 April 2009. Plots were planted to PHY 375 WRF and maintained season-long according to recommendations from the University of Georgia Cooperative Extension. The experimental design was a randomized complete block with four replications. Treatments included Headline (pyraclostrobin) or Quadris 2.08SC (azoxystrobin) applied at 6.0 fl oz/A 2 weeks after 1$^{st}$ bloom, at 4 weeks after 1$^{st}$ bloom, or at 2 weeks and 4 weeks after first bloom. Treatments also included Topsin M

(thiophanate methyl) applied at 16 fl oz/A applied at both 2 and 4 weeks after 1st bloom and an untreated control. Fungicides were applied on 14 and 31 Jul using a Lee Spider Sprayer and a spray volume of 15 gal/A. Leaf samples were collected and assessed for disease severity as described above on 17 Aug and 14 Sep. Plots were harvested on 1 Oct.

All data were analyzed using analysis of variance and a P=0.05 LSD value.

## Results

The severity of disease affecting the cotton at the Attapulgus Research and Education Center could be described as “low-to-moderate” and was primarily attributed to Stemphylium leaf spot and some Corynespora leaf spot. There were no statistical differences in % defoliation or disease severity (% leaf area affected) on 18 Aug or on 8 Sep across all possible combinations of varieties and fungicide treatments. While there were statistical differences between yields in this trial, again these differences were not consistently tied to a variety or to a fungicide treatment (Data not shown.)

A single variety, DP 09R99 B2RF, demonstrated a numeric, yet statistically insignificant, trend for improved disease control and increased yield where fungicides were applied. For this variety, disease severity and defoliation were lower where fungicides were used and yields were greater. This trend was not observed elsewhere in the study. (Data not shown.)

In Table 1, data is pooled across varieties and fungicide regimes. In this field trial, use of fungicides did not affect defoliation, disease severity or yield. Choice of variety did statistically affect % defoliation late in the season and yield; however choice of variety did not affect the severity of damage to the sampled leaves.

Table 1. Results from Attapulgus across varieties and fungicide treatments.

| Rating Date | Oct/01/09 | Oct/21/09 | Aug/18/09 | Sep/08/09 |
|---|---|---|---|---|
| Rating Data Type | Defoliation | YIELD | % Severity | % Severity |
| Rating Unit | % | LB/A | 0-100 | 0-100 |
| Cultivar | | | | |
| 1 DP 09R549 B2RF | 42.1 | 3344.4 | 13.81 | 45.19 |
| 2 DP 09R999 B2RF | 47.1 | 3429.1 | 17.16 | 46.55 |
| 3 DP 09R550 B2RF | 45.4 | 3271.8 | 16.70 | 45.69 |
| 4 DP 09R605 B2RF | 44.6 | 3690.5 | 13.41 | 46.27 |
| 5 DP 09R621 B2RF | 45.8 | 3528.4 | 19.27 | 45.98 |
| 6 DP 0912 B2RF | 51.7 | 3291.2 | 18.36 | 46.37 |
| 7 DP 0920 B2RF | 66.3 | 2901.6 | 14.41 | 44.58 |
| 8 DP 0924 B2RF | 57.1 | 3429.1 | 17.50 | 44.98 |
| 9 DP 0935 B2RF | 60.4 | 2993.5 | 15.21 | 45.90 |
| 10 DP 0949 B2RF | 45.8 | 2855.6 | 17.51 | 45.63 |
| LSD (P=0.05) | 12.7 | 353.9 | 8.6 | 3.5 |
| Fungicide | | | | |
| 1 Untreated Check | 48.3a | 3313.5a | 18.63a | 45.92a |
| 2 Headline 6.14 fl oz | 53.0a | 3219.1a | 16.83a | 46.01a |
| 3 Headline 12.28 fl oz | 50.6a | 3288.1a | 13.54a | 45.21a |

Disease severity was described as low in the trial conducted at the RDC Pivot in Tifton and the limited disease was associated with Stemphylium and Cercospora leaf spots. Neither choice of fungicide nor application regime significantly affected severity of damage to the sampled leaves or yield in this trial (Figure 2).

Table 2. Results from field trial at RDC Pivot, Tifton.

| Rating Date | Oct/01/09 | Aug/17/09 | Aug/28/09 | Sep/14/09 |
|---|---|---|---|---|
| Rating Data Type | YIELD | % Severity | % Severity | % Severity |
| Rating Unit | LB/A | 0-100 | 0-100 | 0-100 |
| 1 Headline, A | 2282.35 a | 3.12 a | 8.85 a | 39.52 a |
| 2 Headline, B | 2347.40 a | 3.66 a | 4.98 a | 45.66 a |
| 3 Headline, AB | 2534.95 a | 2.07 a | 6.27 a | 45.51 a |
| 4 Quadris, A | 2645.35 a | 1.96 a | 4.93 a | 44.66 a |
| 5 Quadris, AB | 2149.25 a | 2.62 a | 6.96 a | 44.94 a |
| 6 Topsin M, A | 2545.55 a | 2.35 a | 4.83 a | 45.51 a |
| 7 Untreated Check | 2560.65 a | 2.03 a | 7.98 a | 42.68 a |
| LSD (P=0.05) | 471.33 | 1.600 | 7.357 | 5.003 |

## Discussion

The use of fungicides in the two field trials included in this study did not affect yield or disease severity. Yield and % defoliation were different among varieties in Trial 1, regardless of fungicide treatment. This observation may be the result that all of the varieties were assessed for defoliation and harvested at the same time without regard to the genetics and optimal management of each particular variety.

Though fungicides did not affect defoliation, disease severity, or yield, it cannot be concluded from this research that fungicides will not be important tools in the future to improve yield and quality. The use of fungicides may prove beneficial to cotton growers if it can be determined which diseases can be effectively controlled with them and the optimal timing for application of fungicides.

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## AUTHORS