# Commonly Asked Questions About Transgenic Cotton

According to the International Service for the Acquisition of Agri-biotech Applications, transgenic crops were planted on 52.6 million hectares in 2001/02. Cotton is grown in over 60 countries out of which only eight have approved transgenic cotton for commercial use. The countries that have allowed commercial production of transgenic cotton resistant to insects are Argentina, Australia, China (Mainland), India, Indonesia, Mexico, South Africa and the USA. The government of India permitted commercialization of cotton in March 2002, and 2002/03 will be the first crop year in India. The herbicide resistant transgenic cotton, alone and in stacked gene form, is allowed for commercial production only in Argentina, Australia and the USA. Outside the USA, insect resistant Bt cotton is more popular than herbicide resistant varieties. In the USA in 2001/02, varieties having the herbicide resistant gene, alone and in conjunction with the Bt gene, were planted on over 97% of the transgenic cotton area, compared with less than 3% of area under Bt gene varieties. However, it is not expected that herbicide resistant Roundup Ready or BXN cotton varieties will have the governments' approval very soon in China (Mainland), India and other developing countries.

The Technical Information Section of the International Cotton Advisory Committee has published many reports and papers on genetic engineering of cotton. All these reports and papers are available at http://www.icac.org/icac/english.html. The application of biotechnology to crop improvement is comparatively new, and it is often misinterpreted. Genetic engineering is a very specialized fundamental science, and most research is in the private sector. This article is a step forward in the work of the Technical Information Section to understand biotechnology and its practical utilization. The article is based on specific questions related to cultivation of transgenic varieties of cotton.

## What is the difference between biotechnology and genetic engineering?

Biotechnology is a much broader term and involves utilization of living organisms for the improvement of living organisms. Biopesticides are biotech products, but they may or may not be, and mostly are not, genetically engineered. The genetic engineering technology is one process used in biotechnology. Using the technique of "gene splicing" or "recombinant DNA technology" (rDNA), scientists can add new genetic information to living organisms to form a new protein which may create new traits, such as immunity against insects or herbicide chemicals or even strengthen/improve existing traits. The technology for dealing with DNA has become so powerful that it is now routine to construct novel DNA molecules by joining sequences from quite different sources.

## What is the correct term to be used for transgenic cotton: genetically modified organism or genetically engineered?

Cotton breeders, whether they were able to achieve something or not, and knowingly and inadvertently, have worked for centuries to improve cotton. One of the most significant achievements has been to domesticate a cotton perennial tree into an annual plant. In the domestication process, many genetic changes have occurred, and they continue to occur in the conventional breeding approach. Before the recognition of genetics as a science, changes were brought without understanding the underlying science. Now the process of variety development has become better understood, though not completely yet. So, the cotton grown on a commercial scale today has already gone through drastic genetic modifications and is continuously going through additional changes. The present day transgenic varieties have been developed through employment of a genetic engineering technique. The cotton varieties, which have been transformed into transgenic varieties, were already genetically modified but now they have been genetically engineered to emerge as transgenic varieties. So, the right term for transgenic varieties is genetically engineered (GE) cotton.

## What is the difference between genetic engineering and Bt cotton?

Genetic engineering and Bt cotton are two separate things. As mentioned above, genetic engineering is a process for producing transgenic products. Bt cotton is just one product, which has been developed through genetic engineering. There is a need to recognize one as a process and the other as a product. The process may be good at all times, but it could be employed to produce bad products.

## Is all genetically engineered cotton a Bt cotton?

Bt cotton has been developed by taking a gene from the soil bacterium *Bacillus thuringiensis* and inserting it into the cotton genome. The gene taken from the soil bacterium is coded as Cry1Ac and now more genes from the same soil bacterium have been isolated and inserted into cotton to produce transgenic cotton like Bollgard® II. Thus, Bt refers to the source of the non-cotton gene in the transgenic varieties. If the source changes, as in the case of herbicide resistant cotton, it will no longer be a Bt cotton.

## Are genetic engineering and conventional breeding complementary to each other?

The processes used in the past to bring about changes in plants by combining all the characteristics of one plant with those of another were very slow. When the science of genetics emerged, breeders tried to understand how specific characters could be inserted together in the shortest possible time and without loosing other benefits of a selected genotype. As the understanding of cotton plant breeding grew, scientists found ways of speeding up the breeding process and making it more precise and reliable. It is now possible to identify exactly (for many characters) which genes are responsible for which traits and how they can be quickly and safely transferred to the target genotype. Using the information on genetic control of various characters, it is possible to make small and specific changes to a plant without affecting it otherwise. The process is called back crossing. The backcrossing process is still slow and has a number of problems, particularly the linkage between/among various characters and complex control of a particular character. Genetic engineering technology provides solutions to such problems.

Genetic engineering is just a small component of breeding. Genetic engineering will permit the transfer of characters quickly and efficiently, create non-existing characters and create many more functions not even known yet in breeding. No doubt genetic engineering can perform functions extremely better than conventional breeding, and functions that are impossible with traditional approaches, but the important role of conventional breeding cannot be eliminated. Genetic engineering will always require breeders for screening the segregating material in the case of a new character and backcrossing in the case of transferring the existing unique gene to another variety. Biotechnology is no different in breeding principles for developing a pure superior genotype and it will go together with conventional breeding.

## Does Bt cotton have higher yield potential?

The insect resistant and herbicide resistant transgenic cottons have specific objectives. The addition of a non-cotton gene from a soil bacteria in no way enhances the genetic ability of the plant to produce a higher yield. The inherent ability of the plant to produce buds, flowers and bolls remains the same as in the case of a parental line with or without the Bt or herbicide resistant genes. Thus, the genetic potential does not improve with the insertion of a non-cotton gene in the currently available transgenic varieties. Whether genetic potential can be improved by developing transgenic varieties is still not known. Yield is the most attractive cotton character, but no work is reported to have been undertaken yet, which could improve the genetic ability of the plant to give a higher yield. However, the possibility for further improvement does exist.

