

ECONOMICS AND MARKETING

An Assessment by U.S. Cotton Growers and Other Cotton Experts of Important Innovations in Cotton Production in the Last Decade (1996-2006)

M. C. Marra and S. W. Martin*

ABSTRACT

Beginning with invention of the cotton gin by Eli Whitney in 1793, cotton production in the United States has experienced many milestone advances over the last 200 years. Some of those were mechanized technological advances, such as the cotton gin and mechanical harvesters, and others were scientific advances, such as Boll Weevil Eradication (BWE) and transgenic cultivars, which, in some cases, revolutionized the industry and, in other cases, saved the industry from further declines. Many scientific and research studies have analyzed and measured the effects of these innovations on cotton production. None, however, have sought the opinions of the people involved in the day-to-day operation of cotton farms on the innovations most beneficial to them, and the innovations they believe will be important to them in the future. Interviews with experts involved in cotton production at the 2007 Beltwide Cotton Conferences suggested that the most important innovations in the last decade were transgenic cultivars, BWE, cotton breeding, and harvesting equipment. Producer responses to a survey conducted in February 2007 confirmed the results from the Beltwide Conference interviews. Survey respondents ranked the Roundup Ready trait as the number one innovation over the last 10 years. Transgenic cultivars as a group, BWE, and improved cotton germplasm ranked as high statistically as the Roundup Ready trait. Some differences of opinion were observed among groups. Smaller farmers ranked new harvesting technologies higher than larger producers, and farmers in the Delta ranked Boll Weevil Eradication lower than farmers in the other regions surveyed.

M. C. Marra, Department of Agricultural and Resource Economics, North Carolina State University, Raleigh, NC 27695-8109; S. W. Martin, Mississippi State University, Delta Research and Extension Center, P. O. Box 197, Stoneville, MS 38776

*Corresponding author: smartin@ext.msstate.edu

Cotton production in the United States has had its cups and downs over the past 200 years. During the 19th century, cotton was the biggest cash crop in the southern states, and cotton production spread rapidly from east to west in the South. The biggest reason for this advance was the cotton gin, patented by Eli Whitney in 1793, that mechanically separated cotton seeds from cotton fiber. Before Whitney's cotton gin was commercialized, this separation had to be done by hand.

In the post Civil War era, cotton yields exhibited a slow downward trend until the mid-1920s. This was mostly because of continuous cotton production that depleted the soil in many areas of the South. Soil depletion was caused by wind erosion where forests were removed, as well as by increased soil acidity from continuous row crop production without proper fertilization (lime) being applied back to the soil. (Ellis and Foth, 1996).

Cotton breeding programs actually began in the 1880s with farmers choosing to save seed from the healthiest and highest yielding plants to plant the next season. In 1898, the first public breeding program was established in California. Private breeding programs did not begin until the early 1920s (Bowman, 2000). Soon thereafter, cotton yields began to improve markedly throughout the Cotton Belt (Fig. 1).

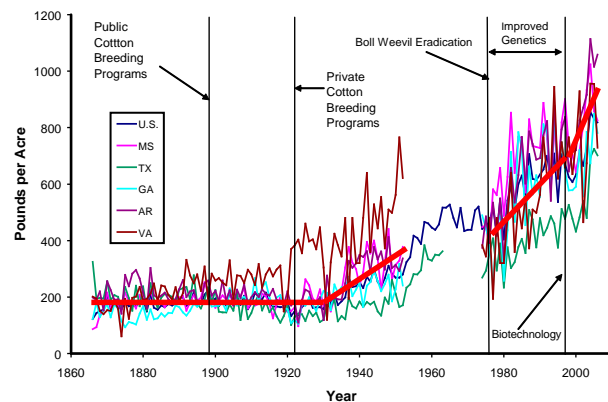


Figure 1. Cotton yield for the United States and select states (1866-2006).

