Regional Consultation on Biotech Cotton for Risk Assessment and Opportunities for Small Scale Cotton Growers (CFC/ICAC 34FT)

Faisalabad, Pakistan
March 6-8, 2007

The Common Fund for Commodities approved the project *Regional Consultation on Biotech Cotton for Risk Assessment and Opportunities for Small Scale Cotton Growers (CFC/ICAC 34FT)* in July 2006 for a period of one year to end on June 30, 2007. The main objective of the project was to organize a consultation and discuss all aspects of biotech cotton. The International Service for the Acquisition of Agri-biotech Applications (ISAAA), a not-for-profit organization registered in the USA, served as the Project Executing Agency. The National Institute for Biotechnology and Genetic Engineering (NIBGE), Faisalabad, Pakistan was the collaborating and host institution for the consultation. The consultation was held at NIBGE from March 6-8, 2007. Forty-four international participants from 27 countries, plus about 80 participants from Pakistan attended the meeting. A summary of the papers presented in the meeting is given here.

Global Status of Biotech Crops

Dr. Randy A. Hautea
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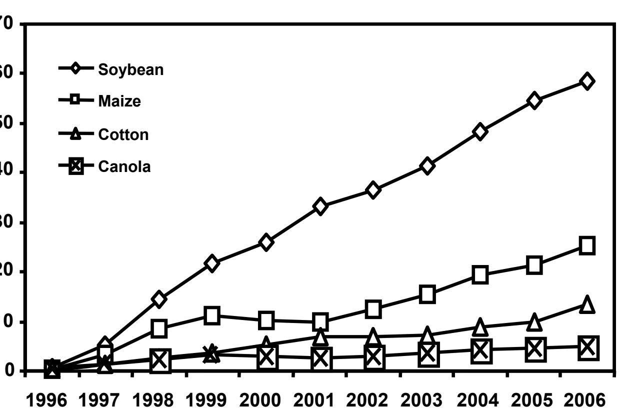
Biotechnology applications and uses include tissue culture/embryo culture, DNA marker assisted technologies, diagnostics, genomics and genetic engineering. However, genetic engineering is the most relevant use of the technology in commercial agriculture. Experience shows that well-targeted use of crop biotechnology applications can improve agricultural productivity and efficiency, reduce rural poverty and enhance food security. Equitable access and broader exchange of information on biotechnology can link societal needs with available crop biotech applications and innovations

A number of crops have been transformed, and cotton is the third most important crop developed with biotechnology. As of March 2006, 22 countries had authorized commercial production of biotech crops, but biotech cotton production is officially allowed in only nine countries: Argentina, Australia, Brazil, China (Mainland), Colombia, India, Mexico, South Africa and USA. According to ISAAA, 63 countries are involved in biotechnology research, and 57 crops have been found to have a potential for biotechnology applications/uses. Biotech crops were planted on 102 million hectares in 2006/07, representing an increase of 13% or 12 million hectares over 2005. Of the total world cotton area, 36% was planted to biotech varieties in 2006/07. Indonesia has discontinued production of biotech cotton.

According to ISAAA, more than half of the 63 countries engaged in biotech research and development are in the developing world. In the Asian region, China (Mainland), India and Pakistan have aggressively committed huge investments to biotechnology research. Argentina and Brazil are poised for further growth. In Africa, South Africa has commercialized biotech cotton, and important developments have recently taken place in Burkina Faso, Egypt, Kenya and Uganda. The challenges for the future include continuing responsible stewardship, risk assessment (with and without biotech crops), improved communications with society for knowledge-based decisions, assurance that biotech crops (together with conventional technologies) can contribute to sustainable agriculture, global food, feed and fiber security, alleviation of poverty and greater environmental safety.

Global Area of Biotech Crops 1996-2006
(Million Hectares)



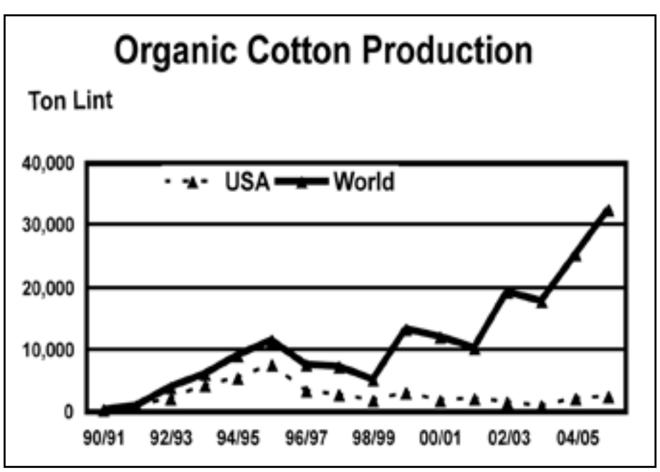
Concerns and Challenges

Dr. M. Rafiq Chaudhry
Technical Information Section, International Cotton Advisory Committee

It is estimated that 45% of cotton production, and 44% of cotton trade in 2006/07 originated from biotech varieties. Australia, South Africa and USA had almost 90% of their cotton area planted to biotech varieties in 2006/07. India and China have experienced significant increases in biotech area in the last few years. Since the commercial adoption of biotech cotton in 1996/97, the world average yield has increased from 575 kg/ha in 1996/97 to 742 kg/ha in 2006/07. Many factors contributed to these yield increases, but the enhanced plant protection offered by Bt varieties has definitely contributed. However, there are some genuine concerns about this technology that have not been properly addressed. For example, the Bt toxin remains available throughout the plant's life, and insects are certain to develop resistance to the toxin. Furthermore, the technology can be easily misused, as was the case with the technology protection system whereby the cotton plant was engineered to produce infertile seed in order to force farmers to buy planting seed every year.

Herbicide resistant biotech cotton may encourage cotton growers to rely more on herbicides thereby discouraging the implementation of weed control through reduced tillage methods and fewer applications of chemicals. The use of herbicides throughout the life cycle of the crop to seven days before picking could change weed patterns. Multinational controls, added to high technology costs, are limiting the dissemination of technologies to developing countries, thus encouraging illegal use of the technology.

People in many European countries are not fully convinced of the effectiveness of biotech food safety regulations. The literature is full of positive and negative reports about biotech products leaving the consumer confused not knowing what to believe. It is extremely difficult to generalize the benefits of biotech products. The data from Australia show that 92% of the sprays on conventional cotton were made against bollworms, whereas bollworm control accounts for only 3% of spray applications on biotech varieties. However, sprays against mirids and aphids on conventional cotton have increased from 15% and 4% to 55% and 21%, respectively, on biotech cotton. Biotech cotton is not eligible for certification as organic cotton, a fact that has affected organic cotton production in the USA.



Biosafety Regulation

Dr. Willy De Greef
Executive Director, International Biotech Regulatory Services, Belgium

Genetically engineered transgenic crops raised questions from the very beginning in connection with their safety for human health and the environment, their socio-economic impact and their impact on food security and agricultural trade. The moral acceptability of transgenic crops has also been an issue, and in many countries genetically modified biotech crops are assumed to be inherently dangerous. This "truism" is not open to fact-based refutation with the result that there is no basis for a positive dialogue and there is no formal way of learning from the experiences of others in this field. Most issues relate to crops for human consumption, but unfortunately cotton has been stigmatized along with food crops. From the earliest times, testing and commercialization of biotech crops was linked to biotech policy and biosafety regulations. Biosafety regulations were implemented before official commercialization of biotech crops but there has been a massive misunderstanding in the application of biosafety regulations. Furthermore, biotech policy and biosafety regulations have often been at odds. Whereas biotech policy centered on the potential benefits, biosafety regulations focused on potential threats that might require keeping the products off the market. Countries must develop a workable regulatory system that will be linked to the broader national development policies and remain open to new information about the risks and benefits of new biotech products. Opposing views from policy makers and the public must be addressed respectfully for a workable regulatory system to exist. Concerned authorities must strive to be more pro-active in this field.

Biotechnology: A Look into the Future

Dr. James McD. Stewart
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The first generation of biotech products that are currently in commercial use lower the cost of production to growers but also greatly benefit technology developers. The second-generation products are expected to bring premium prices to producers, while also benefiting consumers. Technology developers will benefit by gaining market share. The characteristics that offer the greatest potential for improvement of the cotton plant include: improved photosynthetic efficiency for achieving higher yields, improved tolerance to drought, greater tolerance to high temperatures, enhanced tolerance to chilling temperatures, improved salt tolerance, and better lint quality.

Any characteristic that improves the capture of light for photosynthesis would be useful in genetic engineering as a way to improve cotton yield. One way to do this would be to delay senescence of the leaves so that each leaf remains green for a longer period of time. Photosynthetic efficiency is an area that has received much interest, but little progress has been made so far.

Drought tolerance is a complex environmental parameter that is often compounded by heat stress or chilling stress. Much work has been done on model plants relative to gene expression in response to this abiotic stress. Genes have been identified that appear to be related to increased tolerance to water-deficit stress but they have not been reverse engineered to verify any functional roll in tolerance. Genes that in other plants (such as Arabidopsis) have been found to be regulated by water-deficit and other abiotic stresses, have also been found to be similarly regulated in cotton. Some of these genes in model plants are claimed to increase tolerance to water-deficit and other abiotic stresses such as salt-stress. Because tolerance to biotic stress is a complex phenomenon, the expression of any single gene to transform another plant would not be expected to provide much increase in tolerance.

