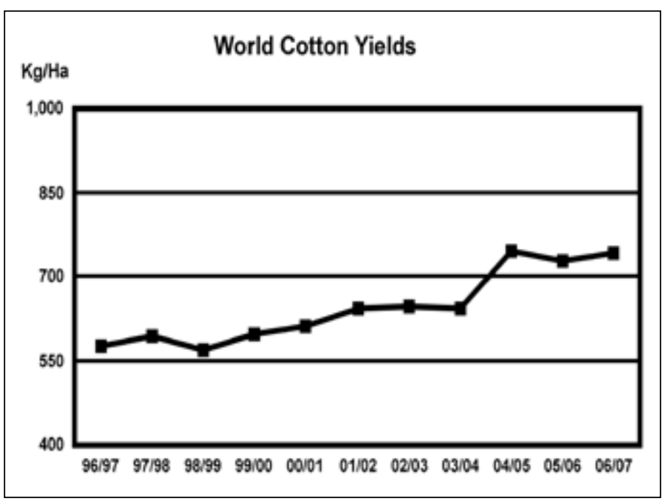
Biotechnology Applications in Cotton: Concerns and Challenges

The use of genetic engineering in agriculture, including cotton is new. Genetically engineered cotton resistant to insects was commercialized in 1996/97, and so far nine countries have allowed commercial production of biotech cotton. The ICAC Secretariat estimates that 36% of world cotton area was planted to biotech varieties in 2006/07, and this area is expected to account for 45% of world cotton production in 2006/07. India commercialized biotech cotton in 2002/03, Colombia in 2003/04, and Brazil only in 2006/07. The area planted to biotech varieties in these countries is still increasing. The requirement for a refuge crop is limiting biotech cotton area in some countries. Nevertheless, biotechnology is the fastest adopted technology in the history of agriculture. If the adoption of biotechnology did not require regulatory approval and, if the technology was freely available, as was the case with other technologies like short stature wheat and rice, many more countries would have adopted biotech cotton by now. However, the biotechnology has proved to be the most controversial technology in the history of agriculture.

Impact on Yield

Over the last 30 years, the world yield rose on average at the rate of 2% or about 8 kg/ha per year. There have been periods of slow growth and similarly there were periods of faster growth. The world yield rose to a new record of 600 kg/ha in 1991/92, but there was no increase in yield for the next six years until 1997/98. Since then, the world yield rose to 742 kg/ha in 2004/05. The average yield in 1996/97, the first year of adoption of biotech cotton was 575 kg/ha. The average yield in 2006/07 is expected to be 742 kg/ha. Not all, but a significant proportion of this increase, comes from the use of biotech varieties providing better protection against pests. The 29% increase in world yield over the last 10 years is un-precedent in the recent history of cotton.



To estimate the role of biotechnology in increasing the world yield, many assumptions are required. A comparison of yields in Bt area versus non-Bt adopted areas is presented here. Cotton producing countries were divided into two groups; countries that produce Bt cotton (Argentina, Australia, Brazil, China (Mainland), Colombia, India, Mexico, South Africa and USA) and countries that do not yet produce Bt cotton.

Performance of Yield in Bt Producing Vs Non-Bt Producing Countries

	Bt Producing	Non-Bt Producing	World
Area in million ha 2005/06	20.4	13.6	33.9
Average annual increase in yield			
1966/67 to 1975/76	1%	1%	1.10%
1976/77 to 1985/86	6%	2%	3.50%
1986/87 to 1995/96	1%	1%	0.80%
1996/97 to 2005/06	3%	1%	2.70%

The data above indicates that there are variable rates of yield increases, and the period of 1986/87 to 1995/96 was slower than the previous two decades. Further analysis of this decade indicates that slower growth was due to no increases for four years from 1992/93 to 1995/96. The two groups of countries, Bt and non-Bt, showed similar behavior for two decades but not for the decades from 1976/77 to 1985/86 and from 1996/97 to 2005/06. The higher increases in yield in Bt growing countries from 1976/77 to 1985/86 can be attributed to the adoption of insecticides. The other countries adopted insecticides, but later and applications were often not done correctly, including use of threshold levels, spray machinery, proper chemicals, etc. The last ten-year differences in yield indicate that countries adopting Bt showed higher increases, which could be attributed to the new technology.