## Where does yield improvement come from in Bt cotton?

The genetic ability of the plant to produce higher yield does not improve in transgenic cotton varieties, but many references are available in the literature about higher yields achieved in Bt cotton varieties over non-Bt parents. Cotton is vulnerable to a variety of pests, and losses occur if cotton is not sprayed. The losses due to pests are directly proportional to the pest pressure. Losses due to pests are minimized by spraying insecticides but the loss is not eliminated. Insecticides are recommended at particular threshold levels, which have been established for various pests and countries. Each threshold is a level or a stage that ensures that the benefit of using an insecticide is greater than the cost of the insecticide and its application. But this is a stage when at least some damage to the fruiting forms has already occurred, particularly in the case of a bollworm attack. The use of Bt cotton minimizes/eliminates the pre-threshold loss that occurs before insecticide applications begin.

## How much of an increase in yield can be expected?

There may or may not be an increase in yield. The increase, if any, depends on the losses due to pests in spite of usual pest control measures. The maximum increase in yield will be achieved if pest pressure is heavy but the crop is not sprayed against the target pests. If a crop is properly protected against pests, there may be no or minimum increase in yield. The increase in yield is a direct indication of how best the insect control practices have been followed in the non-Bt crop. This is one of the reasons that small farmers who presumably did not have good plant protection measures in South Africa received the highest benefit from Bt cotton. Consequently, the adoption rate of Bt cotton is much higher among small farmers in South Africa than among large farmers who were already following good plant protection measures.

## What is the effect of currently available non-cotton genes on fiber quality?

The currently available non-cotton genes are not supposed to have an effect on quality. However, a number of reports indicate a decline in average quality in the USA. Such reports are based on practical experiences, which cannot be denied. The issue must be properly analyzed. Apparently, the effects on yields can be related to the rate of release of new varieties. New varieties are adopted or released in each country at a certain rate, which may be one new variety every year or one variety every two years or three or four years. The rate of introduction of new varieties has a proportional impact on fiber quality improvement.

Biotechnology companies decided to introduce the Bt gene and herbicide resistant genes through accepted varieties. It took many years to insert a Bt gene into cotton, confirm its performance, complete the regulatory requirements and introduce Bt varieties on a commercial scale. This process automatically slowed down the rate of adoption of new varieties with improved fiber qualities.

The other possible explanation is that the protection of early-formed bolls with GE cotton may have changed the location of bolls on the plant that were ultimately harvested. Quality depends upon the position of bolls on the plant, which may have affected quality in the Bt or herbicide resistant varieties compared to their parental varieties.

One more reason for an effect on quality could be the impact on crop maturity. If a plant retains bolls earlier or keeps setting bolls late in the season, it could also affect quality. The bacterial genes themselves as such are not supposed to have an effect on quality.

Positive effects of Bt cotton have also been reported, including improvement in ginning from South Africa. Bt plants do not produce higher lint percentages. If any, it is all due to other changes in plant morphology and fruit bearing.

## Is there a possibility to improve fiber quality through genetic engineering?

Cotton genotypes with improved fiber quality can be developed and it has long been hoped that improved fiber quality will come at some time. However, the new phase, when cotton will have improved "quality traits," still seems many years away. The timetable for improved quality is not known, and the direction in which improvement will come is not certain at this stage. When achieved, GE cotton will provide direct benefits to consumers in the form of improved fiber quality produced at the same cost as normal cotton. The stage when cotton will start its role as a plant biofactory is still farther in the future. The biofactory stage has been forecasted to follow the stage of quality improvement. There is a higher probability of achieving the second stage sooner than any other achievement.

## What are other benefits of Bt cotton?

The primary objective is of course insect control and that is the only guaranteed advantage of growing Bt cotton. But, proper insect control through the Bt gene has a potential to bring additional advantages in the form of lower production costs (due to less insecticide use), higher yields, better grades and quality, environmental safety, improved biological control, and other benefits under specific growing conditions. None of the additional advantages are assured, as is immunity against bollworms in Bt cotton. The same is true for herbicide resistant transgenic cotton. However, over-the-top application of herbicides, resulting in less interculturing operations, may have additional advantages beyond the primary objective of efficient weed control.

- Cost of Production

  Reports from Australia, China (Mainland), South Africa and other countries that have grown Bt cotton over significant areas indicate that the cost of production is lower with Bt cotton. The lower cost of production is only due to reduced spending on pest control. Thus, pest pressure/number of sprays per season to control target bollworms and the cost of pesticides vs. the cost of the technology fee will determine the extent of savings in the cost of production. However, if the target bollworms do not become a major threat in a particular year, and a farmer has already paid the technology fee, savings in the cost of production could be negative.

- Higher Yield

  The chances of increases in yields have been discussed above. Bt cotton should never be planted exclusively to improve yield. The primary function of pest control has to be the main consideration.

- Environmental Safety

  Environmental safety is promoted by reduced pesticide use. Fewer sprays means less pesticides delivered to the environment, fewer pesticide containers to be disposed of, less damage to the natural flora and fauna, and reduced human exposure to toxic chemicals. The case of herbicide resistant transgenic cotton could be different. The herbicide resistant transgenic cotton will encourage the use of herbicides, which is contrary to the environmental safety factor in Bt cotton. The improved fiber quality genotypes could just be neutral on this aspect.

- Improved Biological Control

  Bt toxin is not harmful to natural predators and parasites, and a reduced use of disruptive pesticides will allow increased emphasis on the management and manipulation of beneficial species. Food sprays and many other means of beneficials' conservation and augmentation could be better utilized in Bt cotton compared to fields where insecticide use is frequent. Higher levels of host plant resistance in Bt cotton could further enhance the impact of integrated pest control in Bt cotton.