The work done so far suggests that chaperon-type proteins probably stabilize the rubisco activase and that these proteins might provide a certain level of protection to the vital biochemical functioning of heat-stressed cells. It may be possible to engineer genes coding for chaparon-type proteins to achieve constitutive expression in cotton and thereby boost heat tolerance. Since these proteins play a role in enzyme protection and even in refolding of denatured protein, they would be expected to give a level of increased tolerance to most abiotic stresses. Transformation of cotton with super oxide dismutase increased its tolerance to chilling temperatures. Primarily, the antioxidants aid in removing damaging free radicals generated by poor membrane function, especially as a result of the combination of chilling temperatures and high light intensity. The information compiled so far indicates that temperature membrane transition from a gel to a sol in cotton at around 12°C is related to its sensitivity to chilling temperatures. Genetically engineering cotton to have more flexible membranes (more unsaturated lipids) should increase its tolerance to chilling. On the other hand, this would probably also result in increased sensitivity to heat stress.

Although cotton is considered to be a relatively salt-tolerant crop, its cultivation might be extended into areas where other crops cannot grow because of high salinity. There is a type of plant classified as halophytes (plants that will grow in high salt concentrations.) Several genes from these plants have been identified as possibly playing a role in salt tolerance. Those genes may hold great potential for genetic engineering. A Na^+/H^+ anti-port enzyme, which excludes Sodium (Na) from the plant cell, may have the potential to improve the salt tolerance of cotton.

It would be necessary to have greater knowledge of the molecular biology of fiber before speculating on which genes might contribute to fiber quality. Although the process has been slow, the biology of the fiber is beginning to unravel. It seems unlikely that any single gene could have a dramatic effect on a range of qualitative traits

Concerns, Risks and Issues Regarding Adoption of Bt Cotton

Mr. Derek Eaton
European Consortium for Agricultural Research in the Tropics, Agricultural Research Institute, The Netherlands

One of the broader concern, Europeans harbor in connection with genetically modified biotech crops, is a lack of confidence in the regulation of food safety. Immediate concerns include: safe use of biotech products, controversy about the wide range of differing information on the same issue or product, and reliable data on benefits, costs and unknown risks. The public is also concerned about the benefits actually accruing to small growers in developing countries. The technology may be good, but the cost of that technology is so high that only a small proportion of the real benefits may actually be reaching smallholders in developing countries. It is also true that measuring benefits is difficult and costly. A lot of literature is available on agronomic performance and economic impact but it is hard to generalize conclusions. Counterfactual information, even in the field of marketing channels, is complicating the issue and delaying acceptance of the technology by those who really need it.

Another significant issue, one which is still in the offing but is going to gain importance in the near future, is the Plant Breeders Rights and/or patent. The Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPs), particularly Article 27.3(b) deals with whether patents should cover plant and animal inventions, and how to protect new plant varieties. The TRIPS Agreement is one of the pillars of the global trade regime, which is enforced through the World Trade Organization (WTO). As a whole, Article 27 of the TRIPS Agreement defines which inventions governments are obliged to make eligible for patenting, and what they can exclude from patenting. Inventions that can be patented include both products and processes, and should generally cover all fields of technology. Broadly speaking, part (b) of paragraph 3 (i.e. Article 27.3(b)) also allows governments to exclude some kinds of inventions from patenting, i.e. plants, animals and "essentially" biological processes (but micro-organisms, and non-biological and microbiological processes have to be eligible for patents). However, plant varieties must be eligible for protection either through patent protection or a system created specifically for the purpose or a combination of the two. The issue of overlap between plant breeder's rights and patent protection will arise in the future, although the least developed countries have a grace period until 2013. Cotton is a cash crop where intellectual property rights could have huge implications because of investment opportunities for the private sector and considerable current public sector investment, particularly in countries like China (Mainland), India and Pakistan.

Trade, Socio-economic and Market Acceptance of Biotech Cotton

Mrs. Jolly. K. Sabune
Managing Director, Cotton Development Organization, Uganda (Presented by Dr. Lastus K. Serunjogi, Uganda)

Biotech cotton growers see a positive impact on yield due to reduced pest damage, and lower costs of production, stemming from fewer insecticide applications. These factors compensate for the technology fee that is mandatory under agreements with seed companies providing planting seeds of biotech varieties. Biotech cotton is accepted in local and international markets for fiber, textiles and bi-products on an equal footing with conventional varieties. Biotech cotton was accepted because the transformation of traditional varieties for insect resistance and/or herbicide tolerance does not alter the fiber characteristics and spinning qualities desired by traditional markets. In practice, markets do not identify biotech cotton contents in products but markets take an interest in product properties based on cotton fiber characteristics. There are no price differentials between biotech and non-biotech cotton fibers or textiles, except for "organic cotton," which has niche markets and premium prices. Additionally, adoption of herbicide resistant biotech cottons may lead to improved fiber quality and market acceptance through the reduction of trash and weed-seed contaminants in seedcotton and the resulting lint. Fears connected with biotech cotton by-products, such as cooking oil and livestock feed cakes have been alleviated by studies on non-allergenicity and non-toxicity of biotech cotton DNA and proteins. The cooking oil was found to be free of cotton DNA and proteins. So far, there is also no evidence of any cross-transfer of biotech DNA into human and livestock DNA. The genetic material (DNA) and proteins of biotech cotton are denatured by human and livestock digestion if accidentally ingested orally.

Small-scale cotton producing systems in developing countries are typically hampered by insufficient biotechnology research programs in the public sector funded under national agricultural research systems (NARS). Consequently, if the biotech genes were adopted in exotic genotypes, those producers would have to depend on multinational firms as sources of biotech options. The adoption of foreign transgenic would deprive such countries the intrinsic attributes of the traditional varieties improved over decades through conventional breeding efforts. A good example of this might be the case of Uganda whose Albar varieties *Gossypium hirsutum* L. are resistant to a sucking pest Jassid, have fairly good tolerance to diseases such as the bacterial blight caused by *Xanthomonas campestris* pv *malvacearum* and have earned the Ugandan cottons premium prices in international markets. Furthermore, low seed costs in Uganda approximately US$ 2.5/ha in a seed replacement wave (Informal seed scheme) and the high cost of the technology fee to be paid through planting seed would be prohibitive to small growers without credit systems.

Biotechnology Research Limitations

Dr. Lastus K. Serunjogi
Cotton Breeder – Consultant, Cotton Development Organization, Uganda

Biotechnology research may be classified into two major categories. The first category comprises research into the development of appropriate methodologies, procedures, protocols and tools for manipulation of organisms to achieve the desired products. The second category of biotechnology research deals with the identification and isolation of novel traits or genes that may be used to make desired genetic changes (transformation) in the target organisms. Biotechnology research is conducted globally under two systems of funding, state or public and private companies. It should be noted that the sources of funding for biotechnology research have a great deal of influence on the modes and ease of access to biotech products by the end users. Both funding sources yield public and private biotech goods respectively. It is generally felt that publicly funded research should focus on approaches driven by public demands and the environmental impact of potential biotech products. Thus the ethical priorities would differ from those of private biotech research, which is geared to promoting the commercial aspects and driven by the profit potential. The objective is to dissociate public biotech research from commercial considerations.

Whatever the sources of biotech research funding may be, there are constraints that hamper its smooth progression toward its target goals. Many of the drawbacks affecting biotechnology research are rooted in the myths and fears relating to biotech products. The fears that have influenced biotech research in various ways stem from the following aspects.

- Possible risks to health through ingestion of biotech products and their by-products.
- Adverse effects on beneficial fauna, non-target insects and resistance by insects and weeds.
- Political skepticism
- Inadequate knowledge of the intentions and appropriate use of biotechnology innovations.
- Faith-based fears

Other limitations to biotechnology stem from the very biological system of the cotton plant itself. A case in point is the inability of most cultivated cotton varieties to regenerate from the cell/tissue cultures after the transformation of the tissues. This has led most research laboratories around the world to depend entirely on Coker 312, a variety from the United States, which does have the ability to regenerate after transformation. This shortcoming of the biological system determines a number of limitations to biotech research: the fact that local germplasm cannot be used directly for new genes and the negative impact on cotton genetic diversity for breeding programs. The good news is that science is gradually overcoming these limitations in cultivar regeneration and somatic embryogenesis.

An additional limitation to biotech research is the narrow range of pests susceptible to control by the Cry genes. It would be desirable to extend biotech cotton research to the improvement of the most important product of cotton, the lint. Progress is hampered, however, by the biological nature of cotton. Since each cotton fiber is a single cell, it has proven difficult to modify it with functional substances. Furthermore, disruption of the cotton's crystalline cellulose structure might seriously impact the very quality parameters that give cotton lint its desirable traits as a textile fiber.

