COMMON FUND FOR COMMODITIES

Technical Paper No. 53

PROCEEDINGS OF THE

REGIONAL CONSULTATION ON GENETICALLY MODIFIED COTTON FOR RISK ASSESSMENT AND OPPORTUNITIES FOR SMALL-SCALE COTTON GROWERS (CFC/ICAC/34FT)

National Institute for Biotechnology and Genetic Engineering
Faisalabad, Pakistan
March 6-8, 2007

ISAAA
INTERNATIONAL SERVICE FOR THE ACQUISITION OF AGRI-BIOTECH APPLICATIONS

NIBGE

This publication is an output of the project CFC/ICAC/34FT – Regional Consultation on Genetically Modified Cotton for Risk Assessment and Opportunities for Small-scale Cotton Growers. The project was funded by the Common Fund for Commodities at the request of the International Cotton Advisory Committee. The publication has been prepared by the International Service for the Acquisition of Agri-biotech Applications. Its contents represents the opinion of the authors and does not necessarily reflect the views of the Common Fund for Commodities or the International Cotton Advisory Committee.

COMMON FUND FOR COMMODITIES

Stadhouderskade 55, 1072 AB Amsterdam, The Netherlands
Postal Address: P.O. Box 74656, 1070 BR Amsterdam, The Netherlands

Tel: (31 20) 575 4949 E-mail: Managing.Director@common-fund.org
Fax: (31 20) 676 0231 Website: www.common-fund.org

PROCEEDINGS OF THE

REGIONAL CONSULTATION ON GENETICALLY MODIFIED COTTON FOR RISK ASSESSMENT AND OPPORTUNITIES FOR SMALL-SCALE COTTON GROWERS (CFC/ICAC/34FT)

National Institute for Biotechnology and Genetic Engineering
Faisalabad, Pakistan
March 6-8, 2007

THE COMMON FUND FOR COMMODITIES
- COOPERATION FOR DEVELOPMENT -

Statement by

Sietse van der Werff
Senior Project Manager

on the occasion of the

Regional Consultation on
Genetically Modified Cotton for Risk Assessment and Opportunities for Small-scale Cotton Growers (CFC/ICAC/34FT)

6 - 8 March 2007, Faisalabad, Pakistan

Mr. Chairman, Distinguished Participants, Ladies and Gentlemen:

It is a pleasure for me to be here at this regional consultation and to be able to share with you some of my thoughts on this meeting, its objectives and the expected outcomes. Before doing so I should, however, thank the organizers, both the team from ISAAA and that from NIBGE for hosting this workshop and for providing these excellent facilities which enable us to meet here in the coming three days.

I should add to that that on a personal note I am pleased to be back at NIBGE which was the lead institute for a CFC/ICAC project on whitefly-transmitted Geminiviruses of cotton. Additional research work on that project took place at the John Innes Centre in Norwich, UK and at the University of Arizona in the United States. I am sure that only one little question from any of you hinting in that direction will trigger a long lasting lecture from Dr Yusuf Zafar or from any of his team members involved in that project. I therefore suggest you leave that for after the regular sessions of this consultation.

As we have limited time for these introductions and we all look forward to the start of the presentations focusing on the substance of this consultation, I will be very brief. I will therefore not give the usual introduction on mandate and activities of the Common Fund for Commodities. I have brought some brochures and documents which will inform those who are interested.

Let me just spend two minutes to explain why the Common Fund has funded this consultation:

The focus of the Common Fund's activities is on commodities. All developing and least developed countries are heavily dependent on commodities, which form the backbone of their economies and account for the bulk of their export earnings. Given your knowledge about the importance of the cotton sector for your countries, I do not need to further elaborate on this subject.

The Common Fund thus operates under the novel approach of a commodity focus instead of the traditional country focus. The Fund concentrates on low cost, high impact projects which have the potential of becoming self-sustainable. By the end of 2006, the Fund had approved some 145 regular projects with a total cost of more than USD 420 million, and covering more than 35 commodities. Of this, CFC finances approximately USD 180 million, the balance coming from other donors and from the participating institutions through counterpart contributions.

In addition, about 85 small-scale projects (so-called "Fast Track" projects) have been approved. These Fast Track projects are small projects, with a maximum CFC contribution of US$ 120,000.

The current consultation is one of those Fast Track projects. Its aim is to share information, knowledge, and experience on the subject of the potential, perspectives and problems related to genetically modified cotton, or "biotech cotton" as some people prefer to call it.

The Fund does not take a specific position in favor or against biotech cotton. In line with our mandate, the Fund aims to support cotton-producing countries and its producers to obtain a reasonably secure and rewarding income out of cotton production, processing and marketing. We provide support to the development of a sound and sustainable cotton sector, addressing problems of common interest for the global cotton sector. As our focus is on resource-poor, small-holder farmers, we have no preference at the country level, be it for country A, B or C. Let me recall in this respect that our focus is on commodity rather than country-focused development. As you are aware, there are plenty of other organizations active in support at country level.

This consultation is being supported because we see its objective (sharing information on global developments) important for especially those countries that are possibly interested in new developments, but who can not oversee the implications or the potential long-term costs of their possible introduction. This position is shared by the ICAC, who submitted the proposal to hold this consultation to the Common Fund. It is expected that during the consultations in the coming days, there will be an open exchange on the advantages and disadvantages of the introduction of biotech cotton in specific production environments. Due attention should thereby be given not only to relevant considerations at the national (or possible cross border) level, but also to the potentials or risks for small-holder cotton producers, who are unmistakably mentioned in the full title of this consultation.