Biotech cotton has multiple advantages, and most papers and reports that have been published on this technology are favorable. However, the technology carries risks, and unfortunately the negative aspects of biotechnology have not been properly covered in scientific publications. This article is focused on the negative aspects of biotechnology in cotton, aiming mainly to make people aware and therefore more careful, rather than to diminish the positive aspects of this technology. This discussion does not mean that the ICAC Secretariat is opposed to this technology. Moreover, only issues related to biotech cotton as a fiber crop are discussed in this article.

Misuse of Gene Action Technology

Many biotechnological tools are available to utilize genetic variability from within species, across species and beyond species. Bt cotton was developed utilizing a gene from the soil bacterium *Bacillus thuriengenesis* and it is not the gene as such that actually gives rise to a new characteristic. All genes code for specific proteins, which actually do most of the work in the cell. The Bt gene codes for a specific protein, Cry 1Ac, in genetically engineered biotech varieties, the protein produced by the Cry 1Ac gene performs the function of killing Lepidoptera species. To ensure that the gene-coded protein is made in the right tissue at the right time, genes have switches, or promoters, that direct the cell when and where to make a particular protein. Genes present in the genome have these switches; the switches are turned on only in the right part of the plant. With genetic engineering tools, different switches can be attached to desired genes, directing them to work at a special tissue or remain dormant until they are activated.

Researchers in the private sector, in collaboration with the USDA, employed genetic engineering tools to develop the "Technology Protection System" in cotton (gene terminator). The technology protection system was not commercialized but it would have been if farmers and other segments of the cotton industry had not objected so much to the technology.

Researchers started to develop a self-sterile seed system in 1993, three years before biotech varieties were commercialized. The technology advanced well and received a patent in 1998. The technology protection system was a clever three-gene system that forced plants to produce a toxin that was fatal to their own seeds. The complex array of gene promoters, which in a normal state were inactive, proved successful at all experimental stages in the lab and in the field. The variety with a technology protection system was able to produce viable seeds only when needed. The sterile seeds were treated prior to sale so that they would germinate like normal seeds but the resulting plants would not produce viable seeds. The treatment triggered an irreversible series of actions rendering the produced seed non-viable for planting. The toxin was produced late in the season, so that the seed's commercial value for oil extraction and livestock feeding was not lost. This technology protection system, as is evident from the name, was developed to stop the illegal spread of biotech seeds by making it impossible for farmers to plant the seeds the next year. This technology was not commercialized, but similar tools could be employed in the future in different forms that could work against growers, processors and even users.

Development of Resistance to Bt Toxins

Once a Bt gene is inserted into a variety, the Bt toxin is produced throughout the cotton plant during the entire growing season. Consequently, target pests are exposed to high levels of the toxin continuously, a situation likely to elicit resistance faster than intermittent exposure to conventional insecticides. All sectors of the cotton industry, including pesticide companies and biotech technology owners, agree that it is only a matter of time before cotton pests evolve resistance to the Bt toxin. However, it is possible to delay resistance if farmers incorporate resistance management strategies into their cotton production systems. Otherwise, without effective management plans, the effectiveness of Bt varieties could be lost in just a few growing seasons. Thanks to the lessons learned from the intensive use of insecticides, the resistance problem was identified even before biotech varieties were commercially introduced. Accordingly, appropriate measures in the form of refuge crop and gene pyramiding were undertaken and resistance has not become a problem so far. But the threat is real and acknowledged by everybody.

