Economics of Growing Transgenic Cotton

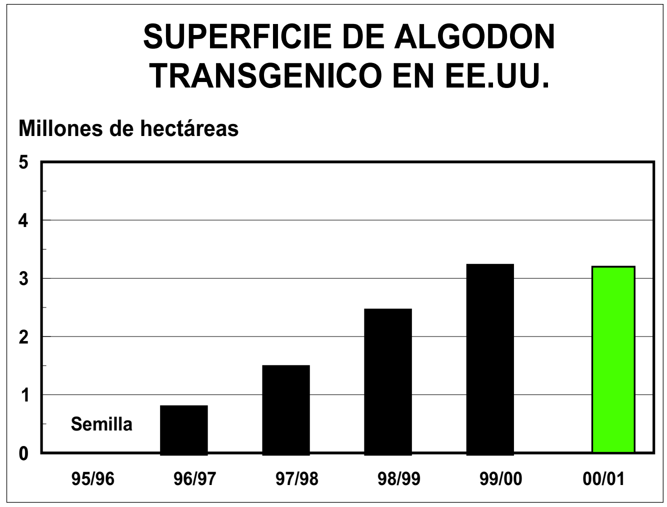
The application of biotechnological knowledge in medical sciences occurred prior to its utilization in agriculture. It had been assumed that knowledge and experience in bioengineering of drugs could carry over into agriculture, but that did not happen until about two decades ago when biotechnology for accelerating plant breeding was successfully applied to agricultural crops with a variety of objectives. Biotechnology for inserting non-cotton genes into cotton for specific objectives was developed in the first half of the 1980s. The utilization of successful agronomic traits requires the following important steps.

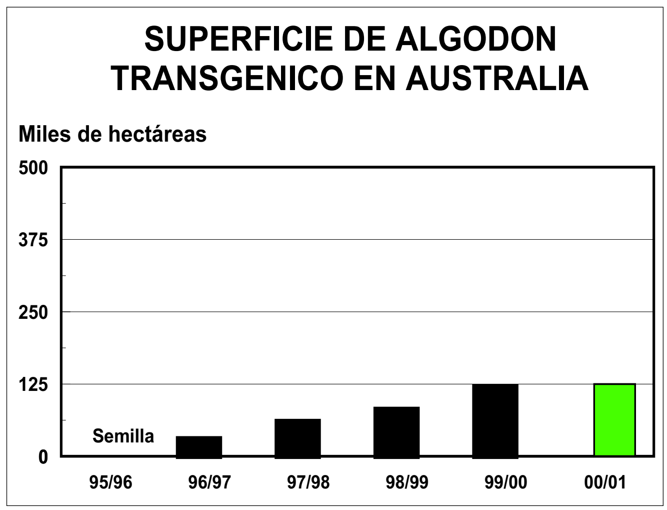
- A new gene, or genes with the ability to express a specific trait, like toxin in the case of Bt cotton, must be identified and characterized for efficacy. The gene must be safe for the environment, the plant genome, the crop product and byproducts.
- An appropriate technology is required to successfully induct purified gene(s) into the target species. Transformation via other species or varieties could delay and complicate transmission to the target species.
- Genotypes developed through genetic engineering having non-species gene (s) or same-species genes need to be tested under controlled and field conditions not only for their performance, but also for their short-term and long-term side effects, if any.

Sizeable expenditures have been made in agricultural research for product development in many crops, including cotton. Before the commercial cultivation of transgenic cottons became a reality in 1996 in the USA and Australia, a long chain of formalities and approvals were completed. Government approval processes are different in each country, however, in the United States agricultural biotechnology is regulated by three federal agencies. The U.S. Food & Drug Administration has the authority to regulate any food product in the market for safeguarding consumers against food-borne risks. The Animal & Plant Health Inspection Service of the U.S. Department of Agriculture assesses the potential impact of new plant varieties and approves or disapproves their release for planting. Finally, the Environmental Protection Agency has regulatory oversight when new plant varieties have pesticide or herbicide characteristics.