Mr Chairman, being a layman in the field of biotech cotton (hopefully the only one in this audience), I have taken enough time with these introductory remarks. I look forward to attending a highly interesting and challenging consultation that should result in solid assessments and recommendations of use for decision makers involved in this highly controversial subject.

I thank you for your attention.

INTERNATIONAL COTTON ADVISORY COMMITTEE
1629 K Street NW, Suite 702, Washington, DC 20006 USA
Telephone (202) 292-1687 • Fax (202) 463-6950 • e-mail: rafiq@icac.org
http://www.icac.org

M. Rafiq Chaudhry
Technical Information Section

Ladies and gentlemen

It is a matter of great honor for me to represent the International Cotton Advisory Committee at this Consultation. The Executive Director, Dr. Terry Townsend, send his regrets that he cannot attend because of a meeting on cotton policies in the WTO that is being conducted in Geneva at this time. Mr. Sietse van der Werff of the Common Fund for Commodities already explained the relationship between the International Cotton Advisory Committee and the Common Fund for Commodities. This very consultation is being held under the project Regional Consultation on Genetically Modified Cotton for Risk Assessment and Opportunities for Small-Scale Cotton Growers. The National Institute for Biotechnology and Genetic Engineering (NIBGE), Faislabad, the International Service for the Acquisition of Agri-Biotech Applications (ISAAA), and ICAC started working on this project almost a year ago. The project was approved by CFC in July 2006 and we are here today. I would like to thank ISAAA and NIBGE for their efforts to prepare this project. Thanks to CFC for funding this project. I am personally thankful to Mr. van der Werff for his help in the smooth approval of the project.

Ladies and gentlemen I am thankful to the Government of Pakistan for hosting this Consultation. Dr. Randy Hautea of ISAAA and Dr. Yusuf Zafar of Pakistan really put in a lot of time and effort to make this meeting a success. Dr. Claudia Canales of ISAAA joined us a little late in the preparations for the meeting but she did an excellent job in securing visas and providing tickets to foreign participants. We have 43 foreign participants from 27 countries. I am also thankful to Dr. Zafar Khalid, the new Director of NIBGE, and his staff for hosting us. After all, this facility belongs to NIBGE.

The ICAC hopes to hold its 68th Plenary Meeting in 2009 in Pakistan, and support of the Government of Pakistan for the ICAC is very much appreciated.

Ladies and gentlemen

Cotton is a technical and cash crop and there is always a lot going on. ICAC estimates that 25.3 million tons of cotton will be produced in the current season. Production jumped from 20.7 million tons in 2003/04, to 26.3 million tons in 2004/05. We do not foresee any such increases, and for many more years production is expected to be less than 27.5 million tons.

Consumption continues to rise, which is good for producing countries. Consumption is estimated at 26 million tons for 2006/07, more than half a million tons higher than production in 2006/07. Higher consumption than production is going to affect ending stocks, which is another good sign for prices to rise in 2007/08. The Cotton Outlook A Index, which is an indicator of international cotton prices, is expected to be US$1.30/kg in the current season. Prices in 2007/08 are forecast to rise to US$1.48/kg lint, 18 cents/kg higher over the current season.

Consumption is rising mainly due to a continued increase in consumption in China (Mainland). China alone is expected to consume 40% of the cotton produced in the world in 2006/07.

Ladies and gentlemen, the cotton trade has also seen substantial changes in the recent past. Consumption continues to decline in the USA, to less than 25% of production in the country. India is expected to export close to one million tons of cotton in 2006/07. This will be the largest quantity of cotton ever exported by India. Driven by Chinese imports, the international trade is growing, and is expected to be 35% higher in 2006/07 than five years ago.

On the production research front, biotechnology is getting lot of attention. For the last many years, I cannot remember a meeting on cotton where biotechnology applications were not discussed. The cotton industry has become more quality conscious, and is quickly moving to instrument testing of quality parameters. Cost of production has been checked partly due to increases in yields, but also due to a reduced use of insecticides. Insecticides worth US$1.6 billion were used on cotton in 2005/06. The cotton industry has realized that the aggressive use of insecticides was a costly mistake. Fortunately, insecticide use on cotton, in terms of number of sprays, is going down in most countries.

At last, ladies and gentlemen, let me say a few words about the Consultation. The objective of this Consultation is not to promote biotech cotton, and neither it is to campaign against biotech cotton. Biotech cotton is a reality. Forty-five percent of the cotton produced in the world in 2006/07 is expected to come from biotech varieties. The Consultation will discuss why to grow biotech cotton, if you decide to grow it, and why you should be careful while making such a decision. The Consultation is particularly focused on small-scale growers and that is why we have invited speakers from China (Mainland), Colombia, India, and South Africa, to share their experiences on biotech cotton.

Good luck and enjoy the Consultation.

INTERNATIONAL SERVICE FOR THE ACQUISITION OF AGRI-BIOTECH APPLICATIONS (ISAAA)
c/o IRRI, DAPO Box 7777, Metro Manila, Philippines
Phone: +63 2 845 0563 • Telefax: +63 49 5367216
http://www.isaaa.org

- Welcome Remarks -

Randy A. Hautea
Global Coordinator

on the occasion of the

Regional Consultation on
Genetically Modified Cotton for Risk Assessment and Opportunities for Small-scale Cotton Growers (CFC/ICAC/34FT)

6 - 8 March 2007, Faisalabad, Pakistan

Distinguished participants, friends and colleagues, ladies and gentlemen.

