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# YIELD AND FIBER QUALITY OF TRANSGENIC VS. CONVENTIONAL COTTON VARIETIES IN THE ARKANSAS COTTON VARIETY TESTS, 1995-2004

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## Abstract

Cotton varieties grown in Arkansas have changed from essentially all conventional in 1995 to essentially all transgenic in 2004. A similar, but slower, trend has occurred among entries in the 1995 through 2004 Arkansas Cotton Variety Tests. The objective of this study was to compare the performance of transgenic entries to conventional entries in the Arkansas Cotton Variety Tests over this 10-year period. Products (i.e. transgenic and conventional variety types) rather than the effects of specific transgenes were compared. Means for lint yield, lint fraction, plant height, open boll percentage, seed index, lint index, seed per acre, and fiber properties of transgenic and conventional entries in these tests were compared within and across years. Weighed means (based on number of transgenic entries per year) were used for across year comparisons. Over the 10 years, transgenic entries have yielded slightly more than conventional entries. Performance of most transgenic variety types has progressively improved relative to conventional entries. RR entries have provided the least favorable yields. However, the relative yields of BR entries suggest that a yield drag is not associated with the RR transgene. Evaluation of yield components suggest that yield stability of transgenic entries may be slightly lower than yield stability of conventional entries. Transgenic entries tended to have higher micronaire and lower fiber strength in most years, which suggests that fiber quality improvement has not been a priority in transgenic variety development. Since there is much variation among transgenic entries, performance of individual transgenic varieties rather than transgenic variety types must be considered.

## Introduction

Cotton acreage in Arkansas has dramatically shifted from nearly all conventional varieties in 1995 to nearly all transgenic varieties in 2004 (Bourland and Brown, 2005). During this 10-year period, the adaptation and fiber quality of the new transgenic varieties have often been questioned. Although their recurrent parents (accepted commercial varieties) had been evaluated extensively, many of the early transgenic varieties had minimum field evaluation prior to their release. Transgenic variety releases were often based on extensive testing of the recurrent parent, gene equivalency testing of the transgenic variety, and direct comparison of the transgenic variety and recurrent parent in relatively few environments.

May et al. (2004) noted the challenges and problems associated with establishing unbiased tests of transgenic and conventional cotton varieties. Perhaps the best method to compare transgenic and conventional varieties is an isoline study, in which the transgenic variety is compared to its recurrent parent. In such a study, the transgenic variety must be assumed to be isogenic to the recurrent parent, i.e. the transgenic variety and recurrent parent are genetically equal except for the addition of the transgene. Usually, the assumption is violated because of the relative few backcrosses used to form a transgenic variety. Also, selection is sometimes used in the backcross generations to ameliorate deficiencies found in the recurrent parent. True isoline tests seldom occur with the development of new transgenic varieties. Even with proper isoline testing of a new transgene, one cannot assume that the transgene functions the same in different genetic backgrounds.

A second way to compare transgenic and conventional varieties is by using large system-level testing as done by Bryant et al. (2004). Systems tests provide a true measure of the value of the transgenic variety in a system, which takes advantage of the benefits of the transgene. By their nature, systems tests require large plot size, relatively few entries and a high degree of individual plot management.

A third way to compare transgenic and conventional varieties is to simply evaluate their relative performance in traditional variety tests, as done by Bourland et al. (1997). Such tests may be biased because they typically do not include balanced numbers of transgenic and conventional varieties and genetic backgrounds of the varieties may differ greatly. However, this method does provide a simple comparison between transgenic and conventional products which are available to producers.

The objective of this study was to compare lint yield, yield components and fiber properties of conventional and transgenic varieties by evaluating their relative performance in the 1996 through 2004 Arkansas Cotton Variety Tests.

## Materials and Methods

From 1995 through 2004, Arkansas Cotton Variety Tests were conducted at six (seven in 2003) locations in the Delta region of Arkansas spanning ca. 200 miles north to south and different soil types. Each year, two non-irrigated tests were included and the rest were irrigated. Production management decisions of the tests were made by resident staff or a cooperating producer.