Change in Weed Control Systems

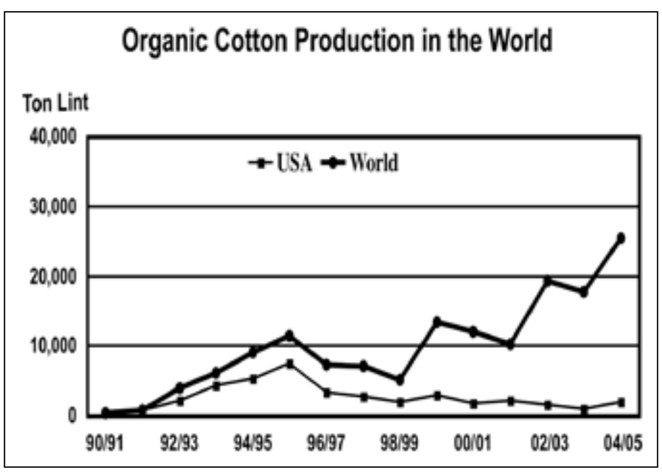
Herbicide resistant biotech crops encourage the use of herbicides. According to James (2006), the herbicide resistant character has consistently been the dominant trait since the commercialization of biotech crops. In 2006, the herbicide resistant trait occupied 70% of the 102 million hectares planted to biotech crops in 22 countries. 19% of the total area had only the Bt gene while the remaining area was devoted mostly to stacked traits of Bt and herbicide tolerance. The herbicide resistant trait in cotton is popular in Australia and the USA. In the USA, herbicide resistant biotech cotton was over 95% of the area planted to biotech varieties in 2006/07.

Herbicide resistant biotech cotton has changed the weed control systems in Australia and the USA. Weed control prior to Roundup Ready cotton involved multi-dimensional approaches from several angles to achieve the best control. These approaches involved preplant incorporation (PPI), applications at planting (PRE), postemergence-directed (PDIR) applications when the cotton reached 3 to 4-inches in height or once a height differential was established between cotton and weeds, cultivations, non-selective herbicides under hoods, layby applications, spot spraying, and hand weeding (Dotray and Keeling, 2006). Studies on weed biology and weed control effects on succeeding crops in a rotation were also considered.

The benefits of a herbicide resistant biotech system include broad spectrum weed control, convenience, simplicity, increased efficacy and crop safety and reduced labor, which is expensive in Australia and the USA. Increased use of herbicide resistant biotech cotton has resulted in fewer tillage operations, more narrow row cotton, larger spray booms, fewer herbicide modes of action, reduced application of herbicides in soils at planting (especially PPI), and reduced labor and machinery requirements. Other changes since the use of herbicide resistant technology include shifts in weed species and the emergence of herbicide (glyphosate) resistant weeds. New weed species and the development of 'super weeds' are the most serious among all effects. Resistance could deprive cotton growers from the most popular herbicide (Glyphosate due to its low cost, ease of use and its activity on a broad spectrum of weeds) used on cotton. Roundup Ready Flex cotton was introduced in the USA in March 2006. Roundup Ready Flex offers a wider window of application timing without the risk of possible yield loss. Applications can be made up to seven days before harvest, which is only going to aggravate the potential of resistance development.

Setback to Organic Cotton Production

Statistics show that 11,527 tons of certified organic cotton were produced in 1995/96. Organic cotton production declined for the next three years before picking up again. The USA was the leading organic cotton producer in the world. The U.S. National Organic Standards Board defines organic agriculture as 'an ecological production management system that promotes and enhances biodiversity, biological cycles, and soil biological activity.' One of the prerequisites for organic production is certification from a recognized certifying agency that the cotton has been produced following the organic cotton producing requirements set under the U.S. National Organic Standards Act. The primary requirements for organic production are to use materials and practices that enhance the ecological balance of natural systems. Organic cotton production was never large, but it was increasing slowly until biotech cotton was introduced. However, the National Organic Standards Board in the United States, on the advice of producers of organic products, regards biotech varieties as not eligible for certification as organic. This decision negatively



affected the spread of organic cotton in the USA. With 88% of the U.S. cotton area under biotech varieties in 2006/07, there are fewer chances of producing organic cotton than there were prior to 1996/97. Currently, Turkey is the largest organic cotton producer in the world sharing 44% of organic cotton produced in the world in 2005/06 (Wakelyn and Chaudhry, 2007).