- Better Grade

  Grade in cotton is determined by trash and color. Due to reduced bollworm damage, Bt cotton is supposed to show fewer yellow spots, thus improving the grade of cotton.

## Can Bt cotton be a component of IPM?

Integrated pest management is the utilization of all possible means of pest control that contribute to an economically feasible and environmentally sustainable pest control approach. IPM involves a multidisciplinary approach that minimizes the use of dangerous chemicals and can be utilized for a long period of time. Transgenic cotton, particularly Bt cotton, provides a new tool and foundation on which IPM programs can be based. However, experience to date indicates that utilization of Bt cotton requires a rigorous and well-implemented resistance management program. Commercial production of Bt cotton has certainly changed the scenario under which an IPM program could be implemented in various countries and production systems. Bt cotton has not emerged as an additional component of IPM, rather it is a foundation of the whole IPM system. However, the utilization of Bt cotton as a foundation of the IPM system has been minimal so far. There is a need to recognize, and accordingly enhance, the role of Bt cotton in IPM.

## Why is a refuge crop required?

One of the hardest lessons learnt from the use of pesticides is the development of resistance to insecticides by many species of insects. Some of the target species of Bt cotton are notorious for the development of resistance, particularly the cotton bollworm *Helicoverpa armigera*. Bt cotton carries an insecticidal protein on which the bollworms feed throughout the growing season, and year after year. Just as with insecticides, insects can develop resistance to the insecticidal protein produced by Cry1Ac and Cry2Ab, Bollgard® and Bollgard® II respectively. Researchers, utilizing experience with insecticides, have devised resistance development delaying tactics in the form of a refuge crop. The strategy has been strictly implemented and no resistance complaints have been reported so far. Therefore, a refuge crop is required to produce a hybrid population from susceptible insects mating with the resistant population to delay development of resistance to the Cry proteins.

## Are transgenic cottons safe in the long term?

The answer to this question is "we do not know." It is claimed by companies in the biotechnology business that the proteins in the currently available biotechnology cotton products have a history of safe use. But the fact is that the Bt gene is being utilized in the cotton genome for the first time and, so far, only six years of experience is available with transgenic cotton products. There is no assurance that a negative interaction between the foreign gene and the cotton genome will ever occur. Moreover, assuming that the currently available transgenic cotton products are safe does not mean that all transgenic cotton products will always be safe.

The six-year experience shows that the Bt gene and herbicide resistant genes interact with different varieties differently and their effectiveness is dependent on growing conditions. This is another indication that the long-term impact of these genes is not known.

## What first: A transgenic cotton or biosafety regulations?

Application of modern biotechnology to cotton in seven countries by 2002 has already proved the success of the technology and the two products. Success stories in other crops include virus-resistant potatoes, delayed ripening tomatoes, rice high in vitamin A, and soybeans and corn with higher quality and more oil and other food components. There are many countries where Bt cotton could be as successful as in the countries using it so far. But, national and international patent laws prohibit the use of transgenic cotton in many other countries. Some countries have accepted the technology based on the experience in other countries and do not want to be left behind in acquiring the uses and benefits of this new agricultural revolution. But systems are not in place to utilize the technology in their countries. All countries that have used this technology on a commercial scale had in-house systems to introduce/develop, test and commercialize it.

Governments and the private sector must work together in the debate on the use of agricultural biotechnology. As a matter of priority, governments must establish adequate regulatory oversight and appropriate scientific protocols for agricultural biotechnology. Regulatory protocols are essential for the introduction of agricultural biotechnology in a manner that does not pose unacceptable health and other environmental risks and which has the publics' confidence.

## Can the transgenes be transferred to other varieties and species?

Cotton no doubt behaves like a self-pollinated crop but is a cross-pollinated crop by nature. Cross-pollination does occur in most countries, though may be as low as only 2-3%. In some parts of Turkey, out-crossing has been reported as high as 13% in some years. Work done in various countries has shown that the percentage of out-crossing decreased with the increase in distance between varieties. By the time the petals open in the morning, anthers have already shed pollen grains, which minimizes the chances of cross-pollination. Moreover, pollen grains are heavy and cannot be carried by wind, and they have spikes, which limit their spread. Frequent insecticide applications limit bee activities and further reduce the chances of cross-pollination. However, the chances of cross-pollination are not zero. Transgenic cotton varieties can out-cross with intraspecies varieties and also with other compatible species of cotton, whether wild or cultivated, if planted in close vicinity. For seed production purposes, it is always recommended to keep some distance between varieties. There is no single recommended distance, which depends on many factors, but it is usually recommended to plant varieties at least 15-20 meters apart for seed purposes. Cross-pollination, though low, could allow non-cotton genes to "escape" into the environment, with unforeseeable consequences.

## What is latest on the technology protection system?

Once a genotype is transformed, the transgenic genotypes have the ability to transmit the new gene to the next generation without any problems. Thus, farmers do not need to buy seed every year unless they are prohibited from using gin-run seed. Saving the seed for next year would save farmers the technology fee, which is only a little less than the price of insecticides used on non-transgenic varieties.

A system was developed in the USA jointly by the U.S. Department of Agriculture and the Delta and Pine Land Company that would force transgenic cotton plants to produce self-sterile seed. The technology, called "terminator" or the "technology protection system," received a formal patent in 1998 and was close to being released on a commercial scale. This technology could help companies protect their investment in genetically engineered cotton, and thus the transgenic technology could spread to many countries sooner. On the other hand, farmers would be forced to buy the transgenic varieties of seed every year. More on this technology was published in the March 1999 issue of *THE ICAC RECORDER*.

Before the technology protection system was commercialized, many countries and organizations dealing with small scale farming systems expressed concerns. Ultimately, Monsanto, having listened to the concerns raised by various experts, development leaders and other stakeholders, decided not to commercialize the terminator-technology/technology-protection-system. No more work is being pursued on this aspect.