Transgenic varieties were marketed to farmers, and their crops entered the marketplace virtually unnoticed and without much concern. In the second year, some farmers had a few problems with the new technology, like excessive boll shedding and malformation of bolls, but there were no problems in the marketplace. The number of people using or consuming these products has reached the hundreds of millions without any adverse human health outcome, verifiable or otherwise, in production, processing, use or consumption. Many private and public sector biotech laboratories throughout the world have screened tens of thousands of protein samples against a number of cotton insects since biotechnology work on cotton started in the 1980s. The largest source of protein mixtures has come from the fermentation of microbes that included Bt and non-Bt microbes. Numerous "Cry" proteins from *Bacillus thuringiensis* (Bt) proved to be effective against bollworms but Cry1A was found to be better than others. The unique protein toxin produced by Cry1A is highly effective against budworms and bollworms in cotton. Though commercially not available yet, Monsanto has isolated a non-Bt protein, cholesterol oxidase from Streptomycetes, and claims it is effective against *Anthonomus grandis* boll weevil, a significant pest in the Americas only.

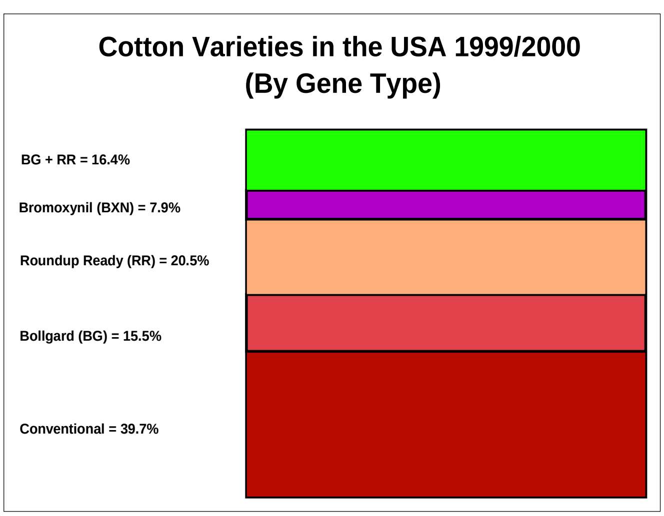
Monsanto has also combined portions of the Bt protein Cry1Ac and Cry1F to form a toxin that retains the capability to control budworms and bollworms, as in the case of the commonly called Bollgard gene, and also provides protection against Spodoptera species including *Spodoptera exigua* and *Spodoptera frugiperda*, beet armyworm and fall armyworm, respectively. It is also known that during 1999, Monsanto tested a different gene, CryX, along with the Bollgard gene, in the same variety against lepidopteran insects.





Transgenic Cotton Area

Transgenic cotton area has increased in the last four years showing the success and usefulness of the technology. In 1999/00, genetically engineered varieties were grown on 60% of the total area in the USA. The total transgenic area increased from 2.43 million hectares in 1998/99 to 3.2 million hectares in 1999/00. It is estimated that the same area will be grown to genetically modified varieties during 2000/01.



Australia is also one of the largest transgenic cotton growing countries in the world. Commercial cultivation of transgenic cotton started in Australia in 1996/97. In Australia, only Bollgard (known as Ingard in Australia) has been approved for commercial cultivation. During 1999/00, 120,000 hectares of Bt cotton were planted, or 26% of Australia's total area. For resistance management purposes, the maximum target was to plant 125,000 hectares, but because of some other limitations, like the proportion of the refuge crop, the target could not be achieved. While trials are being conducted on Roundup Ready resistant varieties, BXN has not been tried for commercial cultivation.

In China (Mainland), some parts of the Yellow River Valley have been affected more than others by *Helicoverpa armigera* making them more suitable for Bt cotton. It is estimated that the Bt cotton area has increased to 270,000 hectares in 1999/00. Both the Bollgard gene and the locally developed transgenic varieties are grown on a commercial scale.

Economic Benefits

A number of reports published by the ICAC show that by the early 1990s, many of the Green Revolution gains in yield had begun to level off. Cotton's world average yield has not increased since 1991/92 while the cost of production has continued to inflate, threatening the economics of cotton production. Thus, the emphasis has shifted from increasing profits through increasing yields to maintaining profits through savings on the cost of production. Environmental concerns regarding the increased use of pesticides also grew during the 1990s. Bt cotton provided an alternative by replacing insecticides with a toxin within the plant.