In addition, organic cotton growers face the challenge of keeping organic produce separate not only from conventional produce but also from biotech produce during handling, ginning, and processing. This is in addition to requirements for distances between fields that prevent biotech varieties from crossing over to non-engineered conventional varieties. The chances of out-crossing with wild species are extremely low, but the chances of contamination with another variety grown under organic conditions are much higher. As long as biotech varieties are grown in the same area as organic cotton, organic producers are at risk of their crops being exposed to background levels of biotech varieties.

Another of the many consequences of insect-resistant biotech cotton to organic cotton is the restriction not to spray microbial insecticides (insecticides also made from *Bacillus thuringiensis*) on biotech varieties. The market for Bt insecticide has been significantly decreased, and biotech use has proved to be a disincentive for producers to continue producing the microbial insecticide. This has had the result that the organic producers have lost one of their most valuable pesticides.

Organic cotton production is increasing lately in India and Turkey, where most cotton is still no-biotech. It is estimated that 23,200 tons of organic cotton were produced in the world in 2005/06 and close to half was produced in Turkey. Over 40% was produced in India and very little in the USA. The area planted to biotech cotton is increasing in India and it could affect organic cotton production.

Labeling and Consumers' Rights

Cotton is a fiber crop, but approximately 40 million tons of cottonseed are also produced annually, most of which is used to make vegetable oil for human consumption in developing countries. In principle, farmers should have a choice of the variety they grow, be it biotech, conventional, or organic. This assures the availability of a variety of products in the market. However, like the producer, the consumer is also entitled to choose the product he or she likes. The introduction of biotech cultivars makes labeling imperative for all countries, and the world in general. Many European countries and environmental groups are concerned about biotech products in the food chain and advocate labeling produce from biotech varieties. Some people even see such labeling as necessary for biotech products to survive and compete successfully with conventional products.

Long Term Consequences

The use of biotechnology in crop plants is new and so far experienced by 22 countries. However, only five countries i.e. Argentina, Brazil, Canada, India and USA, shared 92% of the 102 million hectares planted to biotech crops in 2006/07 (James, 2006). Three other countries China (Mainland), Paraguay and South Africa shared another 6% of the biotech crop area in 2006. The remaining 2% of area was grown in 14 other countries. It means that only a few countries have extensive experience, which is a short experience. Most of the biotech cotton area outside the United States is in developing countries, including China (Mainland) and India. The most intensive use of biotech cotton has been in Australia and the United States, where biotech cotton varieties have been grown for the last eleven years. Eleven years is too short a time to assess long-term consequences of a new technology that is so different from long existing technologies; researchers admit that there is insufficient scientific data regarding the long-term effects biotech varieties may have on the environment or on human health. Even though the technology might not have long-term consequences, the concerns are there.

Percentage of Insecticides Applied to Target Pests in Australia (2004/05)

Pest	Helicoverpa	Mirids	Aphids	Others
Conventional cotton	92	1	4	3
Bollgard II cotton	3	55	21	21

Source: Pyke and Doyle (2006)

Illegal Biotech Cotton With All of Its Consequences

Biotech varieties in Australia, the United States and other countries are sold to cotton growers under an agreement to follow refuge requirements, not to spread the seed to other farmers and not to keep seed for self-planting in the following year. However, these conditions have been violated extensively in a number of countries. Farmers not only save seed for planting, but they pass it on illegally to others. Zoning of varieties has been violated, and varieties have been cultivated on a large scale in areas where they were not approved or recommended. Bt cotton has illegally traveled to many countries. Illegal use of biotech varieties is a blatant violation of biosafety regulations, and could spoil seed purity, performance, and safety as well as the credibility of legitimate biotech products and technology. Illegal sellers can afford to sell their products at a much lower price, as their investment on research is meager. Biotech pirating could affect the confidence and enthusiasm of genuine technology developers, who invest a lot of time, talent, and money in developing new products and getting approval through proper regulatory procedures. At the same time, pirating is misleading and confusing users, who do not observe refuge requirements and contribute to a bigger problem.