### Do agronomic requirements of transgenic varieties differ from non-transgenic varieties, and how can the technology be acquired?

The agronomic requirements of current transgenic varieties are not different from normal varieties. Transgenic varieties require the same amount of water and fertilizer as normal varieties. However, pesticides requirements, and accordingly pest control care, is quite different. Herbicide resistant transgenic cotton will not require intercultural operations carried out in many countries for the sake of removing weeds. The Bt cotton may or may not require insecticide applications against bollworms, but certainly sucking insects have to be controlled as in normal varieties.

There are three ways to acquire transgenic technology, 1) a joint venture with a company or companies that own genes and the technology to develop transgenic genotypes, 2) develop local facilities and a system to transform genotypes, and 3) have varieties transformed by private genetic engineering companies through contractual assignments, which has not happened yet. In each case, there is a cost for the technology, which is limiting its spread to developing countries.

### Is genetic engineering a consumable technology?

Unlike many other options available in plant protection, the genetic engineering technology is here to stay. Many pesticide products have been introduced in the past, some of which were abandoned even before they were commercialized. Some were used for a short period of time compared to others. The genetic engineering technology is above all of these. Genetically engineered products will come and go, but the technology to develop new products—genetic engineering—will stay and new products will continue to be developed.

### What is the other impact of transgenic varieties?

At this stage transgenic varieties have two functions, the control of bollworms and the control of broad leaf weeds by over-the-top use of herbicides. There are certain scientifically realistic apprehensions about both effects. Bt cotton is effective against bollworms only, and the effectiveness varies by species of bollworms. It is apprehended that if a particular species of bollworms is vigorously controlled for a number of years, which the Bt cotton is meant to do effectively, some minor insects may become major insects. Not only this, but it is also feared that in this effort some insect species may emerge, which could be even more difficult to control with current insecticides. Similar apprehensions are also true for weeds. Broad leaf weeds are in general easier to control than narrow leaf weeds. If broad leaf weeds are eliminated through extensive use of herbicides on transgenic herbicide resistant cotton, some threats from grass weeds could become even more severe than broad leaf weeds.

For more information on the issues discussed here refer to papers available on the ICAC web page at http://www.icac.org/icac/cottoninfo/tis/biotech/english.html.

# The Cotton Production System and Bt Cotton in Argentina

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Cotton is grown in Argentina in a broad region roughly bounded by the Tropic of Capricorn and $31^0$ SL. The region is comprised of an abundant bioenvironmental diversity with climatic regions ranging from wet in the extreme northeast (over 1,500 mm of rainfall per year) to the semiarid northwest (less than 750 mm), where irrigated lands account for less than 10% of the national area. The distribution of cotton area by province remained relatively stable during the 1980s, the top province being Chaco (more than 65%), followed by Formosa (about 10%), Santa Fe and Santiago del Estero (8% each) and Corrientes (3%). This ranking changed in the 1990s as a result of increased cotton production in the northwestern provinces. Chaco continued to hold first place with an average of 61% of cotton land from 1998–2002. It was followed by Santiago del Estero (25%), Santa Fe (5%), Formosa (4%), Salta (3%) and Corrientes (2%). The rest of the provinces account for less than 1% of cotton area.

## Varieties Grown

The primary goal of genetic improvement, or the development of new varieties, is geared to the requirements of the two main sectors of the national cotton industry: the agricultural sector and the textile industry. The former demands more productive varieties resistant to pests and diseases, while the latter needs fibers that are best suited to different spinning needs. Thus, cotton cultivars must meet a balanced and harmonious set of economic parameters to satisfy both sectors, but they must also be compatible with other parameters of agronomic importance.

Until the early 1990s, cotton cultivars developed by the Instituto Nacional de Tecnología Agropecuaria (INTA) were used on 100% of the area planted to cotton, which at the time amounted to some 600,000 ha. Cotton production is currently undergoing a crisis in the country and the cotton industry is stagnant. The total surface area planted to cotton dropped to only 174,000 ha in 2001/02.

Some years ago a number of privately run seed improvement companies were created, and by 1998/99 they began to introduce their own cultivars, both transgenic and conventional. The area planted to each cultivar is summarized as follows:

**Conventional Varieties**

| | % |
|---|---|
| Guazuncho 2 INTA | 55 |
| Porá INTA | 15 |
| Gringo INTA | 3 |
| Chaco 520 INTA | 3 |
| Cacique INTA | 4 |
| Oroblanco INTA | 0.3 |
| Morgan – Dow Elanco | |
| U X – 41 | 2 |
| MA 3 | 1 |
| Deltapine – Genética Mandiyú | |
| Deltapine 4049 | 0.7 |

**Transgenic Varieties**

| | |
|---|---|
| Genética Mandiyu (Monsanto-Deltapine-Ciagro) | |
| Nucotton 33 B | 6 |
| Deltapine 50 B | 10 |

The conventional varieties distributed by INTA cover 80% of the area planted to cotton.

The table below contains a summary of the main characteristics of these varieties determined by two years of testing:

**Main Characteristics of Conventional Varieties**

| Varieties | Ginning Outturn % | Fiber Properties: Length mm | Strength g/tex | Micronaire Index |
|---|---|---|---|---|
| Guazuncho 2 INTA | 39.7 | 30.0 | 28.7 | 4.4 |
| Porá INTA | 38.3 | 30.1 | 28.4 | 4.5 |
| Gringo INTA | 38.0 | 31.5 | 29.7 | 4.4 |
| Chaco 520 INTA | 37.0 | 31.6 | 31.7 | 3.7 |
| Oroblanco INTA | 39.6 | 29.7 | 29.2 | 4.3 |
| Cacique INTA | 39.4 | 29.8 | 28.5 | 4.4 |

Findings of comparative tests on INTA cotton varieties by region for 1999/00 and 2000/01. Fiber quality was analyzed on HVI, calibrated to International HVI Standards.