Bryant et al (1998) studied the economic significance of transgenic varieties versus non-transgenic varieties under farmers' field conditions. The studies were carried out for three years from 1996-98 at different locations according to the willingness of farmers to participate in the program. They selected comparable cotton fields on the same farms planted with transgenic and conventional varieties. Both varieties were grown with the objective of maximizing production and profitability according to the farmers' own choices and conditions. The major differences between the Bollgard and non-Bollgard fields were the technology fee (for transgenic varieties), insecticide use and growth regulators for conventional varieties. In the first year (1996), five out of six locations showed economic benefits in planting Bt cotton over non-Bt cotton. On average, the cost of growing cotton was higher in Bt varieties but, because of higher yields, net return in Bt varieties surpassed non-Bt varieties by US$215/ha. However, in 1997, because of low yields, the net profit in Bt varieties was lower by US$67/ha over conventional varieties. Once again, in 1998 Bt varieties provided a higher return by US$160/ha over non-Bt varieties. Although in 1998, as in 1996, most of the additional income came from higher yields, savings on the cost of production also contributed to higher profitability.

Bryant et al (1998) also studied costs and returns of herbicide tolerant and Bt cotton under replicated trials on nine varieties at two locations in the Northeast and Southeast of Arkansas. While other operations were normal, weed and insect control operations were performed on all types of genotypes with the objective of maximizing yields. As far as insect control was concerned, early season spraying was performed on Bt as well as non-Bt varieties. Similarly, late season insects also required spraying on both types of cottons. The major difference was in the control of mid-season insects, Bt varieties did not require any spraying. Bryant and his colleagues observed that, taking into account the fee for technology, the cost of insect operations in Bt varieties was comparable to non-Bt cotton in the Northeast, while in the Southeast Bt cotton provided savings of US$45/ha in insect control. The cost of weed control operations in the herbicide tolerant Roundup-Ready varieties was lower in the Northeast and higher in the Southeast than herbicide susceptible varieties. Higher yields in Bollgard varieties contributed to higher returns but results did not clearly prove the economic advantages of transgenic varieties, as returns from a conventional variety surpassed all others.

Transgenic varieties are developed with specific objectives. The currently available transgenic genotypes are not designed for improved responses to diseases, water stress, etc., as their reaction to those conditions could be positive or negative. It could be particularly true for nematodes as they are responsible for morphological and biochemical changes in the affected cells in addition to hormone mediated changes. Robinson and Bridges (1998) studied 21 transgenic varieties, including the 15 most widely cultivated varieties, and their non-engineered parents under growth chamber conditions for their resistance to *Meloidogyne incognita* (root-knot nematode) and *Rotylenchulus reniformis* (reniform nematode). One each of the most susceptible and the most resistant varieties was also included in the test for comparative evaluation. They concluded that no disease in nematode reproduction could be attributable to any transgenics. Intervarietal differences, as in the case of normal varieties, were significant.

Bt varieties currently grown on a commercial scale have the Bt toxin Cry1A, which is highly effective against *Heliothis virescens*, tobacco budworm, and comparatively less effective against other bollworms. If tobacco budworm is not a major pest, the usefulness of planting Bt cotton in that area could be reduced as reported by Layton et al (1999). In 1998, 55% of the total area planted to cotton in Mississippi was grown under Bt varieties. But, according to Layton et al (1999), in the Hill region of Mississippi, Bt varieties were planted on 85% of the total area as compared to only 40% in the Delta. The table below indicates the savings and differences in the number of insecticide applications in two regions of one state. In Delta, the total number of sprays on Bt varieties is higher than non-Bt in the Hill area but most of these sprays were against boll weevil. In the Hill area boll weevil eradication was completed the first year, and the boll weevil population had been reduced, which kept the total number of sprays low.

A post doctorate research associate at Auburn University studied the economic impact of transgenic Bt cotton and herbicide tolerant soybeans in 1997. The report, financed by the USDA

Bt Cotton in Two Mississippi Regions

Character	Delta		Hill	
	Bt	Non-Bt	Bt	Non-Bt
Percentage Damage				
Caterpillar	2.47	2.56	2.58	6.20
Boll weevil	0.47	0.54	0.17	0.05
Bug	1.49	0.57	0.44	0.29
Average No. of Sprays				
Tobacco budworm and bollworms	1.46	5.24	1.11	5.15
Boll weevil	3.25	1.90	0.04	0
Bug	1.58	1.38	0.13	0.21
Non-gossypol pigment	6.79	9.00	2.20	5.71

and available online, examined the distribution of value on various segments of the industry and public created from planting genetically engineered crops. The studies refer to only U.S. growing conditions and the economic impact may be different in other countries or even within a country depending on growing conditions. Matching pairs of Bt and non-Bt on-farm fields were selected from Alabama, Arkansas, Georgia, Louisiana, North Carolina, South Carolina and Texas. Additional data from Monsanto and Delta and Pine Land Company were also included in the analysis. Falck-Zepeda et al (1997) concluded that out of the total benefits of $190.1 million in the U.S. on planting Bt cotton, the U.S. farmers' share of the total surplus was 42%. Gene developer, Monsanto, received 35% and the rest of the world 23% of the total economic benefits. Delta and Pine Land received 9%, whereas U.S. consumers received 7%. According to the report, for herbicide-tolerant soybeans, the total world surplus was $1,061.7 million. U.S. farmers' surplus was 76%, Monsanto's was 7%, U.S. consumers received 4%, and seed companies captured 3% of total.