Biotech research to develop appropriate tools and their proper use requires certain capacities in a range of connected institutions. A lack of adequate institutional capacity limits the smooth management of research. Bio-physical scientists need to master procedures and protocols for laboratory and field experimentation. Technical teams are also needed to monitor and evaluate technology adoption issues in order to plan future research. Trained scientists then require investments in infrastructure.

Many of the above difficulties might be solved through the development of international or regional co-operations/ networks capable of fostering the sharing of laboratory and personnel resources among developing countries. The lack of the proper enabling policy and regulatory legal frameworks, including intellectual property rights, has proven to be an impediment to well-intentioned researchers who have attempted to initiate research programs or collaborate with international laboratories. Intellectual property management policies are essential at the institutional and national levels in order to support effective negotiations for the appropriate use of biotech innovations by resource-needy laboratories and for the protection of the resulting technologies. This could very well affect the rate of adoption of the new technologies, especially for the low-input, small-scale farming systems in developing countries.

Biotechnology Research: Investing for the Future

Dr. Marc Giband
CIRAD-CA, France (Currently stationed at EMBRAPA Algodão, Brazil)

Over 13 million hectares was planted to biotech cotton in 2006/07, illustrating the great success of biotech varieties, and their appeal to cotton farmers worldwide. Nevertheless, the potential of biotech cotton has not been delivered to all producers, particularly small-scale farmers who could benefit from the technology. Only nine countries have commercialized biotech cotton, and a number of other countries are experimenting with biotech varieties and will probably be releasing them for commercial purposes in the near future. Various hurdles have been preventing the larger dissemination of the technology, including legal, technical, and commercial considerations. Helping countries to develop and implement a legal framework for the deployment of biotech cotton would foster the dissemination of the technology. Similarly, help in training personnel to perform risk and economic assessments of biotech cotton would allow countries to make enlightened choices in regulating these varieties.

Biotech cotton has been adopted by both, large and small-scale farmers, whose technological skills and understanding are quite variable. While the former can take full advantage of the potential of the technology, studies have shown that the latter need to increase their knowledge if they hope to benefit fully from it. Capacity building in this area seems equally important, not only to ensure proper deployment of biotech varieties – and thus their sustainable use – but also to help maximize the benefits stemming from their use.

Three countries (Australia, South Africa and the US) have approved both available biotech traits, insect resistance and herbicide tolerance (and combinations of the two). Other countries only grow insect-resistant varieties, and in most cases, only a single "first-generation" (single gene) event is available. This limited availability does not always respond to the needs of cotton farmers, who are faced with a broader range of constraints. Newer events represent an advance over older ones in that they offer better pest control or allow for more flexible crop management.

Abiotic stresses are among the limiting factors that many cotton growers have to face, particularly small-scale farmers in developing countries. One can hope that future biotech varieties will target these more complex constraints facing cotton growers. Resistance or tolerance to abiotic stresses generally involves mechanisms that are determined by more complex genetic structures, making such traits more difficult to achieve through a transgenic approach. Although some progress is being made in this area, increased availability to farmers of biotech varieties with improved stress resistance or tolerance is still a goal.

Current biotech varieties are predominantly developed by the private sector, with very few examples of the public sector achieving the challenge of delivering such varieties to growers. Industry will primarily target solvable markets and traits of global interest, where they can expect a return on the big investments needed to develop biotech varieties. Specific needs responding to local (or regional) constraints, such as diseases or pests of regional impact, will probably not be attended by the private sector. The strengthening of the local public sector is seen as means of satisfying local needs, but experience indicates that this goal may be difficult in many cases. The question remains of how to attend to local needs in the short- to medium-term.

Even though biotech cotton is presently the most visible spin-off of investments in cotton biotechnology, recent years have seen the development of numerous studies dedicated to a better understanding of the cotton genome, and to the identification of gene and regulatory networks that determine important features of cotton. These studies range from genetic mapping of the cotton genome and the identification of molecular markers associated with important traits, to the development of a broad set of resources (BAC libraries, EST collections, DNA chips, etc.) and their use to unravel the molecular basis of traits. Most work in this area has focused on fiber quality traits, but studies on other important traits, such as disease resistance or resistance to abiotic stresses, are also being undertaken.

Many traits of agronomical importance are under complex genetic control, which makes them difficult to manipulate, either through classical breeding, or through transgenic approaches. A better comprehension of the molecular mechanisms underlying the definition of important traits, and the identification of key genes involved in the processes leading to a particular phenotype would be of great advantage. Such studies could lead not only to the development of breeding tools directly usable for cotton improvement, such as molecular markers for marker-assisted breeding (MAS), but also to the identification of genes that could be targeted for manipulation using transgenic approaches.

Investments in this area and the development of biotechnological tools that would help tape the large *Gossypium* germplasm for particular traits of interest will probably lead to significant advances in the development of germplasm suited to local needs. This may be, at least in part, an answer to the question of how to attend to local needs that are not seen as priorities for developers of biotech varieties.

Biotech varieties have had an important impact on cotton growing in the last decade, and they will continue to do so in the future. For the technology to benefit the most, and notably the small-scale farmers in less favored countries, care should be taken that their introduction takes into account all components of the local environment. Investing not only in the technology itself, but also in important aspects such a germplasm development, the optimization of cultivation practices, or training for the optimized use of the technology are keys to a successful deployment.

Science Communication and Technology Acceptance

Dr. Claudia Canales
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Modern biotechnology, specifically genetic engineering, is a new and powerful tool for breeders to attain their goals, as it allows them to identify precisely the genes responsible for a given trait and transfer them to crop cultivars. Unlike conventional breeding, only the desired gene is incorporated into the target crop, and due to the universality of the genetic code, the sources of genes for improvement are not limited to related species. Genetic engineering is not a replacement for conventional breeding methods but, in specific circumstances, it does provide a better solution to agricultural constraints, such as pests, diseases and adverse environmental conditions. On the other hand, the technology is highly controversial as it generates public concerns that fall both within and outside the scientific domain.

Effective science communications are an essential part of technology acceptance. Communications do not, and should not, necessarily equate to blanket acceptance of new technologies. The notion that public rejection of new technologies is the result of public ignorance has not only been proven erroneous; it has also, in fact, often had a negative influence on the adoption of innovations.

Genetic engineering in Europe preceded a number of food scare incidents, the most notorious of which perhaps is mad cow disease (BSE), which undermined consumer trust in the public institutions meant to protect them. Public attitudes in the UK, therefore, were also an expression of loss of confidence in public institutions. The implications of the genetic engineering debate were vast. In the European Union, it led to a six-year *de facto* moratorium on genetically engineered foods between 1998 and 2004; it affected funding and support for public biotech research; it contributed to the establishment of a biosafety regulatory system that is unable to overcome impasses and provide decisions, either for or against a submission; and it created a negative climate for investment by the private sector. Globally, public opinion on genetic engineering in developing countries was also affected. It raised international trade and market acceptance issues for those countries that trade with the EU and, more importantly, it greatly increased the cost of research and regulatory approvals. The debate has had a very significant and direct impact on the adoption of biotechnology worldwide, including biotech cotton.

The genetic engineering debate brought up a series of existing public concerns, a further indication of the fact that the public and scientists operate under different value systems and perceive risk in a very different way. In addition, socio-economic concerns, such as distribution of benefits, food security and monopoly by industry, also played an important role in the debate.

Effective scientific communications are not a linear flow of information from the scientists to the public. It must also include experts in social sciences and involve participation of all stakeholders. Instead of providing what the public "needs" to know, science communicators should identify what the public "wants" to know and make this information available in clear and accessible terms. Communications should be incorporated into the scientific process from the start, rather than as an optional afterthought of research funded by separate sources independently of the research itself.

Communications should always have a target audience, as the "one-size-fits-it-all" usually does not address issues very well. Finally, effective science-based communications should be proactive and positive, rather that reactive and defensive, because once public perception has been skewed in a specific direction, it is difficult to modify.

The media plays an essential role in science communication, as it represents the bridge between scientists and the public. The main barrier to effective communication is language. Biotechnology requires a highly specialized technical vocabulary; however, messages for the media must be presented in simple terms, avoiding jargon and unnecessary detail. Another difficulty is that the media prefer to cover stories with "news" value, rather than to follow up on research developments. It is important to realize that the media responds to public demand, and that journalists have to work under a specific set of conditions. Since scientists cannot change the way the media work, they would be well advised to understand the paradigms that conform it, and learn to work with them more effectively, to their advantage. Scientists must fully embrace their responsibility to communicate, and they must do so with the means available to them.

Bt Cotton and Implications for IPM in China (Mainland)

Dr. Jingyuan Xia
Director General, National Agro-Tech Extension and Service Centre, Ministry of Agriculture, China (Mainland)

Some of the most important pests affecting cotton in China (Mainland) are the cotton bollworm, aphids, red spider mite and the pink bollworm. Seedling diseases, boll diseases, fusarium and verticillium wilt also affect cotton in China (Mainland). China (Mainland) suffered heavy losses in yield due to the bollworm (*Helicoverpa armigera*) outbreak in 1992/93. The national average yield dropped by 24% from 867 kg/ha in 1991/92 to 660 kg/ha in 1992/93. The bollworm had become resistant to most insecticides, and Bt cotton came just in time for China (Mainland). China started with a single insect-resistant gene from Monsanto, but now it has developed its own genes capable of protecting the plant from bollworms, sucking insects and male sterility. The locally identified insect resistant gene CpTi is more popular than Monsanto's Cry 1Ac. Ninety-nine varieties and hybrids having single and double genes had been released as of March 2007 for commercial production. Only Cry 1Ac and CpTi have been commercialized so far, but other combinations that have been extensively tested and are close to commercial release, are also shown below.