## Production Systems

Production conditions can be grouped in four categories based on structural variables. Each category contains subsets of conditions whose operations have many variables in common: area planted to cotton; type of traction available for agricultural work; farm machinery available; size of the holdings, and available labor (family or contracted). Following is a brief description of the categories.

### Miniholdings

This category comprises establishments where farm work is done by animal traction, using mostly old equipment in a state of overall disrepair and generally short of the minimum number required to do the farm work for efficient management. In most of these establishments, cotton is the only cash crop and in some others it is the main cash crop. These farmers are also involved in horticulture and fruit production. They also raise corn, sweet potato, cassava, beans, pumpkins and other crops for their own consumption. The labor force is mostly limited to members of the family and, occasionally, temporary workers are brought in for tilling and harvesting. About 60% of all producers are in this category. These holdings are generally less than 20 ha, with an average of 4.3 ha devoted to cotton.

### Small Plantations

The growers in this category raise their cotton using mechanical traction; they have a minimum stock of farm machinery needed for their agricultural labor and they have at least one tractor, sometimes even two. In most cases, repair of tractors and other farm machinery is from average to bad. The labor force is mostly limited to family members and, occasionally, temporary workers are brought in for tilling and harvesting. According to estimates, more than 50% of the crop is machine harvested.

These establishments are mainly devoted to farming, but about 70% raise cattle as a complementary activity. Their most important crop is cotton. Other important crops are soybeans, sunflower, corn, sorghum and wheat in a crop mix with cotton determined by geographic location, prices and climate conditions. According to estimates, this category accounts for about 25% of all producers. They generally farm from 21 to 90 ha of land, with an average of 21.1 ha planted to cotton.

### Medium Plantations

The growers in this category normally have at least two complete sets of farm machinery with two or more tractors in an acceptable state of repair. The administration and management of the firm is done by the family unit. They have full-time employees (such as tractor operators) and also employ seasonal hands for tillage and for complementary labor. Cotton harvesting is 100% mechanized and may be carried out using owned or rented equipment.

These establishments are mainly devoted to farming, but about 60% also raise cattle as a complementary activity. Cotton continues to be the main cash crop in some of these farms, depending on the area, but it generally has to compete with soybeans, sunflower, corn, sorghum and wheat. This category accounts for about 14% of all producers. They general farm from 91 to 800 ha of land, with an average of 77 ha planted to cotton.

#### Major Producers

This category has over 800 ha of land in production. They have an average of 1,000 ha planted to cotton, own several complete sets of agricultural machinery and employ tractors with state-of-the-art technology. Some of these firms have only recently gone into cotton production. Although there are no official statistics on the number of these large agricultural concerns, some estimates suggest that they are less than 1% of the total.

#### Cotton Producers Employing Irrigation

This classification of producers is essentially based on structural variables with the main stress on the amount of land under cultivation, but it is also valid for cotton production areas that employ irrigation, such as Santiago del Estero, Catamarca, Cordoba (Cruz del Eje) and La Rioja.

Cotton production operations on farms using irrigation utilize a number of input and output variables that differ markedly from cotton production operations in areas without irrigation. The physical and biological interrelations of these variables within cotton production operations are also different, and it would be logical to expect their analysis to be significantly more complex than that of areas without irrigation.

## Use of Fertilizers

The use of fertilizers is not widespread considering the total area planted to cotton. This is mainly due to the differential between input costs and cotton prices. The use of fertilizers has increased in recent years among some of the larger producers as a result of soil studies and diagnostics recommending the use of fertilizers.

**Area, Production and Yield in Argentina**

| Crop Year | Planted Area | Harvested Area | Production | Yield |
|---|---|---|---|---|
| | 000 Ha. | 000 Ha. | 000 Tons | Kg/ha |
| 1991/92 | 615 | 535 | 250 | 467 |
| 1992/93 | 378 | 367 | 145 | 395 |
| 1993/94 | 504 | 483 | 235 | 487 |
| 1994/95 | 762 | 700 | 350 | 500 |
| 1995/96 | 1,010 | 967 | 420 | 434 |
| 1996/97 | 956 | 887 | 330 | 372 |
| 1997/98 | 1,134 | 851 | 295 | 347 |
| 1998/99 | 751 | 650 | 200 | 308 |
| 1999/00 | 346 | 320 | 134 | 419 |
| 2000/01 | 408 | 385 | 166 | 431 |
| 2001/02* | 174 | 163 | 63 | 384 |

* Estimates

## Approval Process for Bt Cotton

After 1991, the private sector in Argentina as well as local research institutions began to take an interest in experimentation with genetically engineered material. The National Agricultural Biotechnology Advisory Commission, known as CONABIA, was organized to provide advice and technological support to assist the Ministry of Agriculture, Livestock, Fisheries and Food (SACF&F) in designing and enforcing the regulatory framework for the incorporation and introduction of genetically engineered material.

CONABIA is an interdisciplinary and inter-institutional body made up of representatives of public and private sector organizations involved in agricultural biotechnology. The relevant regulations in Argentina focus on characteristics and risks associated with a given biotechnological product instead of on the process by which it is produced. In other words, the regulations are applicable to genetically engineered products as a function of their proposed use. They are applied to the procedures used to create those products only when they could entail a risk to the environment, agricultural production or public health.

The regulations set forth the conditions that must be met before biologically modified materials may be introduced into the environment and CONABIA assesses each application it receives on the basis of these regulations. Furthermore, the regulations are an integral part of the general regulatory system for the agricultural sector: the regulations existing in Argentina in the area of plant protection pursuant to Decree-Law Nº 6.704/63 on health protection of agricultural production, and its subsequent amendments, on seeds and phytogenic creations and animal health. (*Decreto-Ley de Defensa Sanitaria de la Producción Agrícola Nº 6.704/63 y sus modificaciones, de semillas y creaciones fitogenéticas y de sanidad animal).* The evaluation of applications and the ensuing monitoring of tests are the responsibility of the Ministry of Agriculture, Livestock, Fisheries and Food.