Biotech Cotton and the Pest Complex

Bt cotton is effective against a variety of budworms and bollworms, but it is not effective in controlling many secondary pests. The emergence of secondary pests in Bt cotton is by no means a random event. The experience in China (Mainland) showed that populations of secondary pests such as aphids, mites, thrips, lygus bugs, whitefly, and leaf hopper, increased in Bt cotton fields after the target pests—budworms and bollworms—had been controlled (Xue, 2002). It is known that the currently discovered Bt proteins Cry 1Ac, Cry 2Ab, VIP, and Cry1F do not control sucking pests; insecticides have to be used to control them. However, chemicals used to control budworm and bollworms have a relatively broad spectrum toxicity so when used against target insects they also kill sucking insects. The situation may vary from country to country, but data show that organophosphates comprised almost 90% of the insecticides used on cotton in 2000/01 in the world. Therefore, there is an additional advantage of insecticide spraying: partial control of non-target insects. When biotech varieties are used, there is a possibility of recording higher populations of pests that are not Bt targets during the period of no insecticide sprays. This is what has been observed in the work reported by Xue (2002), and this was expected to occur in nature. Wang *et al* (2006) observed that 'China provides strong evidence that secondary pests, if unanticipated, could completely erode all benefits from Bt cotton cultivation.'

In Australia Bollgard II® cotton has dramatically reduced the need to spray for *Helicoverpa* spp. and other lepidopteran pests. Sucking pests previously controlled by these broad-spectrum sprays are now a management issue in Bollgard II® cotton. Such pests include the green mirid, *Creontiades dilutus,* which has increased significantly in Australia and China (Mainland). In the USA, tarnished plant bug *Lygus lineolaris* has become a high concern.

Supporters and opponents of biotech cotton agree that Bt genes provide good control of target pests. But once the targets pests are controlled, minor and non-target pests may emerge as major pests. When minor pests become major ones, they may change the pest complex situation, and pests that are more difficult to control than the target pests may emerge as major pests, bringing new and difficult problems. The possibility of sucking insects gaining higher importance is always there.

Biotech Cottons and Beneficial Insects

The insect-resistant biotech cotton varieties provide resistance to a specific group of insects that includes most bollworms and budworms but excludes natural predators and parasites.

The active toxin binds to receptors in the insect's stomach cells. The binding creates pores in the wall of the insect's gut, allowing ions to equalize, ultimately causing the gut to lose its digestive function. Once the binding has taken place after ingestion, the insect's gut is paralyzed, forcing it to stop eating. After the stomach is immobilized, the cells break open and the pH of the stomach decreases as its fluids mix with the lower-pH blood. A lower pH allows the spores to germinate and colonize the rest of the insect's cells. The bacteria spread throughout the rest of the host by the bloodstream until complete paralysis of the insect occurs. This process takes anywhere from an hour to a week to kill the insect. Beneficial insects might feed on insects that have taken up the toxin but have not died yet, or might digest by-products of insects such as honeydew that are contaminated with toxin. No data show that biotech toxin kills beneficial insects, but the toxin could harm beneficial insects indirectly in the two ways described above. The third, indirect, effect could be in the form of poor quality food if the transgenes reduce the quality of the host or prey insects that are available for feeding. This could be true particularly in cotton of the third and later generations of insects towards crop maturity, when the amount of toxin is reduced and not all the target larvae will be killed.