This trend continued until the boll weevil (*Anthonomus grandis* Boheman) made its appearance in the South. The boll weevil is thought to have originated in Central America and entered Texas from Mexico around 1890 (Bieberdorf, 1926). By 1930, the boll weevil had spread throughout most of the Delta and Southeast. It devastated cotton production in those regions. Virginia was the last cotton state in the Southeast to be subjected to the devastating consequences of boll weevil infestation. The adverse impact of the boll weevil is demonstrated in Figure 1, which shows that the USDA did not report cotton yields for most cotton states during the period 1952-1974. Cotton production almost disappeared in some areas of the South until another innovation reversed the trend. This innovation was an area-wide approach to boll weevil control called the Boll Weevil Eradication Program (BWE).

The BWE program is a cooperative effort in which the USDA and state officials work with cotton growers to eradicate the boll weevil, in incremental stages, from the United States. Since 1892, when it first entered this country, the boll weevil has plagued U.S. cotton farmers. Boll weevil eradication began with a successful trial program in North Carolina and Virginia in 1978-1980. Since then, this program has expanded to include cotton acreage in South Carolina, Georgia, Florida, Alabama, Mississippi, Tennessee, Missouri, Arkansas, Louisiana, Oklahoma, Texas, New Mexico, Arizona, California, and adjacent areas of Northwest Mexico. Approximately 95% of all U.S. cotton is currently covered by the program, and the remaining areas are likely to be included in the near future.

Authorization to operate the program locally is usually established through state legislation and grower-approved referenda. Most states have a boll weevil eradication foundation with cotton-producer members either elected or appointed along with state agricultural officials. USDA cooperates by providing technical support and limited funding. Initially, in each new state, program managers implement an eradication phase to eliminate the boll weevil and then a post-eradication phase to prevent re-infestation (USDA-APHIS, 2002). This area-wide system was quickly adopted in some areas, but growers in other areas were slower to participate.

Throughout the period of boll weevil eradication, cotton breeders continued to improve cotton germplasm and introduce a steady stream of new, higher yielding cultivars. This higher yield was

threatened again when some of the pesticides farmers counted on to protect this higher yield potential began to fail. Lepidopteran pests began to develop resistance to pyrethroid-based insecticides, and some weeds began to develop resistance to some of the newer, acetolactate synthase (ALS)-inhibitor cotton herbicides. The development of resistance was not new for insects or weeds, but the growers thought the newer pesticides were extremely effective, so growers were experiencing greater losses as resistance increased.

The first transgenic cotton to be commercially available was BXN cotton in 1995. BXN cotton was genetically engineered to be tolerant of the broad-leaf herbicide Bromoxynil. This cotton trait enjoyed some early success in the Upper Delta region, but interest has dwindled in recent years to the degree that it is no longer sold. The first insect-resistant transgenic cotton was commercially introduced by Monsanto Company in 1996. The first transgenic cotton developed by Monsanto sold under the trade name Bollgard contained a gene for an insecticidal protein (Bt) from a naturally occurring bacterium, *Bacillus thuringiensis* Berliner. Bt insecticides are approved for conventional, as well as organic crop producers. Bt cotton controls lepidopteran pests, such as the cotton bollworm and the tobacco budworm. In 1996, both of those cotton pests were present in the southern Cotton Belt in numbers sufficient that it was economical to treat them. In the Upper South, the pests were not as prevalent, but caused some damage in most years. Farmers adopted Bollgard cotton immediately, seeing the profit and risk reduction advantages it provided for their farms (USDA-NASS, 2001; 2007; Carlson et al., 1998). Herbicide tolerant cultivars were introduced next in 1966. Roundup Ready cottons were genetically engineered to tolerate over the top applications of Roundup or glyphosate. In 1997, cotton containing more than one transgenic trait became commercially available. The first of these was Bollgard with Roundup Ready cotton. Biotech cultivars accounted for 60% of plantings in 2000 and for 87% in 2007 (USDA-NASS, 2001; 2007). Newer biotech cotton innovations include Bollgard II, Roundup Ready Flex, Widestrike, Liberty Link cotton, and various combinations of these traits. Combining of two traits had become known as "stacked gene" technology and represented 39% of total cotton acreage in 2006, while insecticide-only cultivars represented only 18% and herbicide toler-

ant only 26%. Cotton yield has been significantly influenced by the biotech revolution in the United States. The biotech cotton traits, coupled with continued cotton cultivar improvement, accelerated the rate of yield increase over the past 10 years by approximately 33% compared with the rate of cotton yield improvement before the introduction of transgenic cultivars.