It is my pleasure to welcome everybody, in behalf of ISAAA, to this Consultation on biotech cotton.

Let me also take this opportunity to convey our warmest thanks to CFC, ICAC, and NIBGE, for co-sponsoring and co-organizing this important Consultation.

Allow me a few minutes to explain ISAAA's interest and participation in this Consultation.

ISAAA is a not-for-profit international organization dedicated to the transfer and responsible use of appropriate agri- biotechnology applications in developing countries for their principal benefit, in terms of improved productivity, income, environment, among others.

ISAAA was formally founded in 1991, several years before the first wide-scale commercial deployment of biotech crops, when the great potential of the technology in addressing major constraints in developing country agriculture became apparent. This was way before the subsequent concerns, controversies and global debate about the technology became more prominent and practically overshadowed most other substantive discussions about the technology.

Currently, ISAAA has two core programs: crop biotechnology transfer and the knowledge sharing initiative.

ISAAA remains committed to biotechnology transfer, by continuously monitoring developments in the technology front, and exploring and pursuing opportunities where technology acquisition, access and transfer – mostly of proprietary technology from the private sector - can be facilitated to provide a match between available technology and the identified priority agri-biotechnology needs of developing countries. The technology transfer initiative is complemented with a range of capacity building activities in technical, policy and regulatory aspects of agricultural biotechnology.

The bigger thrust and core program of ISAAA is the Knowledge Sharing Initiative, operated by its Global Knowledge Center on Crop Biotechnology, more popularly known by its acronym, the KC. The KC is a response to the demand of various stakeholders for authoritative information to facilitate an informed discussion and to support decision-making process regarding crop biotechnology. ISAAA shares the belief that enlightened decision making can only be made possible through an open, transparent, and vigorous exchange of authoritative information and knowledge about crop biotechnology and its various aspects and implications.

This Consultation thus provides an excellent opportunity to further the cause of broadly exchanging information, knowledge and experience on biotech cotton, between and among major stakeholders in the cotton producing world, mostly from developing countries of the South. It has been over a decade since the first commercial cultivation of biotech crops, including biotech cotton. Most certainly, more than a decade of biotech cotton cultivation provides a wealth of learning that could and should be broadly shared, and could guide decisions and actions in the future in regard to biotech cotton and the various opportunities and challenges it poses especially to small-growers in the developing world.

Let me again welcome everybody in ISAAA's behalf, and a special note of thanks to those who traveled far to join us in this Consultation. Let me also reiterate our sincere appreciation to CFC, ICAC and NIBGE. We look forward to a very successful Consultation.

Thank you all very much.

National Institute for Biotechnology and Genetic Engineering
P.O. Box #577, Jhang Road, Faisalabad, Pakistan

Address by **Dr. Yusuf Zafar**
Local Organizer
of the International Consultation Meeting on Bt Cotton

Honorable Chief Guest, Dr. Ansar Parvez, Member Science, PAEC

Mr. Sieste van der Werff, Senior Project Manager, Common Funds for Commodities (CFC)

Dr. Rafiq Chaudhry, International Cotton Advisory Committee (ICAC), Washington, D.C United States

Dr. Randy Hautea, Global Coordinator, the International Service for the Acquisition of Agri-Biotech Applications (ISAAA), Philippines

Dr. Zafar M. Khalid, Director, NIBGE

Foreign delegates, distinguished guests representing all the stakeholders of the cotton chain

Good Morning & Asslammualakum.

First of all, I am thankful to the Chief Guest, who despite his pressing engagements, agreed to spare some time for this meeting.

Sir, the original idea to organize this meeting emerged during a two days Second Expert Panel Meeting set up to write a revised version of the Report on Biotechnology of Cotton by ICAC, held in Washington D.C. in July 2004. I along with Clive James from ISAAA, Prof. Stewart and Dr. Rafiq Chaudhry, ICAC, discussed this issue.

The idea was further refined by ISAAA and ICAC, and finally, the CFC agreed to sponsor the project. We are thankful to these international bodies for providing funds to organize such a large meeting.

This is not the first time. Earlier, CFC contributed immensely to our understanding and towards the management of Cotton Leaf Curl Virus in Pakistan through a tripartite project between NIBGE, the University of Arizona, United States, and the John Innes Centre (JIC), Norwich, UK.

The CFC contributed US$1.2 million for this research project in 1994 for a period of five years. Dr. Rob Briddon Co-PI of JIC, UK, has since joined our team and has now been working with us for the last 3 years. What a great outcome of this project!!

Sir, last year the plant biology scientific community celebrated the first decade of the commercial release of biotech crops, first planted in 1996. In 2006, more than 10 million farmers from 22 countries (developed and developing) planted biotech crops on more than 100 million hectares. This is a historical landmark, as no other agricultural technology has ever gained such rapid acceptance, maintaining double-digit growth rates for the tenth consecutive year. In the same year, India, the largest cotton-growing country in the world, tripled its Bt cotton area to 3.8 million hectares, which is more than the total cotton area of Pakistan (around 3 million hectares).