Transgenic Genes Available in China (Mainland)

Single gene: Cry 1Ac (Insect resistant)

Double genes: Bt+CpTi (Insect resistant + insect resistant)

Multi-genes:

Cry 1Ac +CpTi+Go (Insect resistant + insect resistant + verticillium resistant)

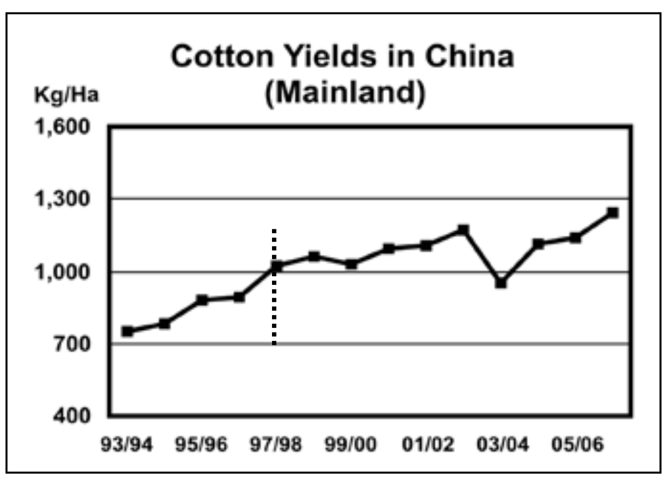
Cry 1Ac +CpTi+GNA (Insect resistant + insect resistant + Aphids resistant)

Cry 1Ac +CpTi+EPSPS (Insect resistant + insect resistant + herbicide-resistant)

Cry 1Ac +CpTi+male-sterile (Insect resistant + insect resistant + male sterility from a cotton gene)

CpTi is a locally developed gene that confers resistance to bollworms. It is estimated that in 2006/07 about 80% of the biotech cotton area was planted to varieties carrying the CpTi gene. The gene encoding snowdrop lectin (*Galanthus nivalis* L. agglutinin, GNA) has been inserted into cotton to protect it against sucking insects and aphids. Production of cotton plants resistant to phloem feeding insects by expressing the *Galanthus nivalis* aglutinin (GNA) gene under the control of phloem-specific promoters has been studied in China (Mainland). The good thing is that Cry 1Ac and GNA have different modes of action against different insects. Diseases are an important issue in China (Mainland), and good yields can be achieved only if the plant is protected against diseases. Seedling diseases cause heavy losses in yield due to poor plant stand. Plant stand is also affected by fusarium wilt and verticillium wilt. Verticillium damage can continue up to and even beyond the flowering stage. China (Mainland) has developed the 'Go' gene that provides protection against verticillium wilt. Boll rot might also be a problem due to overgrowth. Longer rainy seasons and cloudy weather can also increase losses.

Since the introduction of biotech cotton in China (Mainland) in 1997/98, cotton yields have improved significantly. China (Mainland) is strictly monitoring resistance to the Bt toxin, and it has found in tests under lab conditions that the resistance ratio exceeds 20 in 30 generations. However, no resistance to Bt toxin has been detected in the field. It is estimated that biotech cotton lowered insecticide costs by US$120-150/ha, and Bt growers increased their income by US$150-200/ha due to increased yields. Additional data showed that Bt cotton reduced hand labor by 20-30% and poisoning incidents decreased by more than 90% due to fewer insecticide



applications. Insecticide use decreased by 60-80% and beneficial insects increased by 20-40%. China (Mainland) is improving production technology to make it more suited to biotech varieties, including the development of biotech-cotton-based IPM systems. Future plans include development of stress tolerance, improved fiber quality and biotech cotton with biochemical characteristics. China is also working to develop time- and tissue-specific expression of biotech genes. Biotech varieties will be developed based on production systems and integrated pest management systems. China is simplifying the variety approval process while improving regulations to enhance patent protection.

Event-Wise Approval of Bt Cotton Hybrids in India (2006)

Event	North Zone	Central Zone	South Zone	Total
Bollgard-I (Mahyco)	12	29	26	48
Bollgard-II (Mahyco)	-	5	2	7
Event 1 (JK Seeds)	1	1	2	4
GMF Event (Nath Seeds)	1	1	1	3
Total hybrids	14	36	31	62

Regulatory Procedures in India

Dr. C. D. Mayee
Vice Chairman, Genetic Engineering Approval Committee (GEAC), India

The regulatory mechanism in India is managed through six committees acting at various levels: Recombinant DNA Advisory Committee (RDAC), Institutional Biosafety Committee (IBSC), Review Committee on Genetic Manipulation (RCGM), Genetic Engineering Approval Committee (GEAC), State Biotechnology Coordination Committee (SBCC) and District Level Committee (DLC). The Genetic Engineering Approval Committee of the Department of the Environment, Government of India, awards final approval for commercial release of a biotech product. However, before any product is released for commercial use, general biosafety and risk assessment studies must be completed. The parameters included are: a) genetic and molecular parameters that comprise, but are not limited to, copying of the inserted gene, stability of gene expression level and efficacy; b) environmental parameters that include transfer, implications of out-crossing and effects on other species; c) toxicity parameter, including effects on small laboratory animals (rats & rabbits), livestock (goat), birds and fish; d) allergenicity parameters, and e) agronomic parameters, including efficacy of phenotype, yield, growth and development, response to major diseases and insect pests, quality parameters and the cost-benefit ratio.

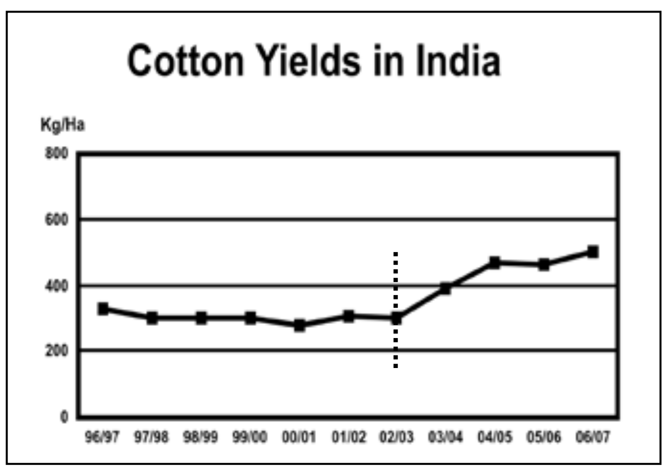
India has acquired a tremendous capacity to produce and commercialize biotech crops. In addition to cotton, a lot of work is going on in the public sector to produce biotech crops from locally identified or modified forms of commercial genes. Biotech varieties of rice, potato, eggplant, tomato and mustard are already close to commercial approval. Greenhouse studies, a step behind commercial release, are underway on cotton resistant to bollworms using a dual gene (Cry 1F and Cry 1Aa3) technology.

Adoption of Bt Cotton in India

Dr B. M. Khadi
Director, Central Institute for Cotton Research, India

The cotton area in India may be divided into three zones: the North Zone, the Central Zone and the South Zone. The Government of India released biotech cotton for commercial production on April 5, 2002 for the Central and South zones and later included the North zone. Since then, cotton production has increased in all zones. Almost all increases in production, from 2.7 million tons in 2001/02 to 4.6 million tons in 2006/07 are the result of increased yields. During the same period, cotton area increased by only 5% in 2006/07. Average yields in India have increased by 66% over the 2002/03 season reaching 502 kg/ha in 2006/07. Such an increase is unprecedented in the cotton history of India. A number of factors contributed to the achievement of such a tremendous increase, but biotech cotton definitely played a major role in increasing yields in India. In five years, the area planted to biotech hybrids/varieties increased to 3.72 million hectares or 41% of the area planted to cotton in 2006/07. The Government of India released three Bt hybrids in 2002 and 2003, four in 2004, 20 in 2005 and 32 in 2006 for commercial production. Liberal release of Bt hybrids/varieties, 62 in five years, has discouraged illegal production of biotech cotton in India.