Many studies have been undertaken to estimate the value of agricultural innovation. The seminal work by Zvi Griliches (1957) led the way. It involved estimating the rate of adoption of hybrid corn. The parameters used to estimate the rate of adoption were based on economic variables. Other work focused on estimating the rate of return to agricultural research and development for specific innovations, specific crops, or on a body of work from a particular institution (Alston et al., 1998; Alston et al., 2000). Others have attempted to elicit farmers' valuations of specific biotech trait/crop combinations, such as an *ex ante* study of Yield-Gard Rootworm corn (Alston et al., 2003) or the *ex post* value of Roundup Ready soybeans (Marra et al., 2004; Popp et al., 2002), to name a few. Additional studies have examined producer returns to Bt cotton (Bryant et al., 2002, Bednarz et al., 2005; Cooke et al., 2001).

To our knowledge no one has examined the relative importance of the major innovations in cotton production from cotton producers and supporting personnel. The purpose of this study was to solicit responses and opinions from those most heavily involved in cotton farming with respect to the relative importance of recent cotton innovations.

MATERIALS AND METHODS

The research was divided into two phases. First, opinions were elicited at the 2007 Beltwide Cotton Conferences from "experts" engaged closely with cotton farmers and the cotton industry. Following the 2007 Beltwide conference, a survey of cotton farmers across the Cotton Belt was commissioned. The objective of the survey was to collect information on producers' opinions as to which innovations have been the most important to them and which innovations will be most important in the future. The survey instrument was designed by the authors. Marketing Horizons, Inc., a professional market research company, administered the survey. The sample was equally divided among the three major cotton growing regions, so there would be enough respondents in each for statistical analysis. Within each cotton growing region, West Texas, Delta, and the Southeastern region, Marketing Horizons selected a random sample of cotton growers from their growers' lists with at least 300 acres of cotton in 2006. In total, 159 farmers were interviewed. Table 1 shows the demographic means of all respondents and by region of the survey.

RESULTS AND DISCUSSION

Personal interviews. In all, nine people were interviewed at length at the Beltwide Cotton Conferences. They ranged from independent crop consultants to members of the farm press to university professors. They were all asked to give their "top 10 list of cotton innovations that have created the most value for cotton producers and changed the way that cotton is produced." The following are their responses (with extraneous information omitted for clarity).

Table 1. Demographic means of participants in the survey

Description ^z	Overall	West Texas	Delta	Southeast
Total crop acres	1,858.5	1,972.8	2,632.4	1,399.9
Cotton acres	1,215.5	1,293.8	1,644.3	936.7
Irrigated cotton acres	448.2	553.7	882.8	134.9
Non-irrigated cotton acres	766.8	740.1	775.5	801.8
Owned cotton acres	588.8	636.0	808.8	440.2
Rented cotton acres	1,110.9	1,026.1	1,836.8	959.7
Years of school	14.2	14.4	14.6	13.9
Age	54.4	55.8	51.8	53.8

^z Assumptions for years of school are high school or less = 12 yr; some college/trade/technical school = 14 yr; college graduate = 16 yr; advanced degree/studies = 18 yr. Assumptions for age are under 35 = 30 yr; 35 to 44 = 40 yr; 45 to 54 = 50 yr; 55 to 64 = 60 yr; 65 or over = 70 yr.