The economic and environmental benefits of the deployment of Bt cotton are well known, however, the flow of genetically modified (GM) cotton among cotton producing developing countries has remained slow. GM crops, unlike conventional breeding material, are tightly regulated by legislation, which include Biosafety and Intellectual Property Rights (IPR). The regulatory costs are much higher than R&D costs, and like in all innovations, the implementation of government regulations is always much slower than the rate of scientific discoveries.

Plant scientists should be aware of the difficulties of the development of Golden Rice: seventy four patents/ material transfer agreements had to be resolved to make one GM crop free for resource-poor farmers!!!

This brings into the debate the fear of monopoly by five or six large agricultural biotechnology multinational companies, and the direct benefits to consumers.

Outside the agri-biotech field, gene technology has had a wider acceptability. Insulin for diabetes, interferon for cancer patients, and bio enzymes of washing powder have been accepted by the society for the last 30 years and NO questions were asked!!

GM crops currently commercialized benefit both farmers and the seed companies, but not the public at large. There is a communication gap between scientists and the public, and reduced funding resources are available for the public agri-biotech sector.

Sir, such a gathering of scientists and policy makers from major cotton producers and users countries of Africa, Asia and Latin America, will push further an ongoing debate on how to rapidly increase the adoption rate of GM cotton in the developing world. This spread should be at a low cost, and with less complex regulatory hurdles, although with responsibility. I strongly hope that the exchange of ideas and the sharing of successful experiences by our Chinese and Indian colleagues will set the road map for other developing countries. We expect such outcome from this meeting.

Sir, there are 53 foreigner delegates from all over the globe. We have invited almost all the stakeholders of cotton, including scientists, seed companies, farmers, regulators, members of All Pakistan Textile Mills Association (APTMA), and government functionaries of Pakistan. The experts will discuss all issues pertaining to R&D, environmental biosafety, IPRs, and they will also exchange the experiences of their respective countries. In all, there will be 22 presentations and two open workshops.

We sincerely believe that this consultation meeting will be a milestone in setting the road map for the development and adoption of Bt cotton in developing countries. Mutual exchange will result in capacity building and technology transfer, which are essential prerequisites for the economic and democratic development of the so-called Third World. Very soon, the Third World will be home of 85 percent of the world's population. The developing world should not miss out on the opportunity to play a major role in the second plant biotechnology wave. The benefits of GM crops cannot remain the sole privilege of the developed world.

After the first announcement of this meeting there have been many major changes in our institution. Despite this, the team members of the Plant Biotechnology Division, and particularly of the Cotton Biotechnology Group, have worked day and night to make this event possible. Everybody was very supportive, but in particular the help of Shahid, Imran, Javaria, Aamer, and Jamil Abid, who carried most of the burden, need special mention. Constant support by Claudia, Randy and Rafiq also needs to be acknowledged, and deserve appreciation.

In the end, I am thankful to the Chief Guest for sparing time, and to the organizers for funding such a useful activity. I wish you a pleasant and rewarding stay. Thank you for your patience in listening.

Table of Contents

Summary Report

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 aimed at discussing all aspects of biotech cotton. The International Service for the Acquisition of Agri-biotech Applications served as the Project Executing Agency. The National Institute for Biotechnology and Genetic Engineering (NIBGE), Faisalabad, Pakistan hosted the consultation. Forty-three international participants from 27 countries plus 73 participants from Pakistan attended the meeting. The list of participants is attached. A summary of the meeting is presented below.

1. Crop biotechnology applications and uses include tissue culture/embryo culture, DNA marker assisted technologies, diagnostics and genetic engineering tools. However, genetic engineering is the most popular commercial use of the technology in agriculture. Nine countries have commercialized biotech cotton so far, and around 36% of the world cotton area in 2006/07 was planted to biotech varieties.

2. Acceptance of biotech cotton depends on a range of issues related to agronomic factors, environmental concerns, farming systems and long-term sustainability of the technology. The technology developers and users have a challenge to maintain high quality stewardship programs to protect sustained use of the technology. Political support and national investment in biotechnology are also crucial for safe and economical use of biotechnology applications.

3. Concerns and apprehensions about the safety and sustainability of currently available biotech products in cotton have been raised. Most safety issues have been adequately addressed at the scientific level. Continuing research and integrating public awareness into the scientific process from the very beginning can effectively address many other concerns.

4. The first generation products have agronomic benefits in the form of lower insecticide use and better weed control, although better weed control may be accompanied by increased herbicide use. The second-generation products are expected to bring premium prices to cotton producers with products that benefit consumers too. Technology developers will benefit by gaining market share. The future traits for potential improvement in cotton include improved photosynthetic efficiency for achieving higher yield, improved tolerance to drought conditions, tolerance to high temperature, tolerance to chilling temperatures, improved salt tolerance and better fiber quality characteristics.

5. The regulatory process for development, approval, testing and commercialization of biotech products is cumbersome and expensive and limits the spread of the technology to developing countries. Countries like China (Mainland), India and Pakistan have developed their own genes against bollworms and sucking insects and are developing genes against other pests. The developed infrastructure may lower the cost of the technology. China (Mainland) already has 80% of the biotech cotton area under a locally developed Bt gene. It is important to incorporate the technology into locally adapted germplasm, as locally developed varieties are usually the most suited to the prevailing environmental conditions, cropping systems and biotic constraints such as pests, and have production of higher quality. Also, more researchers need to be involved in the regulatory bodies set up by governments.