Human Health and Environment

If a genetically engineered plant produces a new protein, there may be some risk that humans could be allergic to the new protein. Biotech products have been tested for their effects on non-target insects, human health, and the environment in their country of origin. No ill effects have been found, but a notion still persists among countries and the public reluctant to adopt biotech products that the new technology carries potential threats to the environment and non-target insects. This issue may be more relevant to food crops than cotton, which is grown as a fiber crop. Unfortunately, biotech cotton has been treated like biotech food crops, since its byproducts are used for food and feed. In addition, biotechnology applications have not reached their peak, and future products could create such problems, particularly if something such as an antibiotic gene is inserted into cotton or other food crops for ease of distinguishing transformed plants from non-transformed types, or for the production of pharmaceutical substances.

StarLink™ corn is grown on a commercial scale in a number of countries, but it is not approved for human consumption. Studies can be cited showing that an allergic reaction has occurred for some consumers who have eaten food products containing StarLink™ biotech corn. StarLink™ biotech corn carrying the Cry9C gene was commercialized in the late 1990s and since then it is approved only for animal feed. The Cry9C protein breaks down slowly in the digestive system, an indication that it might induce allergic reactions. StarLink™ is a corn variety genetically modified to be resistant to the European corn borer and tolerant of glufosinate herbicides such as Liberty™. Some growers in the USA ignored the agreement not to sell StarLink™ corn to mills using the flour for human food and StarLink™ corn ended up in the food chain. After the contamination of StarLink™ was detected in foods, Aventis petitioned the US Environmental Protection Agency (EPA) to consider allowing the "temporary approval" of StarLink™ corn for human consumption, based on new data provided by Aventis. The EPA reviewed the new data and deferred to the advice of its scientific advisory panel (SAP). The SAP published its analysis on December 5, 2000--concluding that StarLink™ does pose a moderate allergy risk. EPA ruled on July 27, 2001, that it would not accept Aventis' petition to allow StarLink™ for food use, and that its policy of zero tolerance would continue.

Technological Limitations

Breeding, the art and science of developing new varieties, has been untaken for centuries, and genotypes and cultivars drastically different from their wild ancestors and relatives have been developed. Developments have been achieved in agronomic performance, including higher yield and better fiber quality in cotton, contributing to productivity and quality improvements. While breeding can bring drastic changes, biotechnology applications, at least so far, have been limited to specific changes in existing genotypes and cultivars. Conventional breeding will always carry a large gene pool to exploit genetic variability according to an area's growing conditions, since, for example, certain varieties perform better under sandy soils while others perform better under rainy or drought conditions. Molecular genetic engineering breaks down the incompatibility barriers among different forms of life and makes it possible to transfer a gene or genes from one level of life to another. However, certain limitations will always apply to biotechnology, and sometimes conventional breeding will prove to be better.

Dominance of the Private Sector

Private companies have a major role in commercialization of biotech products. Certain issues like "international patent to transform cotton" have been of great concern to all countries. Companies own specific genes, which no one else can legally use without their permission. Such conditions are limiting the use of biotechnology applications in developing countries. In contrast, most of the developing countries benefited from the "green revolution" in a short time because the public sector acquired the technology quickly and spread it to farmers. The primary objective of the green revolution was to produce more food and alleviate poverty. Therefore, farmers were the primary beneficiaries and they produced more food without increases in the cost of production. This is not the case with biotechnology. The private sector views biotechnology mainly as a source of income and a way to compete with other companies, and only secondly as a tool to solve problems. The monetary intent is apparent from the technology fee, which is different in different countries for the same Bt gene. The fee is related not to the cost of development but to savings on insecticides used and the financial conditions of farmers. For this reason, the technology fee for the Bollgard gene is higher in Australia than in the United States. Also, the technology fee in Australia has been changed more than once.