Authorizations are given with the proviso that a certain number of precautionary measures must be adhered to. The biological safety of the materials to be authorized for introduction is determined by the characteristics of the material and the agro-ecological features of the area where it will be introduced. Authorization also requires compliance with sound experimental conditions, including the adequate credentials of the person or entity responsible for introduction into the environment.

The follow-up monitoring of tests is the responsibility of INASE, the former National Seed Institute, and SENASA, the National Food and Agriculture Quality and Safety Service, and is intended to ensure that there is an *in situ* verification of practical compliance with the representations made in the application. The monitors must also be prepared to step in to prevent adverse impacts on the environment (such as the spread of weeds). Batch controls are also performed immediately following the harvest to limit the danger of contaminating other organisms with the genetic information contained in the transgenic materials.

## Marketing of Genetically Engineered Materials

Once the authorization for introduction is given, operators may request a flexibility permit as provided for in Resolution No. 131/98 of the Ministry of Agriculture, Livestock, Fisheries and Food. At this stage, and provided that the evaluation of the information presented has ruled out any biological safety issues, a flexibility permit may be granted to allow the operator to make ensuing introductions into the environment with the sole prerequisite of reporting the area planted, the location of the introduction and the date of planting, while CONABIA limits itself to executing inspections of the harvest and of the final destination of materials.

The approval process for marketing consists of a three-step administrative process:

- Evaluation of risks to the agro-ecosystems stemming from commercial-scale cultivation of the genetically engineered material in question –flexibility– in the hands of CONABIA, a stage that takes a minimum of two years for approval;
- Evaluation of the material for the purposes of human and animal consumption, which is the responsibility of SENASA, a stage that takes no less than one year to complete;
- Decision on the advisability of marketing of the genetically engineered material based on an assessment of its impact on the market. This is the responsibility of the National Department of Agricultural and Food Markets and its goal is to prevent potential negative impacts on food exports from Argentina

Mon 531 Bt cotton was granted the Flexibility Permit on May 29, 1998 by SACF&F Resolution No. 290, and the Marketing Permit on June 16, 1998 by SACF&F Resolution No. 428.

## INTA–Monsanto Agreement

On April 22, 1998, the Instituto Nacional de Tecnología Agropecuaria (INTA) signed a technology agreement (joint venture) with Monsanto for the incorporation of transgenic material into INTA's present commercial varieties. The Bt transgenics provide this germplasm with resistance to the main lepidoptera pests, while "RR" provides resistance to glyphosate herbicide. Guazuncho 2000, the first variety obtained resistant to glyphosate was registered and approved for marketing in 2000. Growers will have access to this material for planting for the 2002/03 crop year.

**Bt Cotton Area in Argentina**

| Year | Bt Area (ha) | % of Total Area |
|---|---|---|
| 1998/99 | 4,800 | 0.8 |
| 1999/00 | 12,400 | 3.9 |
| 2000/01 | 23,600 | 6.1 |
| 2001/02 | 7,500 | 4.6 |

## Agreements for the Development of Conventional Varieties

Creation and commercial distribution of the conventional varieties developed by INTA were achieved through two joint ventures (five years duration each) with private seed companies. These companies provided INTA with a yearly budget to finance INTA's Genetic Improvement Program for cottonseed, as well as the production of prebasic seed. These seeds were turned over to them for multiplication and exclusive marketing in the country and in neighboring countries in the following categories: Basic, "Certified" ($1^{st}$ generation) and Registered ($2^{nd.}$ generation).

During the last two crop years (2000/01 and 2001/02), work was carried out pursuant to a Letter of Agreement providing essentially the same system, a financial contribution for the Genetic Improvement Program, and production of prebasic seed. This agreement was signed with four firms (two cooperative and two seed companies), which assumed responsibility for production and marketing of INTA's six commercial varieties in the country and in neighboring countries. This agreement expires at the end of 2002.

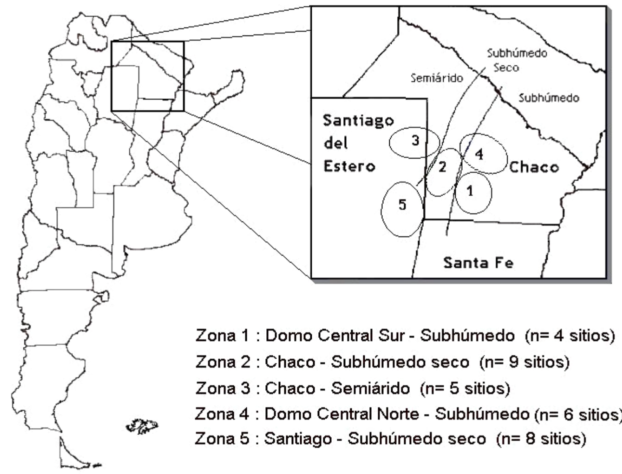
## Economic Advantage of Bt Cotton in Argentina

Commercial production of transgenic cotton varieties has changed the production system in Argentina, and area planted to transgenic varieties is growing. The new technology requires changes in pest control strategies. An economic analysis was conducted on the 1999/00 crop in different ecologic areas to compare Bt cotton to conventional varieties. The study focused on analyzing costs and income differences between transgenic and conventional varieties. Additional benefits were determined through the analysis of direct costs of the crop cycle and not just the costs of insecticide application. Widespread use of this technology seems to be rooted in its potential to provide better total economic results associated with better yields and lower costs.