Data were extracted from reports for the 1995 through 2003 tests which were published in Arkansas Agricultural Experiment Station Research Series 444, 454, 465, 473, 481, 491, 501, 513, and Special Report 185. Data for the 2004 tests are posted at www.ArkansasVarietyTesting.org. The tests in each of these years included both transgenic and conventional varieties (Table 1). The percentage of transgenic entries in the tests ranged from 0% in 1995 to 92% in 2004, with an average of 39% each year (44% after 1995). Transgenic types in the tests included BXN (Buctril® tolerant), Bt, RR (Round-up Ready®), BR (stacked Bt and RR) and LL (Liberty Link®). Starting in 1999, the Arkansas Cotton Variety Test has been split into two tests each year, a main test (includes entries tested the prior year) and a 1st year test (includes entries not previously tested). Only entries in the main tests in 1999 through 2004 were considered in this study.

**Table 1**. Number of conventional and transgenic entries in the Arkansas Cotton Variety Tests, 1995-2004.

| Year | Conv. | Trans. | %Trans. | BXN | Bt | RR | BR | LL |
|---|---|---|---|---|---|---|---|---|
| 1995 | 40 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1996 | 24 | 6 | 20 | 1 | 4 | 1 | 0 | 0 |
| 1997 | 29 | 18 | 38 | 2 | 8 | 5 | 3 | 0 |
| 1998 | 38 | 20 | 34 | 1 | 9 | 7 | 3 | 0 |
| 1999 | 20 | 12 | 38 | 1 | 5 | 3 | 3 | 0 |
| 2000 | 15.5 | 15 | 49 | 1 | 3 | 4 | 7 | 0 |
| 2001 | 15.5 | 16 | 51 | 1 | 3.5 | 6 | 5.5 | 0 |
| 2002 | 23 | 15 | 38 | 1,Bt | 3 | 4 | 7 | 0 |
| 2003 | 14 | 19 | 58 | 1,Bt | 1 | 7 | 10 | 0 |
| 2004 | 2 | 23 | 92 | 0 | 0 | 9 | 12 | 2 |
| Sum | 221 | 143 | - | 9 | 35.5 | 46 | 50.5 | 2 |

Parameters in this study included lint yield, plant height, open bolls percentage, number of seed per acre, lint fraction, seed index, lint index, micronaire, fiber length, uniformity index, strength, and elongation. Data for each test site included four replications for the first four parameters and two replications for the last eight parameters. Data were not available for height in 1996-1997, open bolls percentage in 2000-2003, and seed index, lint index and number of seed per acre in 1996-1998. Within each year, means (over all locations) for each transgenic variety type were compared to means for conventional varieties. Means of transgenic vs. conventional variety differences over years were weighted by the number of transgenic varieties in each test.

## Results and Discussion

The percentage of transgenic entries in the Arkansas Cotton Variety Test has consistently been lower than the percentage of Arkansas cotton acreage planted to transgenic varieties (Table 1, Bourland and Brown, 2005). This lower percentage is due to the testing of older conventional varieties as their market shared declined and the testing new conventional breeding lines for their potential prior to insertion of transgenes. The proportion of entries by transgenic variety types (BXN, Bt, RR, BR, and LL) has generally followed the proportion of these transgenic variety types planted in Arkansas (Bourland and Brown, 2005)

Compared to conventional varieties, transgenic varieties had slightly (+3.2%) higher lint yield over all years (Table 2). In four of the first six years, conventional entries yielded more than transgenic entries. However, lint yields of

transgenic entries relative to conventional entries have steadily increased over the past three years. The advantage in 2004 might be skewed in favor of transgenic entries because the test only had two conventional entries (Table 1). This trend suggests that transgenic varieties have not imposed a drag on lint yield in these tests, and that relative yields of transgenic entries are improving.

Among the transgenic variety types, LL and BXN transgenes appear to have the most positive effect on yield (Table 2). With only one year of testing, this conclusion may be premature for LL entries. BXN entries consistently provided improved yields over conventional entries. This conclusion likely applies specifically to one variety, 'ST BXN47' (the primary BXN variety tested), rather than to the effect of BXN in other backgrounds.