Technology is Expensive

Agricultural technological innovations like the green revolution came at various stages, always bringing with them some cost in developing and acquiring that technology, but nothing like the cost of biotechnology products. Further, if the technology was acquired through seed, the cost was paid only once, except in the case of hybrid seed in corn or commercial cotton hybrids in India. This condition was not coming from technology developers but it was a genetic issue where nothing could be done except to produce planting seed every year. For biotech crops, farmers have to pay for insect- and herbicide-resistant technology every year, which makes the technology more expensive. Argentina commercialized Bt cotton in 1998, but so far Bt varieties cover less than 25% of the area. The high cost of biotechnology is limiting the use of this technology in many countries. The high cost also encourages the illegal use of technology products. Biotechnology research is expensive and if started, particularly under limited resources in developing countries, could be done at the cost of other research.

Search for Newer Genes

It has been 11 years since insect-resistant and herbicide-resistant cottons were commercialized. The only two new biotech cotton products commercialized since then belong to the same two categories. The search for additional genes may have been initiated even before the commercialization of biotech cottons, but new forms of biotech cotton (other than insect- and herbicide-resistance) are not expected to be released any time soon. New genes are needed but how far we can go to explore and utilize new genes is another consideration. The ICAC's Second Expert Panel on Biotechnology of Cotton observed that the difficulty in identifying new genes with classical traits is the most important limitation to the use of biotechnology applications (ICAC, 2004).

Biotech Cotton is not Suitable for all Production Systems

Cotton is grown under a variety of growing conditions and production systems. Cotton in general is a small growers' crop, as most farmers in developing countries own only a small piece of land. Private companies can sign direct contracts with large growers, something that is very difficult to do under small-scale farming systems. Additionally, insect- and herbicide-resistant biotech varieties are not suitable for all production systems. The target pests do not exist everywhere, and many countries just do not need them. The boll weevil *Anthonomus grandis* is the most serious pest in the Latin American region. Many Central American countries had to quite cotton production due to extremely high costs to control boll weevil. Argentina, Bolivia, Brazil, Colombia, Mexico and Paraguay would see a higher benefit in boll weevil resistant biotech cotton compared to lepidoptera resistant biotech cotton.

Opposition Due to Lack of Knowledge and Over Cautiousness

Genetically engineered biotech varieties resistant to insects have faced opposition from a number of organizations and individuals from the beginning, even before the technology was commercialized. The issues raised were mostly speculative, complex, and confusing. It was claimed that the Bt protein might be harmful to humans, farm animals, other beneficial organisms, and soil. In India, such groups threatened farmers with serious consequences if they were to seed Bt cotton. They also held repeated public demonstrations against this technology in India, the United States, and many European countries. Unfortunately, the year when biotech varieties were introduced in India coincided with a new disease. The disease, commonly named as "parawilt," was found on Bt as well as on non-Bt hybrids, but biotechnology was blamed for the disease's occurrence. Later, it was revealed that parawilt was a physiological disorder that occurred when Bt hybrids were exposed to prolonged dry spells or unusually high temperatures during boll formation, followed by heavy rains. A similar allegation occurred in the United States when excessive leaf/boll shedding was attributed to the herbicide-resistant gene. Biotechnology has faced enough opposition due to lack of knowledge and to unnecessary cautiousness, to create doubts and confusion in the minds of farmers and the public.

Need for Public Participation

The Cartagena Protocol was adopted in January 2000; it entered into effect in September 2003. One hundred eleven countries had ratified the Protocol by the end of 2004. The essence of the Protocol is "to ensure an adequate level of protection in safe transfer, handling and use of living modified organisms resulting from modern biotechnology that may have adverse effects on the conservation and sustainable use of biological diversity, taking also into account risks to human health, and specifically focusing on transboundary movements." Article 23 of the Protocol specifically addresses the issue of public awareness and participation, stating "The Parties shall: (a) Promote and facilitate public awareness, education and participation concerning the safe transfer, handling and use of living modified organisms in relation to the conservation and sustainable use of biological diversity, taking also into account risks to human health. In doing so, the Parties shall cooperate, as appropriate, with other States and international bodies; (b) Endeavor to ensure that public awareness and education encompass access to information on living modified organisms identified in accordance with this Protocol that may be imported." The Protocol also says that parties "shall, in accordance with their respective laws and regulations, consult the public in the decision-making process regarding living modified organisms and shall make the results of such decisions available to the public, while respecting confidential information in accordance with Article 21. Each Party shall endeavor to inform its public about the means of public access to the Biosafety Clearing-House." Public awareness and participation have become key in the acceptance of biotech products. The Food and Agriculture Organization of the United Nations has done elaborate work on public participation in the decision-making process regarding adoption of biotech crops. FAO's electronic forum on biotechnology at http://www.fao.org/biotech/Conf10.htm provides a lot of information on biotech issues.