### Data Sources and Methods

The work was conducted in 64 lots in growers' fields (32 sites of transgenic varieties and their corresponding plots), scattered in the provinces of Chaco and Santiago del Estero. The survey covered different agro-ecological areas, such as: a) Central North and South Domo (areas 4 and 1) are defined by the Thornthwaite Index (TI) as sub-humid; b) Sub-humid dry Chaco and Santiago, TI's sub-humid dry (areas 2 and 5), and c) Semi-arid Chaco (area 3), TI's semiarid (INTA, 1990). The soil from areas 1 and 4 is made up of original loess material, while the remaining ones are alluvial (Ledesma, 1977). The geographic location of the areas described is shown in the figure.

The transgenic variety used was NC 33B. The control varieties (S) were conventional varieties generally used in the area, mainly Guazuncho 2 INTA, Chaco 520 INTA, Gringo INTA, Porá INTA and DP 5690. Data gathering for costs covered from the beginning of land preparation to the end of harvesting. Labor costs are for a 100 HP tractor. Input prices were averages for the area of Sáenz Peña, as of June 2000, excluding VAT. Raw cotton yield/ha, ginning outturn and commercial quality of cotton produced were taken into consideration to determine income, the latter two as determining price factors. The price of cotton was the current market price passed by the Argentine Cotton Chamber for the same date, without premium or discounts. The exchange rate used is the one applicable at the time of this study: 1 Argentinean peso = US$1.




Geographic Location of Agro-ecological Areas

The methodology used was partial budget (Bryan et al. 1997). Direct costs were disaggregated in components: land preparation labor and crop handling, insecticide application, seed (Gibson et al., 1997), other inputs, and harvesting and marketing. The incremental benefit, such as income differences and additional costs, were calculated (ReJesus *et al*., 1997).

## Results

Results obtained were separated by components for costs as well as for income, and they were expressed in $/ha. Labor costs necessary for crop handling were estimated, except insecticide application. In total, there were practically no differences in labor costs between both alternatives. Minimum and maximum values were $14.30 and $76.9/ha, respectively, the minimum corresponding to a no-till planting system, and the maximum to a conventional tillage system. At each site, the planting system was the same for both alternatives. No differences in labor costs were seen within an area, except in area 5. There were differences among locations, location/area 4 being the one with highest labor costs at $62.0/ha; and area 5 with the lowest labor costs, with Bt at $42.8/ha and S $38.6/ha.

Regarding the number of insecticide applications, Bt accounted for an average reduction of 2.4 applications, which represents a 64% reduction over the control. Maximum and minimum values ranged from 3 to nothing for Bt, and from 8 to 1 for control. Reductions in insecticide applications between Bt and S ranged, depending on the area, between 1.2 and 4.4 (33% to 85% fewer applications) in areas 3 and 5 respectively. The average of the 32 sites analyzed showed a difference in costs of –$27.6/ha in insecticide applications, favoring Bt use. In all areas pest control cost was lower for Bt, and savings ranged from $15.4 to $46.4/ha.

The cost of transgenic seed includes charges for the Bt technology, and the cost of conventional seed includes only the planting seed costs. Bt seed costs exceeded the cost of conventional seed in values that ranged from $68.5 to $79.3/ha. Average Bt seed costs were $73.9/ha higher than for conventional seed.

**Economic Analysis of Benefits Between GE and Control ($ per ha.)**

| Description | Average | Area 1 | Area 2 | Area 3 | Area 4 | Area 5 |
|---|---|---|---|---|---|---|
| Income | 159.02 | 62.29 | 183.71 | 58.73 | 95.68 | 289.8 |
| Labor costs | 0.87 | 0 | –0.63 | 0 | 0 | 4.19 |
| Insecticide application costs | –27.55 | –18.7 | –24.01 | –15.38 | –23.84 | –46.36 |
| Seed costs | 73.88 | 71.75 | 79.32 | 69.16 | 78.27 | 68.5 |
| Other input | 1.65 | –3.94 | 6.17 | 1.06 | 2.3 | –0.75 |
| Harvesting and marketing costs | 45.11 | 25.61 | 43.15 | 13.43 | 27.97 | 89.73 |
| Direct total costs | 93.97 | 74.72 | 104.02 | 68.27 | 84.7 | 115.31 |
| Bt incremental benefit | 65.05 | –12.43 | 79.7 | –9.54 | 10.97 | 174.5 |

Benefit attributed to Bt was calculated as the difference between income and additional costs.

The greatest difference between Bt and S was observed in seed cost components. According to this data, a 460 kg/ha seedcotton difference in average additional yield of Bt seedcotton would be required to offset the difference in seed costs. Additional yields ranged from 345 to 518 kg/ha seedcotton, among the test areas.

Herbicides, growth regulators, fertilizers, defoliators, etc., were included in other inputs. No major differences were seen between average costs, being higher for Bt by $1.7/ha. Cost differences by area were –$3.9/ha in area 1 and –$0.7/ha in area 5. In areas 2, 3 and 4 costs were higher for Bt cotton by $6.2, $1.1, and $2.3 /ha, respectively.

Harvesting costs were calculated by type of harvesting used by the producer: mechanical or manual (manually, only 1 producer for 50% of the land). Marketing costs included taxes and contributions based on current legislation. Average harvesting and marketing cost differences for the 32 sites showed that GE cotton presented higher values by $45.1/ha. Maximum costs ranged from $181.1/ha to $241.5/ha, and minimum costs from $67.9 to $52.8/ha for Bt cotton and control respectively. With regard to area, costs were also higher for Bt cotton. Differences ranged from $13.4/ha in area 3, to $89.7/ha in area 5.

Total direct average costs for Bt cotton were $94.0/ha higher due to increases in seed costs and harvesting and marketing, which exceeded savings obtained by reduced use of insecticides and other components. Differences by areas ranged from $68.3/ha to $115.3/ha. The direct total cost per ton of Bt seedcotton was found to be $56/ton lower than S. In areas 4 and 5, the cost of Bt per ton was $31/t and $91/t lower than S, respectively. In areas 1 and 3, it was $23/t and $14/t higher than S, and in area 2 there were no cost differences between the alternatives.