Jassids (*Amarasca bigutulla)*, Aphids (*Aphis gossypii)*, thrips (*Thrips tabaci*) and whitefly (*Bemesia tabaci*) appear on cotton soon after sowing and may require spraying until 50-60 days,



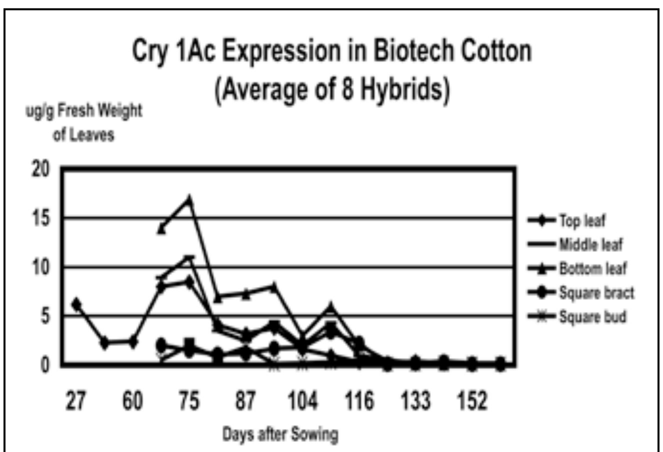
except for whitefly which may continue until the crop maturity stage. Spotted bollworm *Earias vittella* and *Earias insulana* appear at about 35 days after planting, while the pink bollworm (*Pectinophora gossypiella*) and the American bollworm (*Helicoverpa armigera*) appear at about the same time–65 days after planting. Bollworms continue to be a major pest until 110 days after planting. Red cotton bug (*Dysdercus cingulatus* and *Dysdercus koengnii*) and dusky cotton bug may also appear at about 50 days after planting and continue along with the bollworms until about 110 days after planting. Therefore, India really requires a good plant protection system, one that was lacking in conventional non-biotech hybrids/varieties.

Genes Utilized for the Development of Transgenic Cotton Hybrids in India

Company/Organization	Gene Utilized
Mahyco	Cry 1Ac
Monsanto	Cry 1Ac + Cry 2Ab
Nath Seeds	Cry 1Ab+ Cry Ac fusion (China)
JK Seeds	Cry 1Ac modified (IIT Khargpur)
Syngenta	vip 3A + Cry 1Ab
DowAgro Sciences	Cry 1Ac + Cry 1F
Metahelix	Cry 1Ac
Indian Council of Agriculture Research	Cry 1Aa3, Cry 1F, Cry 1Ia5, Cry 1Ab, Cry 1Ac
National Biotechnology Res. Institute	Cry 1Ec

Biotech cotton has reduced insecticide use, particularly pyrethroids. This has also had an indirect impact on the white fly population. However, rainfed and less fertile soils have shown comparatively poorer results. The expression of Bt in the plant has shown that the quantity of the toxin starts to decline at about 70 days after planting. Data showed that even as late as 120 days after sowing, if there are susceptible bolls, insecticide applications may be required on Bt hybrids. Stacked gene varieties with the Cry 2Ab gene provided protection for an extended period of up to 140 days. India has also found that different varieties express different quantities of the toxin in the same parts. The quantity of the toxin is also different in different parts of the plant. One hybrid/variety may have a higher quantity (µg/gm dry weight) of Cry 1Ac in the sepals while another may have a higher quantity in the petals.

Biotech cotton has gained immense popularity in India. As of March 2007, a total of 62 Bt-hybrids had been commercialized in India. Twenty-eight seed companies are pursuing biotech cotton research in India, and the country has also discovered its own genes resistant to bollworms, but they are not commercialized yet.



Biotech Cotton Area in India

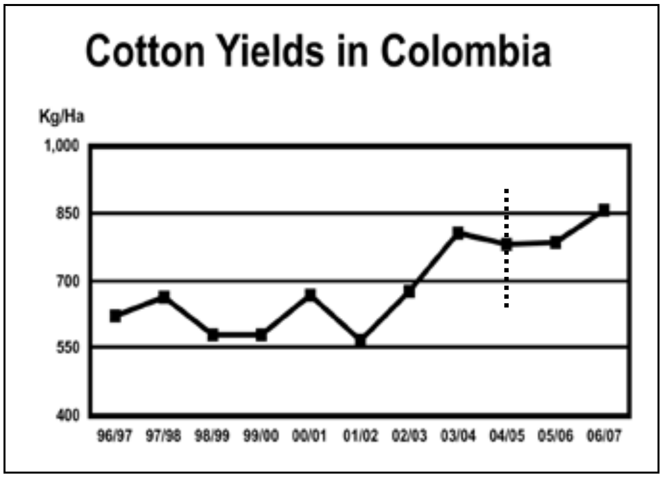
Year	Area (000 Ha)	Percent of Total Cotton Area
2002/03	29.3	< 1
2003/04	85.9	1
2004/05	534.7	6
2005/06	1,250.8	14
2006/07	3,721.0	41

Experience with Bt Cotton in Colombia

Dr. Jorge Cadena Torres
Colombian Corporation for Agricultural and Livestock Research (CORPOICA), Colombia

Cotton can be grown all year in Colombia, and Colombia is the only country in the world where it actually happens. The two main cotton-producing regions are Interior and North Coast. It can rain at any time of the year, but the two rainy seasons are February-March and July-August. Seventy-two percent of Colombian growers own less than five hectares; 22% of growers own 5-10 hectares and only 6% own more than 20 hectares. The average farm size is 8.6 ha/grower. In 2006/07, 7,584 growers planted cotton and attained an average yield of 789 kg/ha.

It was easy for Colombia to switch to biotech varieties as most planting seed is imported directly, and 86% of the varieties in 2006/07 were of U.S. origin. The varieties developed by the Colombian Corporation for Agricultural and Livestock Research (CORPOICA) accounted for only 14% of the total area. The Colombian Agricultural Institute of the Ministry of Agriculture is a designated agency for introduction, testing and adoption of biotech crops. The National Biosecurity Committee, constituted in 1998, approved the protocol and regulations in 2002 for dealing with biotech products. Field-testing of Bt cotton was carried out for three years, from 2001 to 2003, along with semi-commercial trials in 2003. Insect-resistant Bt cotton was finally approved for commercial production in 2004. Roundup Ready herbicide-resistant cotton



was approved in 2006. Colombia is currently testing Bollgard II cotton.

On average, insecticides make up about 12% of production costs. Although 56% of the sprays in Colombia are made against the boll weevil *Anthonomus grandis*, which is not controlled by the Bt gene, Colombia has still benefited from biotech cotton, especially in the Interior region where the pink bollworm *Pectinophora gossypiella* is more prominent. In 2006/07, 30% of the cotton area in the coastal region and 73% of the cotton area in the Interior region were planted to biotech varieties. The cost of Bt seed is US$170/ha compared to US$110/ha for conventional planting seed (US$12.55/kg for biotech seed + technology fee vs. US$6.00 for conventional seed). Biotech genes are not yet available in local varieties. In Colombia, Bt varieties produced an average of 217 kg/ha more lint than conventional varieties. Colombia has had an increase in non-target pest populations. The Colombian Government is exploring options by which to minimize reliance on multinational companies and foreign varieties. Colombia would also prefer to develop its own capacity to transform cotton and use non-Monsanto genes, but is still far from that stage.

Biotech Cotton Area in Colombia

Year	Area (%)
2004/05	17.2
2005/06	34.7
2006/07	43.4

Biotech Cotton in South Africa: A Farmer's Perspective

Mr. Phenias Gumede
Cotton Grower, South Africa

South Africa was one of the first countries, and up to recently, the only one in Africa, to adopt genetically modified biotech cotton for commercial production. Insect-resistant cotton has been in production since 1997/98, followed by herbicide-tolerant cotton in 2001/02 and stacked-gene cotton in 2005/06. In 1998/99 biotech cotton was planted on 10% of total area. By 2002/03 it had increased to 84%, and it is estimated that 90% of all cotton currently planted in South Africa is biotech. The experience with biotech cotton in South Africa can be divided into two types of production systems, commercial or large growers and small scale growers.

Commercial/Large Growers

According to surveys undertaken by the University of Pretoria, South Africa, in 2002, 39% of the large-scale growers stated that the most important benefit of Bt cotton is the savings in pesticide and application costs with peace of mind about bollworms coming in second as the next biggest reason for adoption. When asked to indicate all the benefits of insect-resistant cotton, 77% of the farmers surveyed said that peace of mind and the managerial freedom to go on with other farming activities were the most important. Most commercial cotton farmers are also involved with other farming activities during the cotton season. Finding hired labor, scouting and spraying are particularly difficult over the Christmas - New Year period, and this is the crucial time in the production cycle of cotton in South Africa. The cotton farmers interviewed indicated other indirect benefits of biotech cotton, for example spraying fewer pesticides or none at all has caused predator insects to flourish. The major disadvantage of biotech cotton, according to most farmers, is the relative high cost of the seed and technology fee. Also, both large- and small-scale farmers still have to spray against sucking insects like jassids and aphids. These pests are now increasingly becoming the main cotton pests and a major concern for cotton growers. Not only is the cost of controlling sucking insects escalating, but predator populations are being threatened by increased spraying.

The personal experience with biotech cotton of a commercial cotton farmer growing wheat and cotton on 1,600 ha under irrigation in the Limpopo Valley area of Weipe, on South Africa's northern border, is as follows:

In 1993, bollworms, aphids and red spider mites affected cotton profits to such an extent that the farmer was considering giving up cotton production. During this period, before the introduction of biotech cotton, yields were declining and up to 15 sprays were required during a normal growing season. Since adopting biotech cotton production, insecticide sprays are down to about 3 per season, mainly for secondary insects such as jassids. The farmer also reported that for the past 8 years it had not been necessary to spray for aphids and red spider mites at all, as these insects are controlled by natural predators, which have increased in number due to the limited spraying of insecticides. In his view, farming with biotech cotton had a very positive effect on the environment. For example, he is now seeing on his farm predator birds such as falcons and owls that had been absent from this area for some time. This farmer is of the opinion that cotton farming would not have been sustainable if normal conventional cotton farming practices had continued.