6. China (Mainland) and India have seen tremendous increases in yields since the adoption of biotech cotton. Small growers in South Africa have equally benefited from this technology, as did the growers in areas of Colombia with a high incidence of target pests. However, the insect resistant biotech varieties may not bring the same benefits to growers in areas/countries where the cost of controlling the targets insects is lower than the cost of the technology fee.

7. 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 have interests in product properties based on cotton fiber characteristics. Safety studies on non-allergenicity and non-toxicity of biotech cotton DNA and proteins have alleviated fears about biotech bi-products, such as cooking oil and livestock feed cakes from cotton.

8. Only South Africa has commercialized planting of biotech crops in Africa, while six other countries, i.e. Burkina Faso, Egypt, Kenya, Mauritius, Zimbabwe and Uganda, are fieldtesting biotech crops. Twenty African countries are engaged in biotechnology research. However, only Burkina Faso, Egypt, South Africa and Zimbabwe have functioning regulations and/or legislations to import, test and use biotech products. There is a need to improve strategic policy making for advancing sustainable production, research, trade and other biotechnology uses.

9. The experience in India shows that the Bt expression decreases as the crop matures, so the level of protection by the transgene decreases at later stages of plant development. The expression decrease needs to be monitored, particularly in long-duration varieties or growing conditions similar to Northern India and Pakistan.

10. Biotechnology research in cotton is limited due to a lack of technical staff, high cost of research and development work, controversies and opposition from policy makers, lack of financial support from governments, political skepticism that biotechnology is an economic maneuver by developed countries and private companies, costly risk management studies, narrow scope of Cry genes and inability to modify single cell (fiber) growth. Limitations could be alleviated through regional and international cooperation and networking.

11. The Government of Pakistan established the 'Pakistan Biosafety Rules' in April 2005. The Government also published the 'National Biosafety Guidelines' in May 2005. Roles of various organizations have been established, setting the stage for commercial use of biotechnology applications. Local researchers have developed a modified form of the Cry1Ac gene that has been extensively tested throughout the main cotton growing areas. The data show significant savings to growers in insecticide applications in spite of the fact that drought and temperature affected expression of the transgene. Farmers are demanding biotech varieties, but the government is still considering commercial release of biotech varieties.

12. Ninety seven percent of the biotech cotton area in 2006/07 was located in three cotton producing countries: United States, India and China (Mainland). Six other countries are commercially growing biotech cotton (Argentina, Australia, Brazil, Colombia, Mexico, and South Africa) and several others are testing, or growing biotech cotton without the benefits of official regulatory approval. Unregulated use of biotech cotton is a major stewardship challenge that needs to be addressed to assure seed and product quality to cotton growers, and the sustainability of the technology.

13. The rate of adoption of biotech cotton in producing developing countries is slow due to various policy-related, regulatory, technical, and trade constraints. Partnerships and international cooperation could help allow stakeholders to work more effectively for improving understanding of the technology and its commercial use.

1. Global Commercialization of Biotech Crops

Randy A. Hautea
Global Coordinator and Director, *SEAsia*Center
International Service for the Acquisition of Agri-biotech Applications

Panfilo De Guzman
Assistant Scientist
International Service for the Acquisition of Agri-biotech Applications, *SEAsia*Center

Introduction

Crop improvement facilitated by modern biotechnology is undoubtedly one of the most significant developments in crop research and development. Modern biotechnology comprises a suite of technologies and techniques that include cell and tissue culture, DNA markers, and gene transfer technologies. These allow the improvement of plants that is otherwise not possible or difficult to do through conventional breeding.

Genetically modified (GM) or transgenic crops, now more commonly known as ***biotech crops***, have been commercially grown since the mid-1990s, and have provided significant benefits to growers such as increased and protected yields and greater flexibility in crop management. Worldwide, the most extensively commercialized biotech crops are soybean, maize, canola and cotton.

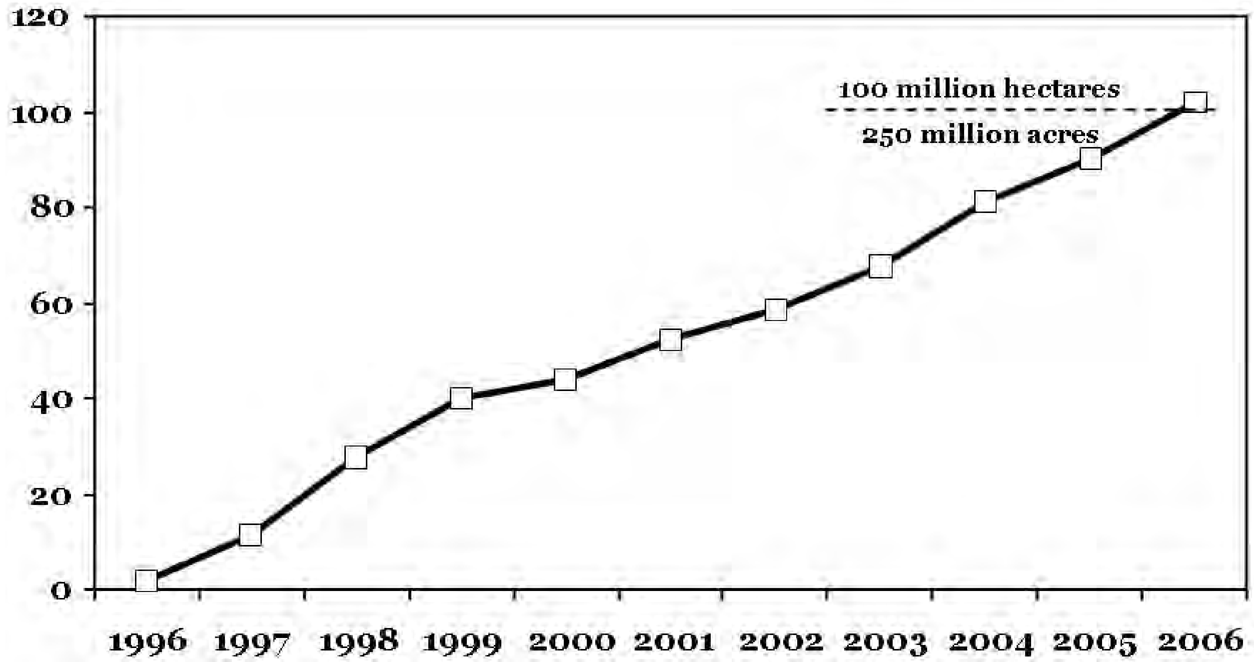
This presentation, based principally on a review by James (2006), provides a brief overview of the global status of commercialized biotech crops, with particular emphasis on biotech cotton, and offers some perspectives on the development implications and challenges of the adoption of biotech crops.