To determine income, yield, commercial quality and ginning outturn were analyzed, the latter two determining the price obtained for the product. Average raw cotton yields were taken and weighed by total area sown for Bt and S. Bt raw cotton yields were 907 kg/ha seedcotton higher, on average, varying by area from 216 to 1,252 kg/ha seedcotton. Most frequent values for quality were taken, without observable differences between Bt and S. Among maximum values, Bt had a superior quality with a 1.25 quality difference and 0.75 at minimum values. Ginning yield is another variable that determines price. S's average value exceeded Bt by 0.54%, and the variability obtained among data was low (4 to 6%). In the analysis by area, just the opposite took place in area 3, i.e. Bt exceeded S by 0.64%. The average raw cotton price in the 32 sites was $0.009/kg higher for Bt cotton ($0.236 for Bt cotton and $0.227/kg for control).

Average income for the 32 Bt sites was $159.0/ha higher than for S. In the analysis by area, average income was also higher for Bt. Differences among areas, from area 1 to 5 were $62.3/ha, $183.7/ha, $58.7/ha, $95.7/ha and $289.8/ha respectively. The smallest difference was found in area 3, and the highest difference in area 5 because of the difference in yields spotted between Bt and S in both areas: 1,252 kg/ha seedcotton in area 5 and 227 kg/ha seedcotton in area 3.

The average incremental benefit generated by the use of a Bt variety was $65.1/ha. The degree of variation between maximum and minimum values ranged from –$214.39 to $326.48/ha. For the 32 data sets analyzed, 11 (34%) exhibited negative results; 9 (28%) exhibited positive results up to $100/ha; 7 (22%) presented values ranging from $101 to $200/ha; and 5 (16%) presented more than $200/ha. The average incremental benefit in areas 1 and 3 was –$12.43 and –$9.5/ha. Positive but different values were obtained in areas 2, 4 and 5. Bearing in mind that the data corresponds to only one year, the analysis per area would indicate that under the 1999/00-season conditions, the most appropriate areas for GE cotton, as measured by Incremental Benefit, were 2 and 5.

## Conclusions

It is concluded that Bt cotton lowered insecticide use by 2.4 applications (64%) and saved an average of $27.6/ha. GE cotton produced higher yields, from 345 to 518 kg of seedcotton/ha. Higher yields offset the difference in seed costs that existed between Bt and S. The reduction of insecticide application costs couldn't offset cost increases generated by Bt. Direct total costs for Bt per unit area, on average for the 32 sites, were $94/ha higher than those obtained with conventional varieties. Direct total cost per unit of product in Bt cotton is $56/ton lower than control. Bt yield was 907 kg/ha higher than control, the difference ranged from 216 kg/ha to 1,252 kg/ha seedcotton. Bt income was $159/ha higher on average, varying by area from $58.7/ha to $289.8/ha. The average incremental benefit ascribed to Bt was $65/ha.

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# Short Notes

## • Bt Cotton Approved in India

By area, India is the largest producer of cotton in the world. According to the latest ICAC estimates, cotton was grown on 8.7 million hectares during 2001/02. The average yield is expected to be 287 kg/ha, one of the lowest in the world. Pests are an important factor in limiting yields. In India, cotton is sprayed an average of 5-6 times every year, and only 2% of area is not sprayed; 15% of the total area gets only two sprays, 30% gets up to four sprays, and 20% gets up to six sprays. On average, 30% of the total area gets over six sprays per season. Sucking insects *Amrasca biguttula*, *Bemisia tabaci* and *Thrips tabaci*, and bollworms attack cotton in India, but most of the sprays are directed to control bollworms. The cotton bollworm and the pink bollworm, *Helicoverpa armigera* and *Pectinophora gossypiella*, are the major bollworms affecting cotton in India. Transgenic Bt cotton is particularly effective against *Helicoverpa armigera*, which has already developed resistance to a variety of insecticides in India. Bt cotton also controls *Pectinophora gossypiella*, which is widespread in India and during most years is the second most damaging pest on cotton in the country.

Maharashtra Hybrid Seed Company, a private seed company that has a joint venture with Monsanto to introduce Bt cotton in India has been testing Bt cotton since 1996/97. On March 26, 2002, the government of India approved commercial production of Bt cotton. The Genetic Engineering Approval Committee, on recommendations from the Indian Council of Agricultural Research, granted the approval. Initially, only three hybrids having the Bt gene Cry1Ac have been allowed to be grown on a commercial scale. Hybrids Bt Mech 12, Bt Mech 162 and Bt Mech 184 have been cleared, while trials on the fourth hybrid continue. It is expected that more hybrids and varieties will be allowed for commercial production.

Initial approval is valid for three crop years from April 2002 to March 2005. It is also required that a refuge crop be planted with the Bt hybrids. The Genetic Engineering Approval Committee has stipulated that fields where Bt hybrids are grown must be surrounded by a non-Bt variety of the same origin. The refuge crop will comprise five rows, or 20% of the area, whichever is more, of the non-Bt hybrid of the respective Bt hybrid.

Cotton is the first transgenic crop approved for commercial cultivation in India. Some varieties of mustard are awaiting similar approval. It is expected that about 150,000 hectares will be planted to Bt cotton hybrids in 2002/03. Hybrid cotton is not grown in the northern region and 150,000 hectares are less that 2% of the ICAC forecast on the area to be planted to cotton in India during 2002/03. Therefore, an immediate impact on the national average yield may not be visible in one year. But a significant area may go to Bt Mech 12, Bt Mech 162 and Bt Mech 184 and other Bt hybrids already approved by 2003/04.

India is the eighth country to approve commercial production of Bt cotton. One of the significant limitations in extending Bt cotton to other countries affected by the bollworms mentioned above, and other bollworms controlled