Small-scale Growers

The major small-scale cotton production areas are currently at Tonga, in Mpumalanga, and Makhathini, in northern KwaZulu-Natal. The area planted to cotton and the number of cotton producers varies from year to year depending on the availability of production credit and the price of cotton. Small-scale cotton farmers have reacted positively to the introduction of biotech cotton in Makhathini with an increase in the adoption of biotech cotton from 7% in 1997/98 to 75% in 1999/00 to over 90% currently.

This impressive increase in adoption of biotech cotton by small-scale farmers may be attributed mainly to the success of farmers who first adopted the new technology in relation to those farmers who did not. For the small-scale farmers who adopted the new technology the most important benefit of biotech cotton was the savings in pesticide costs. In rural areas, where infrastructure, transportation and services are almost non-existent, managing pest infestation in crops like cotton is a big problem. Pesticide application implies huge difficulties for small-scale cotton farmers. Given the low level of education among small-scale farmers, mixing pesticides and calibrating backpack sprayers are problematic. Farmers have to cover long distances in hot weather carrying sprayers on their backs. Water is often scarce and has to be fetched from communal water points. By the time a farmer has detected bollworms, bought his pesticides and started to spray, severe damage has already been done.

According to a survey of 100 smallholders in Makhathini conducted by the University of Reading, South Africa, in 2001, all farmers who adopted biotech cotton benefited from the new technology. Average yield per hectare was higher for adopters than for non-adopters and the increase in yields and reduction in chemical application costs outweighed the higher seed cost, so that gross margins were also higher for adopters.

Current Status and Prospects of Biotech Cotton in Pakistan

Dr. Yusuf Zafar
Director, Agriculture and Biotechnology, Pakistan Atomic Energy Commission, Pakistan

Pakistan is the fourth largest cotton producing country and on the average, over three million hectares are planted to cotton every year. Pakistan was traditionally a cotton exporting country but since 1993/94 has become a cotton importer. Total consumption is expected to be about 2.6 million tons, or 10% of world consumption in 2006/07. The establishment of a Center of Excellence in Molecular Biology at the Punjab University, Lahore, in 1985 was the first significant step towards a full-fledged biotechnology research institution in the country. The Center has focused on Bt culture collection, gene hunting and promoters other than 35 S. The Center has filed two cases for field testing of biotech cotton. The National Institute for Biotechnology and Genetic Engineering (NIBGE), Faisalabad, was established in 1993. NIBGE is working on virus resistance, salinity tolerance, male sterility, fiber improvement, insect resistance and has already filed a case for commercial release of an insect-resistant biotech cotton: IR-FH 901. The variety contains a modified form of the Cry 1Ac gene. Fifteen other centers have research programs on various aspects of biotechnology applications. More recently, the Punjab Government established a biotechnology research institute where most of the work will be focused on biotechnology applications in cotton.

Biotech cotton is still not commercialized in Pakistan. The Government of Pakistan established Pakistan Biosafety Rules on April 26, 2005. The rules deal with a) manufacture, import and storage of microorganisms and gene technological products for research in the uses and applications of genetically modified organisms and products thereof, b) work involved in field testing of genetically manipulated organisms, and c) import, export, sale and purchase of modified living organisms, substances or cells and products thereof for commercial purposes. The Government also published the National Biosafety Guidelines in May 2005. The roles of various organizations have been established, thereby setting the stage for commercial use of biotechnology applications. A modified form of the Cry1Ac gene has been extensively tested for impact on non-target insect pests and effect on the environment in addition to field performance. Field data showed that 'insect- resistant' cotton with a modified form of the Cry1Ac gene saved US$124/ha in insecticide applications. Water stress and high temperature affected expression of the transgene. The data show that while there are zero chances of gene escape from *G. hirsutum* to *G. arboreum*, the chances of gene escape drop from 10% in close proximity to almost zero when the distance between fields is at least 15 meters. Four-year studies on the effect on soil microorganisms will be completed at the end of 2006/07.

Future plans include increased Bt expression through new genes and gene pyramiding; use of the chloroplast genome; use of novel gene resources like the spider venom gene; pyramiding of morphological traits, and development of multi-resistance varieties. However, there is an immediate need for a massive awareness campaign on all aspects of biotech cotton; science-based field testing/evaluation of biotech varieties in all their aspects, taking the necessary steps for legal adoption of biotech cotton in conformity with national/international rules, and enhancing coordination among the key government organizations involved in approval/commercialization of biotech products.

Biotech Cotton and Challenges for Africa

Dr. Osama A. Momtaz
Deputy Director, Agriculture Genetic Engineering Research Institute, Egypt

Only South Africa has commercialized planting of biotech crops (cotton-insect and herbicide tolerant, maize-insect and herbicide tolerant and soybean-herbicide tolerant) in Africa while five other countries, i.e. Burkina Faso, Egypt, Kenya, Mauritius and Zimbabwe, have reported field trials of biotech crops. Twenty African countries (Benin, Burkina Faso, Cameroon, Egypt, Ghana, Kenya, Malawi, Mali, Mauritius, Morocco, Namibia, Niger, Nigeria, Senegal, South Africa, Tanzania, Tunisia, Uganda, Zambia, Zimbabwe) are engaged in biotechnology research and development work. At least 24 countries (Algeria, Benin, Botswana, Burkina Faso, Cameroon, Egypt, Ethiopia, Ghana, Kenya, Madagascar, Malawi, Mali, Mauritius, Morocco, Namibia, Niger, Nigeria, Senegal, South Africa, Tanzania, Tunisia, Uganda, Zambia, and Zimbabwe) have the capacity and institutions needed to conduct research and development in agricultural biotechnology. To date, many African countries have ratified the Cartagena Protocol on Biosafety, and Burkina Faso, Morocco, Mauritania and Tunisia already have biosafety guidelines in place. Kenya, Mauritius, Namibia, Nigeria, Uganda and Zambia have draft guidelines. Only Egypt, South Africa and Zimbabwe have functioning legislation governing the importation, testing and use of biotech products. The current status of biosafety regulations in Africa may be summarized as shown in the table below:

Insect-resistant, virus-resistant, drought-tolerant and fungus-resistant biotech crops could be of great interest to Africa. The major barriers to the adoption of biotech products in Africa are: trade policies, consumer acceptance, availability of technology/technology transfer, professional capacity and the high cost of technology. Popularizing biotech crops in African countries require political will to use the technology, resources and capacity, practicable regulatory frameworks, public and private sector commitment, stakeholder involvement, minimal or no trade barriers and public understanding and acceptance. Governments must work to improve the design of strategic policies intended to foster sustainable production, research, trade and biotechnology uses.

Egypt has undertaken extensive work on biotech cotton. It is the only country where only *G. barbadense* is grown. Yields are as high as one ton or close to one ton of lint/ha. Efforts are underway to develop biotech *G. barbadense* varieties resistant to insects and environmental stress. Work is also going on to improve oil quality and seed proteins. Traditional fiber properties are being improved through biotechnology, while efforts are being made to add novel properties to the extra fine *barbadense* cotton.

Status of Biosafety Regulation in Africa

Biosafety Development	Countries
Signed the United National Environment Programme development project (will accede to the Cartagena Protocol on Biosafety)	Algeria, Benin, Botswana, Burkina Faso, Cameroon, Cape Verde, Democratic Republic of the Congo, Djibouti, Egypt, Eritrea, Ethiopia, Gambia, Ghana, Kenya, Lesotho, Liberia, Libyan Arab Jamahiriya, Madagascar, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Seychelles, South Africa, Sudan, Swaziland, Togo, Tunisia, Uganda, United Republic of Tanzania, Zambia, Zimbabwe (37 Countries)
Have biosafety guidelines	Burkina Faso, Mauritania, Morocco, Tunisia
Have draft legislation	Kenya, Mauritius, Namibia, Nigeria, Uganda, Zambia
Have legislation, but frameworks not yet functioning	Cameroon, Malawi
Have functioning legislation	Egypt, South Africa, Zimbabwe

Agricultural Biotechnology Research in Turkey

Dr. Isa Özkan, Cotton Research Institute, Turkey

Agricultural biotechnology research started in Turkey during the 1970s and extended to tissue culture, particularly *in vitro* micropropagation of fruit trees and ornamental plants. During the 1990s, the research focus shifted to plant regeneration via organogenesis or embryogenesis, *in vitro* micropropagation of valuable plant material, anther and ovule culture, transformation of crop plants by Agrobacterium tumefactions or particle bombardment, gene expression, gene isolation and use of molecular marker techniques for polymorphism between different genotypes, and genetic mapping. At least nine universities and many other federal and state institutes are working on plant biotechnology research including cotton. Biotechnology research specific to cotton improvement has been intensified over the last five years. The Genetic Engineering and Biotechnology Research Institute of TÜBITAK's Marmara Research Center is working on developing cotton resistant to fungal (verticillium) diseases. A shoot regeneration system suitable for gene transfer has been established and selectable and reporter marker genes have been introduced into cotton via *A. tumefaciens* and particle bombardment. In the future, genes resistant to verticillium will be introduced into cotton. The Agricultural Faculty of Kahramanmaras Sutcu Imam University (KSU) is studying the genetic diversity of diploid and tetraploid cottons to use the relationship of their fiber quality parameters to identify molecular markers that might be used in conventional breeding. Efforts are also underway to identify molecular markers for lint quality parameters (length, strength, and micronaire) for use in ongoing breeding programs. Molecular analysis of gossypol contents and resistance to biotic and abiotic stresses is also of interest to the center. The Cotton Research Institute, Nazilli, is developing a molecular genetic linkage map of cotton, using AFLP, CAPS and SSR markers to identify quantitative trait loci (QTL) for verticillium resistance and fiber traits and transfer target genomic regions into elite genetic background using marker-assisted selection. Currently, Turkey does not plan to commercialize insect-resistant or herbicide-resistant biotech cotton.