Global Status of Commercialization of Biotech Crops

Adoption of biotech crops

Between 1996-2006, there was a dramatic increase in the adoption of biotech crops worldwide (Figure 1). Global area of biotech crops expanded by more than 60-fold, and the number of countries growing these crops more than doubled. From approximately 1.7 million ha in 1996, global biotech crop area increased to 102 million ha in 2006. The rapid expansion in the global area of biotech crops, increasing at double digit rates every year since 1996, indicates growing appreciation of the technology by farmers in both industrialized and developing countries. In 2006, biotech crops were officially grown in 11 developing countries and in 11 industrial countries. A number of countries are also known to grow biotech crops without official approval from their respective governments. Data and related information on these unofficial adoptions are not included in this presentation.

Figure 1. Global area (million hectares) of biotech crops, 1996-2006.



In 2006, the largest adopters of biotech crops in terms of hectarage grown were the United States, Argentina, Brazil, Canada, India and China. Interestingly, the proportion of global biotech crops grown by developing countries has consistently increased every year during the period 1996-2006. In 2006, 40 percent of the global biotech crops area was in developing countries.

Dominant biotech crops

In 2006, soybean, maize, cotton and canola remained to be the dominant biotech crops grown worldwide (Table 1). Biotech soybean occupied 58.6 million ha accounting for 57 percent of the global biotech crop area.

Biotech maize, the second dominant crop, was planted to 25.2 million ha, or 25 percent of the global biotech crop area. Pest resistant maize occupied 11.1 million ha or 11 percent of the total global area planted to biotech crops. Approximately 5.0 million ha were planted to herbicide tolerant maize and 9.0 million ha planted to biotech maize with combined agronomic traits (pest resistance/herbicide tolerance).

The global area of biotech cotton reached 13.4 million ha in 2006. A dramatic increase in the area planted to biotech cotton was reported for India, which almost tripled its pest resistant cotton area from 1.3 million ha in 2005 to around 3.8 million ha in 2006.

Biotech canola plantings were reported to have increased marginally from 4.6 million ha in 2005 to 4.8 million ha in 2006.