In the USA, of the four cotton growing regions, the Southeast (Virginia, North Carolina, South Carolina, Georgia, Alabama and Florida) and the Mid-South (Missouri, Arkansas, Tennessee, Mississippi and Louisiana) regions are the most suitable for Bt cotton. Monsanto (Mullins and Mills, 1999) undertook an extensive study at 109 locations in nine different states in both regions. The yield data and cost and return comparisons were based on the information developed by farmers at their own fields. Bollgard types included many varieties of different origins, however, farmers selected comparable genotypes themselves. As expected, there were differences among fields within regions and across regions but the average data from 109 locations showed a US$98/ha advantage in the case of Bollgard varieties. The return was calculated on the basis of US$1.43/kg of lint. The Bollgard gene not only required less pesticide applications but also resulted in higher yields. Taking into account all costs including the technology fee, savings in insecticides averaged about US$40/ha while additional income from higher yields averaged US$58/ha.

Economics of Bt Cotton in the Southeast and Mid-South in the USA

Category	Conventional Variety	Bollgard Variety
No. of Sprays (TBW and BW*)	5.30	1.40
Cost per spray/ha $	23.82	17.62
Total insecticide costs $	126.45	24.67
Total No. of all sprays	8.30	6.0
Total insecticide costs $	197.71	105.72
Total insect control costs $	248.06	209.94
Yield (kg/ha)	934.00	975.00
Net return @$1.43/kg lint $	1,087.56	1,184.31
Bollgard advantage $		96.75

Note: Total insect control costs include application costs and technology fee for Bollgard varieties.

* TBW and BW = Tobacco budworm and bollworms

Factors Affecting the Economics of Bt Cotton

Bt cotton is not suitable for production in all areas. Frisvold et al (2000) called the suitable and highly suitable areas low impact and high impact scenarios. According to him, under a low impact scenario, Bt adoption increased production by 0.6-1.1%, while under a high impact scenario, production increased by 1.8-2.9%. The use of the genetically modified cotton technology is not to be determined only by the size of the growers but by the following factors which will determine the economic usefulness of growing genetically engineered varieties under different sets of production conditions.

- The currently available bollworm resistant Bt varieties have a toxin effective only against bollworms. If a cotton growing area is not affected by bollworms or bollworm damage does not exceed the economic threshold levels, growing Bt varieties will have no economic advantage (Bryant et al, 2000).
- The toxin is not effective against all bollworms. It is most effective against the tobacco budworm *Heliothis virescens*. A most suitable area for growing Bt cotton would be one severely affected by the tobacco budworm every year.
- The fee for the Bt cotton technology is supposed to be at least equivalent to the savings from insecticides. If in a particular year the cotton growing area is not severely attacked by tobacco budworm or any other bollworm also controlled by the Bt gene, at the end of the season the economics of Bt cotton may be different than originally calculated.
- All economic calculations of the technology can be made based on the technology fee. If the technology fee is increased, the suitable areas for growing Bt cotton will be reduced accordingly.
- The economics of Bt cotton may again be different if the tobacco budworm appears on cotton along with cutworms or other worms against which Bt is not effective.
- The same is true for herbicide tolerant BXN or Roundup Ready varieties. If broadleaf weeds are not a major problem, it may not be a good idea to pay for the herbicide tolerant gene.
- If cheap labor is available for weeding, it will not be a financially wise decision to grow herbicide tolerant varieties.

What is Next?