Current Status of Biotech Cotton in Thailand

Dr. Banpot Napompeth
Chairman, Advisory and Steering Working Group on the Development of National Biosafety Framework, Kasetsart University, Thailand

Cotton in Thailand is grown in humid tropical conditions characterized by 'rain growth' which creates favorable conditions for heavy pest pressure. Traditionally, Thailand used to grow *G. arboretum*, but *G. hirsutum* was introduced during 1960s. A breeding program resulted in the development of a number of suitable varieties, some of which are still being grown. Cotton area started to increase thanks to low pest pressure and good yields, and rose to 133,120 hectares in 1968/69 but dropped to about 61,000 hectares in 1978/79. The main reason for such a drastic decline was heavy pest infestation, particularly the bollworm complex, dominated by the American bollworm *Helicoverpa armigera,* and a number of sucking insects. Initially, the pink bollworm *Pectinophora gossypiella* and the spiny bollworm, *Earias vittella*, were the major bollworms and the American bollworm was not even a serious pest. Extensive use of insecticides favored the American bollworm population and the number of sprays increased to 10-15 per season during 1970s. Cotton production became unprofitable. The Government prepared various plans to revive cotton production but high insecticide costs due to the insecticide resistance problem prevented the materialization of those plans/targets.

The government established the National Center for Genetic Engineering and Biotechnology in 1983, and an a*d hoc* Biosafety Subcommittee was appointed in 1990 to draft biosafety guidelines for laboratory and fieldwork. The Guidelines were completed and approved by the National Science and Technology Development Agency in June 1992 and the National Biosafety Committee was established in January 1993. These guidelines were not legally binding, but did make it mandatory for all researchers, as well as for the funding agencies providing research grants in modern biotechnology, to comply with the guidelines in their work. The existing law applicable for the regulation of biotech crops is the Plant Quarantine Act of 1964 and the Plant Variety Protection of 1999. The Plant Quarantine Act was amended in 1999 and the importation of 89 plant species known to have undergone genetic modification was prohibited. However, a permit can be obtained from the Ministry of Agriculture and Cooperatives for study and research purposes in accordance with the biosafety guidelines. Biotech products for food, feed and processing come under the Food and Drug Administration of the Ministry of Public Health.

The Ministry of Agriculture and Cooperatives approved imports of biotech Bt cotton by Monsanto in 1995, 1996 and 1997 and biotech Roundup Ready cotton in 1999. The biosafety guidelines are not law yet, and the government is still considering the Convention on Biological Diversity and the Cartagena Protocol. On the other hand, under pressure from anti-biotech forces, the Government banned all field trials of biotech crops in April 2001.

Trials were completed on biotech cotton but it was never deregulated because of an accusation that biotech cotton escaped from farm field trials had contaminated non-biotech cotton fields. Later, samples collected from two locations detected Bt cotton in conventional cotton fields. In fact this event has led to the banning of biotech crop field trials until the biosafety guidelines are passed into law. In August 2005, the Government further tightened the law and confined all research work on biotech crops to labs at government research institutions. Universities were advised to stop all research on biotech crops and to destroy all biotech crops in the field. However, the fact of the matter is that farmers continue to plant biotech Bt cotton year after year using self-seeds. Official surveys undertaken in September 2006 showed that some districts had as much as 60-85% of the cotton area under biotech varieties. In Thailand, insect-resistant Bt cotton is called '*Fai Sa Mo Lek*' which means '*iron boll cotton*.'

Economic Threshold Level in Syria

Season	ETL for Bollworms	% Area treated with insecticides
1992/93 - 1994/95	6 live larvae/100 fruiting forms	3.5
1995/96 - 2000/01	7 live larvae/100 fruiting forms	2.1
2001/02 - 2003/04	10 live larvae/100 fruiting forms	0.4
2004/05 - 2005/06	10 live larvae/100 fruiting forms	0.3
2006/07	10 live larvae/100 fruiting forms	0.4

Cotton Production and Integrated Pest Management in Syria

Dr. M. Naif Al-Salti
Director, Cotton Research Administration, Syria

Only *Gossypium hirsutum* is grown in Syria, and cotton occupies about 17% of the irrigated area in the country. The Ministry of Agriculture and Agrarian Reform, through a unit specialized in cotton issues— the Cotton Research Administration (Cotton Bureau)—deals with cotton research and production. The Cotton Research Administration receives planning advice from the General Commission for Scientific Agricultural Research (GCSAR), an advisory body under the Ministry of Agriculture and Agrarian Reform. All cotton growers must obtain a license from the Ministry to grow cotton. The seedcotton price is announced for the base quality grade before the planting season starts. The price is valid for one year. The Cotton Marketing Organization (CMO) is the only buyer of seedcotton. The price for the 2006/07 season was 30.75 Syrian pounds (US$0.66) per kilogram of seedcotton.

Overall coordination of the sector is secured by means of an annual "Cotton Congress." The Thirty-Sixth Congress will be held this year, and about 400-500 people will attend this event. The congress reviews the results of the past cotton season, including research findings, and formulates policy directions for the industry. Cotton area is limited, and each extension unit is responsible for pest control, advice on cotton growing practices and yield estimates for every field. The Cotton Research Administration issues a bulletin containing recommendations for the next season.

Cotton is grown using various production systems, depending upon conditions in each region. Typically, wheat is harvested in June and the land is plowed two times and left exposed to the air and sun. The third plowing takes place in February or March of the following year and is followed by land leveling. Planting begins in early April and must be completed by mid-May. Planting is done by dibbling 4-10 seeds in a configuration of 65-75 cm between rows and 18-25 cm between plants. Pre-emergence herbicides are commonly used. All cotton is irrigated and three irrigation methods are used; flood = 82%, furrow = 14%, and drip = 4%. The three sources of water are: rivers = 51%, irrigation projects = 20%, and wells = 29%. On the average, 8-10 irrigations are applied, with average water consumption of about 14,000 cubic meters per hectare. On average, 150-190 kg/ha of nitrogen and 30-75 kg/ha of phosphorous are applied.

Syria has a very successful integrated pest management system. In the late 1970s about half of all cotton fields in Syria were treated with insecticides to control the American bollworm *Helicoverpa armigera*, the spiny bollworm *Earias insulana*, green worms *Spodoptera* spp., thrips and aphids. Researchers concluded that spraying insecticides resulted in the decline of natural enemies (predators and parasitoids). Syria decided to eliminate the use of insecticides and implemented a very successful insect control system. The key components of the system are: spraying insecticides only when it is inevitable and increasing the economic threshold level with emphasis on a biological control system. Economic threshold levels, particularly for bollworms, were revised upward to minimize reliance on chemicals. Natural enemies started to multiply at a higher rate and surpassed the insect population. The cotton area sprayed with insecticides was less than five percent after 1995/96 and less that one percent since 2001/02.

While the area treated with insecticides has declined, the area treated with parasitoids mainly *Trichogramma principium* and *Habrobracon (Bracon) brevicornis* has increased.

Area Treated with Parasitoids in Syria

Years	Area (ha)
2001/02	1,293
2002/03	1,541
2003/04	1,577
2004/05	2,912
2005/06	3,388
2006/07	5,270

Average Yields and Cotton Area Sprayed with Insecticides

Year	Average Lint Yields (Kg/ha)	Area treated with insecticides (%)
1987/88	750	18.9
1995/96	1,044	3.5
1997/98	1,377	1.5
1999/00	1,260	1.2
2001/02	1,370	0.5
2003/04	1,274	0.4
2005/06	1,512	0.1
2006/07	1,028	0.4

Cotton in Myanmar

Ms. Than Than Nu
Cotton and Sericulture Department, Myanmar

Cotton in Myanmar is planted in a solid block of close to 300,000 hectares in the Mandalay, Magway and Sagaing administrative divisions. A small portion of the cotton area spills over into the Bago division in the south. The Mandalay and Magway divisions, taken together, plant about 80% of the cotton area, with the Sagaing division planting about 17% during a normal year. Cotton was planted on 310,076 hectares in 2006/07, out of which 73% was *G. hirsutum* and 27% *G. arboreum*. Upland cotton is planted pre-monsoon, during monsoon and late monsoon with over 80% of the *G. hirsutum* area planted close to the end of monsoon. Half of the remaining upland area is planted before the monsoon starts and the remaining half during the monsoon season. The Mandalay and Magway divisions are lowland areas where the weather is hot, and the dry season is long. The hottest month is April when the temperature can reach 40ºC in the daytime. The summer season is generally from February to July. The rainy season starts in June and lasts until October. The coolest season spans from November to mid-February.