1. *Cotton Economics Extension Specialist/University Professor.*

- “Cotton growers have completely changed their tillage practices, to more no-till or reduced tillage since the introduction of Roundup Ready cotton.
- A major breakthrough for growers was the Boll Weevil Eradication Program. You can't put enough bolls on a plant that the weevils can't eat it up.
- Bt and Roundup Ready cotton was beyond a dream just a few years ago. Now growers can control worms and weeds with much less effort and expense.
- Our harvest techniques and defoliation technology have turned around. With improved cotton strippers and bur extractors, we're getting less bark and better quality lint. Spindle pickers have also improved with greater efficiency and larger (more row) pickers.”

2. *University professor.*

- “What has made the most impact on cotton [in our state] is *Bt* technology, Bollgard and Bollgard II. Bollgard was so successful that it led the way for adoption of other transgenic traits. Anything that came along after that, like Roundup Ready cotton, growers snapped it up. Growers are going to adopt Roundup Ready Flex cotton when they are convinced the trait is in varieties that will yield as well or better than the higher yielding varieties they are planting today. DP 555 has been so successful in increasing yields that growers are looking forward to cotton varieties with the Bollgard II and Roundup Ready Flex traits that will yield as well or better than 555.
- The boll weevil eradication program made it possible for us to grow cotton again in [state].
- Module builders, multi-row pickers, and now, module builders on pickers have made production much more efficient. One man can harvest the cotton and leave it in the field in modules by himself with the new picker/module builder machines.”

3. *An independent crop consultant.*

- “The adoption of module builders and how much that has reduced labor at harvest time.
- Bollgard cotton, we were on the verge of not being able to control worms with pyrethroids and then we had Bollgard cotton.

- The plea for more soil conservation meshed with the release of Roundup Ready (cotton) technology.
- What Cotton Incorporated has done in cotton research and promotion has improved grower productivity and helped us sell more U.S.-grown cotton.”

4. *Member of the farm press.*

- “Improved seed and seed treatments.
- Roundup Ready and Bollgard cotton.
- GPS, GIS, precision planting, and spraying.”

5. *University professor.*

- “Obviously Bollgard and Roundup Ready technologies.
- Boll weevil eradication and its continued success.
- The generational change in varieties. The yield plateau myth has been dispelled.
- Roundup Ready technology has expedited the movement to conservation tillage.”

6. *Independent crop consultant.*

- “Cotton technology ... Bollgard, Roundup Ready, Roundup Ready Flex.
- Growers will plant more Flex when they get varieties that yield like 555.”

7. *Employee of a research organization.*

- “The top two are Bt cotton and herbicide resistant cotton ... Bollgard and Roundup Ready cotton.
- Number three is probably yield gain from improved breeding. The level of genetic potential of current varieties is the highest we've ever seen it.
- GPS systems ... auto steering, precision agriculture, cell phones, and two-way radios.
- More effective and efficient seed treatments, insecticides, and fungicides improve the chance of getting a stand.”

8. *Member of the farm press.*

- “Bt cotton has to be first. That technology has made a lot of other things possible.
- Roundup Ready would be next.
- Boll weevil eradication is right up there with them.
- Advances in no-till cotton production, with equipment and varieties and weed management. I never dreamed we would see people using reduced tillage in the Delta, and they are.
- Auto guidance systems on tractors and cotton yield monitors.
- Onboard module builders.”

9. *Executive director of a state cotton commission.*

- “Transgenics are probably the biggest revolution.
- Over the top herbicides like Staple.
- Successful boll weevil eradication.
- Conservation tillage.
- Cotton Inc. and Cotton Council International.”

Survey results. Recent innovations. First, survey respondents were asked an open-ended question, “Over the past 10 years, since 1996, what innovation has had the biggest impact on the way you produce cotton?” The Roundup Ready trait was, by far, the innovation mentioned first by a majority (58%) of the growers surveyed. The next highest was biotechnology in general, with 7% of the growers mentioning this category first. The boll weevil eradication program and no-till production each were mentioned first by 5% of the growers.