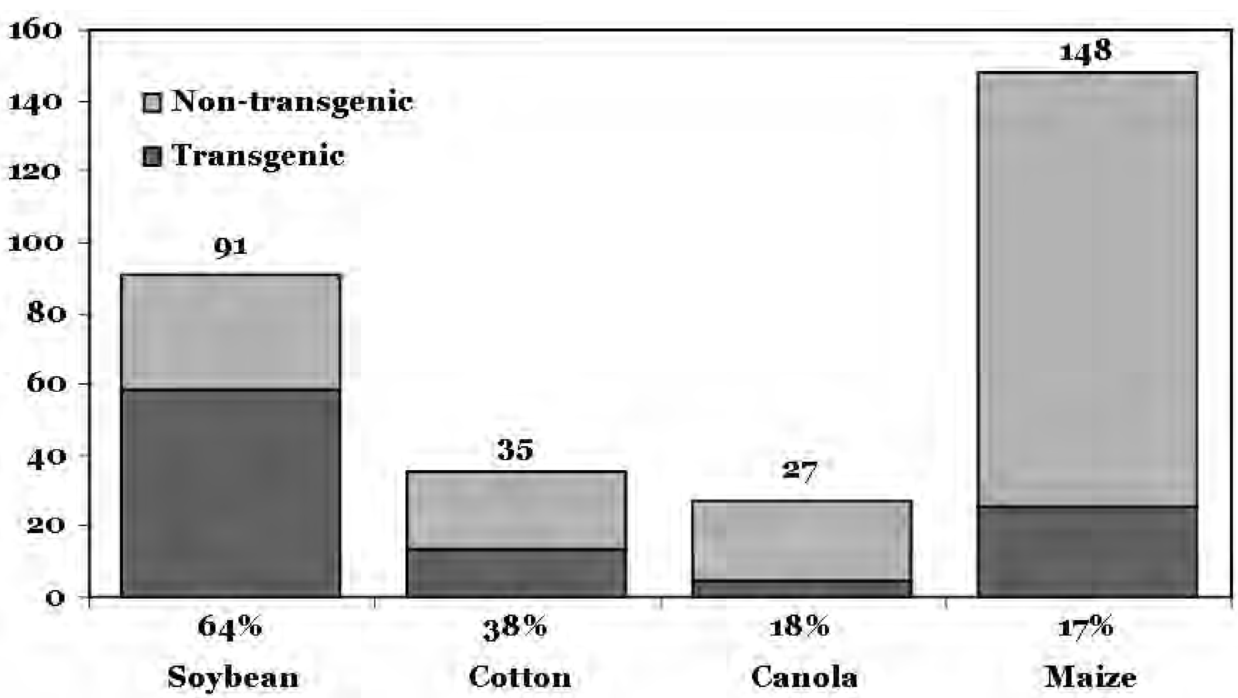
Adoption rates by crop

Adoption of the dominant biotech crops relative to total crop hectarage provides another perspective of the global status of commercialization of biotech crops (Figure 2). Of the total 91 million ha of global area devoted to soybean production in 2006, 58.6 million ha (64%) were planted to biotech soybeans. Of the total global area planted to these crops, biotech cotton occupied 13.4 million ha (38%), biotech canola occupied 18 percent while biotech maize occupied 17 percent.

Table 1. Global area of biotech crops, by crop, 2005 and 2006 (million hectares).

Crop	2005		2006		+/-	
	Area	**%**	**Area**	**%**	**Area**	**%**
Soybean	54.4	60	58.6	57	4.2	8
Maize	21.2	24	25.2	25	4.0	19
Cotton	9.8	11	13.4	13	3.6	37
Canola	4.6	5	4.8	5	0.2	4
Alfalfa	--	--	<0.1	<1	--	--
Rice	<0.1	<1	<0.1	<1	--	--
Others	<0.1	<1	<0.1	<1	--	--
Source: James, C. (2006)						

Figure 2. Global area adoption rates (%) of principal biotech crops, 2006.



Regulatory Approvals

A total of 51 countries have since granted regulatory approvals for cultivation and/or use for feed and/or food of biotech crops after the first batch was officially commercialized in 1996. In 2006, in addition to the 22 countries that officially grew biotech crops, 29 other countries officially granted approval for the importation and use of biotech crops for use as food and/or feed, including major food and feed importing countries such as Japan, the EU and South Korea.

As of November 2006, a total of 539 approvals have been granted worldwide. Most of the approvals have been issued in industrialized countries such as the United States, Japan, Canada, South Korea, Australia and countries of the European Union (Table 2). In developing countries that have granted regulatory approvals, the majority of the approvals issued were for importation for feed and food use, rather than for cultivation. The lack of regulatory approvals is considered a major reason why developing countries are lagging behind in the adoption of biotech crops (Pardey and Beintema 2001).

In terms of the number of crops, 21 have received regulatory approvals as of 2006, with maize having the most number of approvals at 210, followed by cotton, canola and soybean, respectively, with 105, 76 and 38 approvals.

Table 2. Regulatory approvals for selected biotech crops, selected countries, 2006.

Crop	USA	Canada	EU	Japan	Australia	China	Philippines
Maize	22	18	10	25	12	8	21
Soybeans	6	3	1	4	3	1	1
Canola	10	12	6	15	7	7	1
Potato	6	4	0	8	3	0	3
Cotton	12	8	5	16	11	4	7
Other Crops	21	16	5	8	4	5	3
Total	**77**	**57**	**27**	**76**	**40**	**25**	**36**

Source of basic data: Compiled by ISAAA (James, 2006)

Biotech Cotton Adoption

Of the major biotech crops, biotech cotton had the highest rate of increase in adoption in 2006, registering a 37 percent growth over the 2005 figures. In 2006, nine countries had been growing biotech cotton with the total hectarage estimated to have reached an aggregate of 13.4 million ha, or around 38 percent of the total global area of cotton of 35 million ha.

Bt cotton was the most widely grown biotech cotton in 2006 at around 8 million ha, followed by biotech cotton with the stacked traits *Bt* and herbicide tolerance at around 4.1 million ha, and herbicide tolerant cotton at 1.4 million ha (Table 3).

Table 3. Global area of biotech cotton in 2006 by product type (million hectares).

Biotech Cotton	2006 (million ha rounded figure to the nearest 0.1M)	% of global biotech crop area in 2006
Bt cotton	8.0	8
Bt/herbicide tolerant cotton	4.1	4
Herbicide tolerant cotton	1.4	1

Biotech Cotton Regulatory Approvals

Since the first commercialization of biotech cotton in 1996, 10 countries have granted regulatory approval for commercial cultivation. In 2006, eight countries were officially growing biotech cotton. Since 1996, biotech cotton had 105 regulatory approvals for cultivation and/or direct use in 15 countries (counting the EU as one), second only to maize. It also had the second highest number of approved biotech events (18).

In the EU, where biotech crops regulatory approvals have been stymied by consumer concerns, there have been five regulatory approvals for biotech cotton (Table 4).