Cotton yields in Myanmar are very low, almost one-third of the world average. The main reason for low yields is bollworm damage. Cotton yields have not increased in Myanmar for many years and the ICAC forecast for 2006/07 is 208 kg/ha lint, close to the average for the last 10 years. Bt cotton has been tested in Myanmar for four years and the average increase in yield is more than double.

Achievements, Challenges and Prospects of Cotton Research and Production in the Sudan

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Cotton farming is a livelihood issue and indeed a heritage and a way of life for more than 300,000 Sudanese farmers. The year 2004 marked the 100th anniversary of the Cotton Research Program. It is worth noting that during the period prior to the mid-seventies cotton production research was entrusted to the Empire Cotton Growing Corporation (ECGC). The ECGC was undertaking research on cotton in several countries (Sudan, Uganda, Tanzania, Nigeria, South Africa, Rhodesia, etc). The ECGC was headquartered in Sudan where voluminous cotton research findings were derived, benefiting not only the African member countries but all cotton producing countries in general. Genetic control of the devastating bacterial blight disease is known worldwide as an achievement based on pioneering research work close in Sudan. Currently, the broader objectives of the Cotton Research Program (CRP) are: variety improvement, diversification of intrinsic quality characteristics through breeding of new styles and variants, vertical upgrading of productivity via generation of multidisciplinary technological packages that fit into the integrated crop management strategy, furnishing of innovations and decision-making assistance to the various partners in the cotton commodity system, and reduction of stickiness in cotton.

The contribution of conventional breeding to cotton improvement in Sudan is enormous. When the outbreak of the leaf curl and bacterial blight diseases occurred, the program was geared towards developing resistant varieties utilizing the available gene pool. The gene combination B2B6 gave adequate and durable protection against bacterial blight race. Later, new races of bacterial blight were controlled through different gene combinations (B2B3B6B7B9). The leaf curl virus disease was controlled in the *barbadense* material through incorporation of a single partially dominant gene. The number of released varieties and registered lines to date totals more than 50. Seven varieties are currently grown either commercially or in limited propagation plots. These are: Barakat 90 (EFC), BarakatS (EFC), Shambat-B (FC), Nour (HCA), Barac (67) B (MC), Albar (57)12(CC) and Acrain (CC).

Biotechnological research is focused on production of doubled haploid cotton and molecular tagging of useful traits for DNA marker assisted selection. There is special interest in incorporating the double haploid (DH) technology in the hybrid breeding project. Through DH, one can fix the hybrid vigor and overcome the problem of hybrid seed production. Insect control costs are 30-40% of total production costs and control is still not good. Farmers in the same location obtain varying yields, despite using the same inputs. Thus efficient agronomic management of the basic cultural practices and an understanding of the inputs and their interactions (i.e. avoiding rank growth and unnecessary use of insecticides) are the decisive factors in enhancing productivity. Cost of production continues to increase, even though yields are stagnating. To sustain cotton production, Sudan must increase yields and lower the cost of production. Cotton planters and pickers had been well researched and even commercially implemented by some schemes during the 1970's and 1980's until they were abandoned for socioeconomic reasons. Today, however, shortage of labor is a chronic problem, hence, reintroduction of machine planting and picking is very necessary. Future research should therefore be launched into new techniques that will facilitate a better understanding of the cotton plant's response to input use and help increase the efficiency of cotton farmers in this area. If such understanding can be achieved and implemented in practical farming, the course of the long-standing stagnation will definitely be changed.

The Leaf Curl Epidemics: The Situation with Cotton Leaf Curl Disease

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Cotton leaf curl disease (CLCuD) is transmitted by the whitefly, *Bemisia tabaci*. It is a disorder that afflicts several malvaceous hosts, of which cotton is the most important. CLCuD is endemic across most of Pakistan and northwestern India. The disease is also reported in Egypt, Sudan, Nigeria, Malawi and South Africa. Affected plants exhibit characteristic symptoms that consist of vein swelling, upward or downward curling of leaves and the formation of enations on the main veins on the undersides of leaves that frequently develop into cup-shaped, leaf-like structures (Figure 1). Infected cotton plants are conspicuously greener than non-infected plants due to the proliferation of chloroplast-containing tissues. Symptoms are highly variable, depending on the varieties, but also on the age of the plant at the time of infection. Plants infected late in the season show only mild symptoms and may not suffer a significant yield reduction, whereas plants infected early are severely stunted and usually yield no harvestable lint.

Cotton production in Pakistan suffered heavily from an epidemic of CLCuD that began in the mid 1980s and spread to virtually all cotton growing areas, as well as into western India. Prior to the 1980s, the disease was only a minor sporadic problem. It has been suggested that the introduction and widespread use of highly susceptible cotton varieties such as S-12 and CIM70 was the main factor in converting this minor nuisance into an epidemic problem. *Gossypium arboreum*, the cotton species native to this region, is immune to CLCuD. Although CLCuD remained endemic, losses due to the disease were gradually reduced by the replacement of susceptible varieties with locally developed, tolerant and resistant cotton varieties. In 2001, however, there was a change in the prevalent virus population and resistant varieties began to show the typical symptoms of CLCuD infection, signaling a second, resistance-breaking wave of the CLCuD epidemic. Since then the new strain has spread to most cotton growing areas of Pakistan and into India.

Figure 1. Typical Symptoms of a Cotton Leaf Curl Disease

CLCuD is caused by a begomovirus complex consisting of monopartite begomoviruses (genus *Begomovirus*, family *Geminiviridae*) and a recently identified single-stranded DNA satellite termed DNA β. Begomovirus-DNA β infections in cotton are invariably associated with a third component, known as DNA-1, which is a satellite-like molecule that plays no essential part in the etiology of CLCuD.

The strain of CLCuD prevalent in the 1990s (referred to as the "Multan strain") has been shown to be caused by one of at least six distinct begomovirus species (Cotton leaf curl Multan virus [CLCuMV], Cotton leaf curl Kokhran virus [CLCuKV], Papaya leaf curl virus, Tomato leaf curl Karnataka virus, Cotton leaf curl Alabad virus and Cotton leaf curl Rajastan virus). Affected cotton plants frequently contain more than one of these viruses. A further begomovirus species, Cotton leaf curl Bangalore virus, has been isolated from CLCuD affected *G. barbadense* in southern India. Although the precise geographic distribution of this virus has not yet been determined, it is unlikely that it is involved in causing the disease in the epidemic areas of northern India. The Burewala strain has thus far been shown to be associated with one begomovirus, a recombinant derived from CLCuMV and CLCuKV, although there is mounting evidence to suggest that additional viruses are being drawn into the epidemic.

The DNA β molecules are a recently identified group of symptom-modulating, single-stranded DNA satellites associated with monopartite begomoviruses and occurring only in the Old World. Since their identification in 2000, over 200 full-length DNA β sequences have been deposited with the databases. They have a highly conserved structure, being approximately half the size of their helper begomoviruses (~1370 nucleotides), encoding a single gene (known as βC1).

This gene encodes a protein which is the major pathogenicity determinant of the complex. βC1 is capable of inducing a full range of symptoms typical of CLCuD. In addition, the product of βC1 has been shown to suppress post-transcriptional gene silencing (a form of host defense), bind DNA and possibly have a role in virus movement.

The Multan strain of CLCuD was associated exclusively with a single type DNA β (the CLCuD DNA β), despite the fact that the disease is caused by upwards of six begomovirus species. Similarly, the resistance-breaking Burewala strain appears to be associated with a single DNA β derived from the CLCuD DNA β. This maintains the CLCuD DNA β βC1 gene but contains some sequences derived from a DNA β associated with tomato leaf curl disease. The significance of this is unclear.

The natural resistance of the host plant to CLCuD in cotton was a major factor in overcoming the devastating losses caused by the Multan strain during the 1990s and will be important in the future. Interest is now mounting in genetically engineered resistance to the CLCuD complex. The major challenge to all forms of resistance to CLCuD is the diversity of viruses which cause the disease. For any strategy to stand a chance of achieving an effective and durable solution, it would have to incorporate a broad-spectrum of resistance effective against all the viruses present in the field.

The transgenic strategies under investigation rely almost exclusively on post-transcriptional gene silencing (PTGS) or transcriptional gene silencing (TGS). These are natural phenomena, which stimulate the plant's own defenses to target the invading virus. The one "target" present in all CLCuD-affected plants is CLCuD DNA β, but initial studies attempting to induce PTGS/TGS against this molecule met with little success. Somewhat more promising have been the efforts targeting the replication-associated protein (Rep) gene and AV2 gene (the function of which remains unclear) of the viruses by antisense expression as either full-length (AV2) or truncated (Rep) coding sequences. Both these strategies are presently being assessed in cotton under field conditions to determine whether the sequences being used provide a spectrum of resistance to all the CLCuD-associated begomoviruses broad enough to be effective and durable.

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