When the same question was asked as a relative rating question (aided), 89% ranked improved cotton cultivars; 89% ranked herbicide tolerant cotton; 83% ranked the boll weevil eradication program; and 82% ranked insect-protected cotton as being somewhat or very important. These percentages were not different statistically between responses (all results are reported at the 95% confidence level). Cotton modules, conservation tillage or no-till production, disease resistance, and growth regulators were ranked statistically the same with 82%, 72%, 69%, and 65% of growers ranking each as somewhat or very important (Fig. 2).

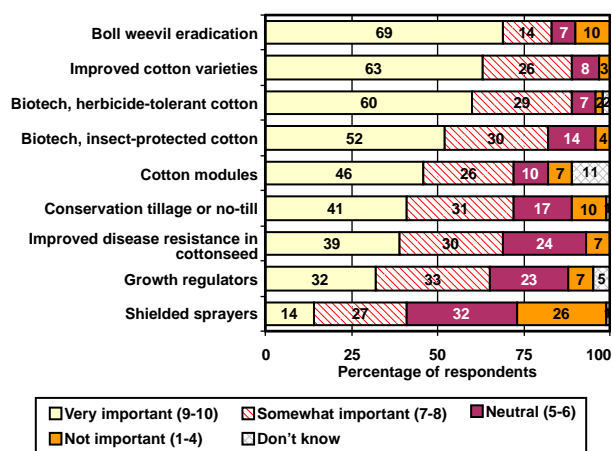


Figure 2. Overall importance of cotton innovations.

Breaking down the responses by geographic location and farm size revealed that there were no statistical differences in the importance rankings for cotton varietal improvement, insect-protected cotton, herbicide-tolerant cotton, cotton modules, or improved disease resistance across the three regions, West Texas, the Delta States, and the Southeast. All were ranked by about 80-85% of growers as being somewhat or very important innovations for cotton production.

One exception is the boll weevil eradication program, where 88% in West Texas ranked it as somewhat or very important, but only 76% ranked it as important in the Delta States. The lower ranking is not surprising considering the Delta region experienced less comparative losses prior to BWE than the other regions (Head, 1989-1993; Williams, 1994-2005). In the Southeast, 80% of growers ranked the boll weevil eradication program as somewhat or very important to cotton production in their area. The other exception is conservation tillage or no-till. This innovation, the growth of which has been associated with the herbicide-tolerant (primarily Roundup Ready) cultivars where effective, safe herbicides can be applied over-the-top of the growing crop and no cultivation for weeds is necessary, was ranked important by 82% of growers surveyed in the Southeast, 68% in the Delta States, and 58% in West Texas. This relative ranking makes sense in terms of relative weed pressure in the three regions.

Generally, growers farming more than 1,500 acres ranked improved cotton cultivars, insect-protected cotton, boll weevil eradication, improved disease resistance in cottonseed, growth regulators, and shielded sprayers higher than growers farming less than 1,500 acres. The smaller farmers ranked cotton modules higher than the larger farmers. There were no differences in the grower responses by farm size for herbicide-tolerant cotton.

Institutions and organizations leading the way. One survey question dealt with eliciting farmers’ thoughts on which institutions or organizations are leaders in cotton innovation. The results are shown in Figure 3. The most-mentioned was the Monsanto Company, with 67% of the growers surveyed considering them to be a leader in cotton innovation. Next was Bayer/FiberMax with 37% of farmers mentioning them as leaders. Delta and Pine Land Company came in a close third, with 34% of the

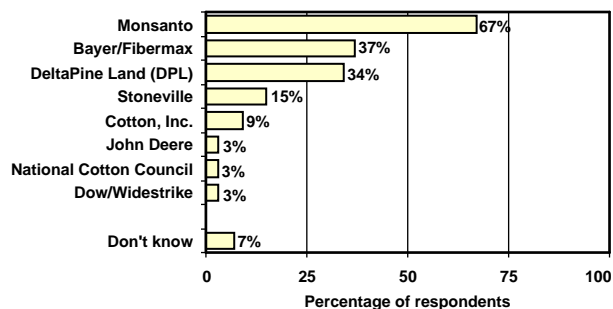


Figure 3. Organizations/companies perceived as leaders in cotton innovation.