**Table 2.** Lint yield of transgenic entries compared to conventional entries in the Arkansas Cotton Variety Tests, 1996-2004.

| Year | Conv. yield | All trans. | BXN | Bt | RR | BR | LL |
|---|---|---|---|---|---|---|---|
| 1996 | 1042 | +39 | +74 | +26 | +100 | . | . |
| 1997 | 1134 | -5 | +62 | +3 | -45 | -4 | . |
| 1998 | 969 | +22 | +56 | +25 | -5 | +64 | . |
| 1999 | 1006 | -34 | +27 | -55 | -27 | -24 | . |
| 2000 | 953 | -26 | -3 | +39 | -58 | -40 | . |
| 2001 | 1019 | -33 | +37 | -33 | -99 | +14 | . |
| 2002 | 1031 | +13 | +71 | +10 | -41 | +36 | . |
| 2003 | 869 | +39 | +144 | +50 | -6 | +58 | . |
| 2004 | 1241 | +69 | . | . | +46 | +83 | +82 |
| Wt. mean | 1015 | +33 | +59 | +4 | -18 | +34 | +82 |

Over all years, Bt and BR entries had higher lint yields than conventional entries (Table 2). In these tests, any entry possessing the Bt gene (either alone or stacked with RR) has the advantage of Bt toxin control of sub-threshold injury associated with certain insect pests. All tests were scouted for insect pests and treated as if they were all non-Bt lines. The advantage of BR entries relative to conventional entries has steadily increased over the past four years.

RR (alone, not including BR) is the only technology that has yielded less than conventional entries (Table 2). The first RR entries (in 1996) yielded very well compared to conventional, but most of these were removed from the market due to their susceptibility to bronze wilt. Since 1996, RR entries have consistently yielded less than conventional entries until this trend was reversed in 2004. Additional testing of new RR entries is needed to determine if this reversal reflects actual improvement in RR entries.

Over all years, transgenic entries were similar to (less than 2% difference) conventional entries for lint fraction, plant height, open bolls percentage, and seed index (Table 3). BXN and LL entries tended to deviate from conventional entries than the other transgenic types. As indicated above, the deviations associated with BXN and LL may be due with limited number of these entries tested.

**Table 3.** Average influence of transgenic entries of selected parameters relative to conventional entries in the Arkansas Cotton Variety Test.

| Parameter | Years | Conv. mean | All trans. | BXN | Bt | RR | BR | LL |
|---|---|---|---|---|---|---|---|---|
| Lint fraction, % | 1996-2004 | 38.9 | +0.1 | +1.7 | -0.3 | -0.2 | 0.0 | +0.5 |
| Height, cm | 1998-2004 | 109 | -2 | +3.2 | -0.7 | 0.0 | +2.5 | -2.5 |
| Open bolls, % | 1996-98,04 | 58.0 | +0.5 | +1.3 | +0.3 | -0.2 | +0.1 | +3.5 |
| Seed index, g | 1999-2004 | 10.2 | 0.0 | -0.2 | -0.1 | -0.2 | 0.0 | +0.4 |
| Lint index, g | 1999-2004 | 6.5 | +0.2 | +0.2 | -0.2 | -0.3 | 0.0 | +0.4 |
| No. seed/acre, mil. | 1999-2004 | 6.886 | +0.185 | +0.115 | +0.165 | +0.125 | +0.225 | +0.128 |

Transgenic entries had 2.3% higher lint index and 2.7% more seed per acre than conventional entries (Table 3). Lewis et al. (2000) indicated that cotton yield may be defined as weight of lint per seed (i.e. lint index / 100) times the number of seed per area. Since synthesis of fiber requires less energy than synthesis of seed, they suggested that yield stability might be improved by developing varieties having higher lint per seed relative to number of seed per area. Lint index and seed per acre values relative to conventional entries suggest that lint yields of Bt, RR and BR

entries may be less stable than yields of conventional entries. Obviously, considerable variation for yield component parameters among entries within each of these transgenic types likely exists.

Except of elongation, average fiber properties of the transgenic entries were within 2% of fiber properties of conventional entries (Table 4). The weighed mean of elongation for transgenic entries was 4.5% higher than the weighed mean for conventional entries. However, this value was skewed because elongation values for all entries in the 1996 through 1999 tests averaged 8.4% compared to 7.2% for all entries in the 2000 through 2004 tests. Since the 1995 through 1999 tests were composed of a disproportional number of conventional entries, the weighed mean of elongation for all conventional entries was skewed toward a low value. Thus, the difference between elongation of conventional and transgenic entries was exaggerated.