New Products and New Concerns

Biotechnology in a broad sense includes genetic engineering, tissue culture, embryo rescue, marker-assisted breeding, and many more applications. There are two kinds of concerns about biotechnology: concerns about available products and concerns about biotechnology products in the pipeline or yet to come. Many people agree that many biotechnology applications are not always risky and dangerous, while transgenic biotech products carrying non-related genes could be harmful. Thus, even if researchers convince people of the safety of currently available products, new concerns will arise as new products are developed and commercialized. Biotechnology applications are technologies that will continue to be controversial for a long time.

References

Anonymous. Genetically Engineered Organisms, Public Issues Education Project, StarLink: GE corn in taco shells available at http://www.geo-pie.cornell.edu/issues/starlink.html

Benbrook, Charles. 2001. Do GM Crops Mean Less Pesticide Use? *The Royal Society of Chemistry*, October 2001. Available at http://www.mindfully.org/Pesticide/More-GMOs-Less-Pesticide.htm (Last accessed 2/16/05).

Clive, James. 2006. Global Status of Commercialized Biotech/GM Crops: 2006. *International Service for the Acquisition of Agri-Biotech Applications,* Brief 35, 2006.

Dotray Peter A., and J. Wayne Keeling, 2006. Transgenic cotton: Where we are and where we are going? *Proceedings of the Beltwide Cotton Conferences*, National Cotton Council of America, Memphis, TN, USA, 2006.

Downes, Sharon. 2004. Do GM crops harm beneficials? *The Australian Cottongrower,* Vol. 25, No. 7, December 2004-January 2005.

International Cotton Advisory Committee. 1999. Technology Protection System, *The ICAC RECORTDER*, Vol. XVII, No. 1, March 1999.

International Cotton Advisory Committee. 2004. Report of the Second Expert Panel on Biotechnology of Cotton, ISBN 0-9704918-6-7, International Cotton Advisory Committee, November 2004.

Manjunath, T.M. 2004. Bt Cotton in India: The Technology Wins as the Controversy Wanes. Papers presented at the 63rd Plenary Meeting of the International Cotton Advisory Committee, Washington DC, USA.

Serunjogi, Lastus K. 2004. Why Fear Biotechnology? Papers presented at the 63rd Plenary Meeting of the International Cotton Advisory Committee, Washington DC, USA.

Wakelyn, P.J. and M.R. Chaudhry. 2007. Organic Cotton, in Cotton: *Science and Technology*, edited by S. Gordon and Y-L. Hsieh, Woodhead Publishing Limited Abington Hall, Abington, Cambridge CB21 6AH, England.

Wang, Shenghui, David R. Just and Per Pinstrup-Andersen, 2006. Tarnishing silver bullets: Bt technology adoption, bounded rationality and the outbreak of secondary pest infestations in China. Presented at the American Agricultural Economics Association Annual Meeting, Long Beach, CA, July 22-26, 2006. Also available at http://www.biosafety-info.net/article.php?aid=399.

Xue, Dayuan. 2002. A Summary Research on the Environmental Impact of Bt Cotton in China. Nanjing Institute of Environmental Sciences, State Environmental Protection Administration of China, Nanjing, China (Mainland).