growers mentioning them. The Stoneville Company was mentioned by 15% of growers as being a leader in cotton innovation, and Cotton Inc. was mentioned by 9% of growers. John Deere, the National Cotton Council, and Dow/WideStrike were mentioned by 3% of the growers as being innovation leaders.

A few differences in the relative rankings of companies were evident when the responses were divided into the three geographic areas. Monsanto and Bayer/FiberMax were the top two mentioned by growers in West Texas, with Monsanto being mentioned by 64% of respondents and Bayer/FiberMax mentioned by 59% of the growers surveyed. Delta and Pine Land Co. was third in West Texas with 32% of the growers mentioning them as a top leader in cotton innovation. In the other two geographic areas, Monsanto was the organization mentioned the most (78% in the Delta States and 66% in the Southeast), and Delta and Pine Land Co. was listed second with 32% and 35% in the Delta States and the Southeast, respectively. Relative rankings of the top three companies were not different by farm size.

Future innovations. Cotton growers were also asked about the overall importance of some future innovations. Future biotechnology innovations were the most important, along with improved cotton cultivars (Fig. 4). Biotech cotton traits with expanded weed control, expanded insect control, and drought control were ranked by 92%, 84%, and 86% of growers as being somewhat or very important future innovations. Improved cotton cultivars were ranked by 91% of growers as being important. None of the above percentages are statistically different from each other. Improved disease resistance and new crop insurance programs were ranked as important future innovations by 71% and 61%, respectively, of the growers surveyed.

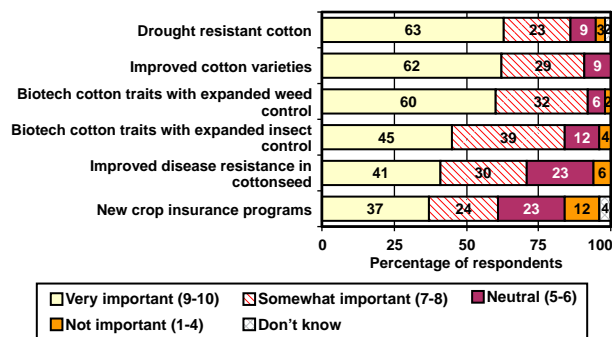


Figure 4. The relative importance of future cotton innovations.

CONCLUSIONS

It seems clear from both the personal interviews and the farmer survey results that herbicide-tolerant cotton, insect-resistant cotton, improved cotton cultivars, and the Boll Weevil Eradication program are uppermost in the minds of both growers and a small group of those professionally associated with cotton production as being the most important innovations in cotton in the recent past.

The top three companies that growers see as leaders in cotton innovation are two biotechnology companies, with one being focused on more basic biotech research and one having the expertise to develop traits and get them to market, and a seed company with a well-established breeding program. Growers appear to be looking toward these companies to provide future innovations that will sustain profitable cotton production in the United States. A few of the experts interviewed at the 2007 Beltwide Cotton Conference mentioned specifically that they think a combination of the newest biotech traits from Monsanto with the best cultivars from Delta and Pine Land Company would enhance southern cotton growers' yield substantially. At the time of this study, a merger of those two companies was under review by U.S. governmental agencies and has now been approved. Drought resistant cotton, improved cotton cultivars, and expanded weed and insect control in the form of biotech traits are the most important future innovations in the minds of the surveyed growers. It is clear from the information presented in this report that many in the cotton industry, i.e. growers and experts who work with growers, are of the opinion that continued improvement in germplasm, future innovation with biotech traits, and the combination of these activities are the keys for the future, just as they have been in the past ten years.

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