**Table 4.** Fiber properties of transgenic entries compared to conventional entries in the Arkansas Cotton Variety Tests, 1996-2004.

| Parameter | Conv. mean | All trans. | BXN | Bt | RR | BR | LL |
|---|---|---|---|---|---|---|---|
| Micronaire | 4.76 | -0.04 | +0.08 | 0.00 | +0.10 | +0.05 | -0.15 |
| Length, in. | 1.14 | -0.01 | -0.02 | -0.01 | -0.03 | -0.03 | -0.02 |
| Unif. index, % | 84.0 | +0.1 | -0.3 | -0.2 | -0.2 | -0.5 | -0.2 |
| Strength, g/tex | 29.9 | -0.4 | -1.6 | -0.8 | -0.9 | -1.1 | +3.9 |
| Elongation, % | 7.6 | +0.3 | -0.1 | +0.2 | +0.2 | -0.1 | -0.5 |

Among the transgenic variety types, the LL entries had the best combination of fiber quality with lower micronaire and high strength. Although tested only one year, the fiber quality of the LL entries reflects the quality of their FiberMax recurrent parents.

Over the past 10 years, transgenic entries have tended to have higher micronaire and lower strength than conventional varieties in the Arkansas Cotton Variety Tests (Table 4). This trend for micronaire appeared to be reversed in 2001 through 2003, but was present again in 2004 (Table 5). Other than in 1996, strength of transgenic entries was less than strength of the conventional entries in all years. These data suggest that improvement of fiber quality has not been a major goal in the development of transgenic varieties.

**Table 5.** Comparisons of fiber micronaire and strength of conventional and transgenic entries over years in the Arkansas Cotton Variety Tests.

| Year | Micronaire, Conv. entries | Micronaire, Trans. - Conv. | Strength, Conv. entries | Strength, Trans. - Conv. |
|---|---|---|---|---|
| 1996 | 4.80 | +0.11 | 29.6 | +0.3 |
| 1997 | 4.74 | +0.16 | 28.9 | -0.2 |
| 1998 | 4.85 | +0.12 | 28.2 | -0.6 |
| 1999 | 5.34 | +0.05 | 30.6 | -1.4 |
| 2000 | 4.57 | +0.25 | 29.2 | -1.7 |
| 2001 | 4.52 | -0.04 | 30.4 | -1.5 |
| 2002 | 4.48 | -0.13 | 31.8 | -1.1 |
| 2003 | 4.61 | -0.08 | 32.7 | -1.2 |
| 2004 | 4.40 | +0.04 | 31.7 | -0.5 |

## Conclusions

Over the past 10 years, conventional cotton acreage in Arkansas has reclined from greater than 99% to less than 1%. The proportion of transgenic to conventional entries in the Arkansas Cotton Variety Tests has also shifted, but at a slower rate than planted acreage. The slower rate is due to continued testing of conventional breeding lines to determine if they are suitable of transgenic trait introgression.

Over all years, variation between transgenic and conventional entries were relatively small for lint yield, height, lint fraction, open boll percentage, seed index, yield components and fiber properties. Since 2002, lint yield of transgenic entries have consistent been higher than conventional entries. This increase appears to be primarily

associated with increased number of seed per area rather than increase weight of fiber per seed. Improvement of fiber quality in transgenic entries relative to conventional entries has not been observed.

Among the transgenic variety types, RR entries have performed least favorably. Average lint yield of RR entries was less than conventional years in eight of the 10 years. A positive difference in 2004 suggests that newly developed RR entries may not express this yield drag. BR entries have yielded more than conventional entries for the past three years, and had a positive difference in yield over the 10 years. The performance of BR entries suggests that RR genes are not linked to low yield, and that BR variety development has received more emphasis RR variety development. Based on limited data, BXN and LL variety types performed very well in the variety tests.

These data suggest that there is no inherent problem with transgenic varieties. Obviously, variation among transgenic varieties is great. Therefore, the individual performance of a transgenic variety should be considered rather than the average performance of variety types.

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