All the currently available commercially grown transgenic cotton varieties have been produced with altered agronomic qualities. Changes in the agronomic behavior are just one aspect of the utilization of biotechnology. Recent biotechnological approaches now visualize a change in which farmers will grow cotton designed for the specific needs of the end-users. The end-users could be in various fields like the food industry, the livestock sector and the pharmaceutical industry. Conventional breeding has been used to develop novel products and in the case of cotton, colored cotton and gossypol free varieties are good examples. But, due to the lack of control on transferring specific genes, the rate of success has been slow with limited success. Work is undergoing on many end-use products but results may still be 3-4 years away. However, future developments will not change the fundamental purpose of growing cotton as a fiber crop. Value added consumer preference would be acceptable only if fiber quality and agronomic performance is not sacrificed at the cost of end-use products. In addition to insect and herbicide resistant varieties, colored cotton, cotton with a polyester-type quality, gossypol-free seed, fire retardant quality and wrinkle-free cotton may be among the next transgenic cottons to become commercial.

As mentioned in the first article of this issue of *THE ICAC RECORDER*, cotton seed has tremendous potential for improvement with respect to oil contents and amino acids. While great successes have been achieved in other crops in similar fields, cotton could easily be worked on those lines. High oleic acid soybean varieties with less saturated fat have been developed and commercialized, thus saving on the hydrogenation process. Similarly, high lauric acid canola varieties and mid oleic sunflower varieties are already grown on a commercial scale. It is hoped that many new corn and soybean varieties with higher amino acid contents will be available for animal feed.

The current trend shows that crops that do not have a big seed market have been behind crops with bigger seed markets. Wheat is one example that does not have a big seed market, as most farmers throughout the world keep their own seed. Though the seed rate used in wheat is more than three times the rate used in cotton, no transgenic wheat variety has been released so far. In this regard, cotton is lucky to be paid high attention because of its high pesticide consumption and also because of farmers' inability to keep seed for the next planting.

The new increased consumer oriented value of cotton in addition to lint characters will bring significant changes into the marketing of cotton. It is anticipated that growing, picking, ginning, storage and transporting of cotton based on identity preserved will become more common. It will be something similar to organic cotton, which requires formal certification in field, processing and manufacturing operations. The biotechnology of cotton is in itself a new subject and no value-added user-specific products are available yet. Such products are expected to come soon and at a faster rate than the pioneer products.

References

Anonymous, 1999. Value-enhanced crops: biotechnology's next stage. *The Cotton Gin and Oil Mill PRESS*, Volume 100, No. 15, July 17, 1999.

Bryant, K. J., Robertson, W. C. and Lorenz III, G. M. 1999. Economic evaluation of Bollgard cotton in Arkansas. *Proceedings of the Beltwide Cotton Conferences*, National Cotton Council of America, P. O. Box 820 285, Memphis, TN 38182, USA.

Bryant K. J., Allen, C. T., Bourland, F. M. and Earnest, L. D. 1999. Cost and return comparisons of Roundup Ready and Bollgard cotton varieties. *Proceedings of the Beltwide Cotton Conferences*, National Cotton Council of America, P. O. Box 820 285, Memphis, TN 38182, USA.

Bryant K. J., Allen, C. T., Bourland, F. M., Smith K. L. and Earnest, L. D. 2000. Cost and return comparisons of transgenic cotton systems in Arkansas. *Proceedings of the Beltwide Cotton Conferences*, National Cotton Council of America, P. O. Box 820 285, Memphis, TN 38182, USA.

Falck-Zepeda, Jose B., Traxler, Greg and Nelson, Robert G. 1997. Rent creation and distribution from biotechnology innovations: The case of Bt cotton and herbicide tolerant soybeans in 1997. http://www.biotechknowledge.com/showlib_us.php3?2728

Frisvold, George B., Tronstad, Russell and Mortensen, Jorgen. 2000. *Proceedings of the Beltwide Cotton Conferences*, National Cotton Council of America, P. O. Box 820 285, Memphis, TN 38182, USA.

Layton, M. B., Stewart, S. D., Williams, M. R. and Long, J. L. 1999. Performance of Bt cotton in Mississippi, 1998. *Proceedings of the Beltwide Cotton Conferences*, National Cotton Council of America, P. O. Box 820 285, Memphis, TN 38182, USA.

Mullins, J. W. and Mills, J. M. 1999. Economics of bollgard versus non-bollgard cotton in 1998. *Proceedings of the Beltwide Cotton Conferences*, National Cotton Council of America, P. O. Box 820 285, Memphis, TN 38182, USA.

Robinson, A. F. and Bridges, A. C. 1999. Reproduction by root-knot and reniform nematodes on the transgenic cotton cultivars grown commercially in 1998. *Proceedings of the Beltwide Cotton Conferences*, National Cotton Council of America, P. O. Box 820 285, Memphis, TN 38182, USA.