Table 4. Biotech cotton regulatory approvals in the EU (as of 2006)

Event	Regulatory Approval
MON 1445	Cottonseed oil for food use, food additives, feed and feed additives
MON 531	Cottonseed oil for food use, food additives, feed and feed additives
MON 15985	Food additives, feed material and additives
MON 15985 x MON 1445	Food additives, feed and feed additives
MON 531 x MON 1445	Food and feed additives

Crop Biotechnology and Agricultural Development Challenges

Significant economic and environmental benefits from the use of biotech crops are increasingly becoming evident in countries adopting the technology. Documented benefits include increased farm productivity, reduced use of chemical inputs and cost savings to farmers. Examples of such benefits and utility to farmers have been documented in the United States (Cornejo and McBride 2000; Marra *et al.* 2002), and in developing countries such as China (Pray *et al.* 2001), South Africa (Ismael and Piesse 2001; Stewart *et al.* 2001), Mexico (Traxler *et al.* 2001), and India (Bennet *et al.* 2004; Gandhi and Namboodiri 2006). More recently, the global experience with regard to benefits from adoption of biotech crops during the first decade of commercial use in 1996-2005, has been documented (Brookes and Barfoot, 2006).

Biotechnology has become of greater concern and importance, particularly in developing countries, because of the need for increased and efficient agricultural production to provide sufficient food, feed, fiber, and now biofuel, for the growing population. It is estimated that by 2050, 90 percent of the world population will reside in developing countries. The International Food Policy Research Institute (IFPRI) estimated that by the year 2020, global demand for staple foods such as rice, wheat and maize will increase by 40 percent. It is widely perceived that production from traditional crop production systems, including the use of current plant types and varieties developed through conventional breeding cannot adequately provide the amount of food, feed and fiber needed to meet the increasing demand. Modern plant biotechnology will serve as an important tool to help achieve food security and sustainable agriculture, particularly in developing countries (FAO 1999; UNDP 2001), in conjunction with and complementary to the best and most appropriate conventional technologies.

Concluding Remarks

The deployment of biotech crops is significantly changing the landscape and opportunities in agricultural production, as adoption of biotech crops expands rapidly. Future trends indicate continuing increase in global adoption, particularly in developing countries, largely because of demonstrated benefits experienced during the first 11 years of commercialization, and the wider range of available biotech crops from an increasing number of technology developers and providers from both the private and public sectors.

The use of biotechnology in improving agricultural production has become imperative in the light of increasing demand for food, feed and fiber, and now biofuel; persistent and chronic poverty and undernourishment of a large segment of both the urban and rural populations in many developing countries; and declining natural resource base for productivity gains in agriculture.

It is acknowledged that modern crop biotechnology involving complex systems have associated risks, in both technical and non-technical aspects. The challenge is how to manage and minimize the risks so that the gains and benefits from the technology can be optimized. Broader public acceptance of biotechnology would require striking a balance between the risks and benefits associated with the application of the technology. Communicating science-based information is necessary to build farmers' and consumers' confidence in biotechnology. Attention could be given to capacity building and sustaining investments in research and development, public and private sector partnership in research, and creation of policies and regulatory framework that optimize the use of biotechnology for increased and enhanced agricultural productivity.

References

Bennett, R., Y. Ismael, U. Kambhampati and S. Morse (2004). Economic impact of genetically modified cotton in India. *Agbioforum*, 7(3):1-5.

Brookes, G. and P. Barfoot (2006). GM Crops: The First Ten Years – Global Socio-economic and Environmental Impacts. *ISAAA Brief No. 36*, ISAAA: Ithaca, NY

Cornejo, J.F. and W.D. McBride. (2000). Genetically engineered crops for pest management in US agriculture: farm level effects, *AER-786, Economic Research Service/USDA*, April.

FAO. (1999). Committee on Agriculture: Biotechnology, 15th Session, 25-29 January 1999. http://fao.org/unfao/bodies/COAG/COAG15/X0074E.htm#P105_3692

Gandhi, V. and N.V. Namboodiri (2006). The adoption and economics of Bt cotton in India: Preliminary results from a study, *IIMA Working Paper No. 2006-09-04,* pp. 1-27, September.

Ismaël, Y. and J. Piesse. (2001). Efficiency effects of Bt cotton adoption by smallholders in Makhathini Flats, KwaZulu-Natal, South Africa. Paper prepared for the 5th International Conference, Biotechnology, Science and Modern Agriculture: a New Industry at the Dawn of the Century, 15-18 June 2001, Ravello, Italy.

James, C. (2006). Global Status of Commercialized Biotech/GM Crops: 2006. *ISAAA Brief* No. 35, ISAAA: Ithaca, NY.

Pardey, P.G. and N.M. Beintema (2001). Slow Magic: Agricultural R&D a Century After Mendel. Agricultural Science and Technology Indicators Initiative, International Food Policy Research Institute, Washington, DC, 26 October.

Pray, C., D. Ma, J. Huang and F. Qiao. (2001). Impact of Bt cotton in China. *World Development*, 29(5):813-825.

Stewart, R., K. Vermaak, R. Pharoah, and S. Stavrou. (2001). Makhatini Flats cotton: Final Report, DRA, 14 December.

Traxler, G., S.G. Avila, J.F. Zepeda and J.E. Arellano. (2001). Transgenic cotton in Mexico: economic and environmental impacts. Paper prepared for the 5th International Conference, Biotechnology, Science and Modern Agriculture: a New Industry at the Dawn of the Century, 15-18 June 2001, Ravello, Italy

UNDP. (2001). Although controversial, GMOs could be breakthrough technology for developing countries, Human Development Report 2001 – *Making Technologies Work for Human Development* (Press Kit), 10 July 2001.

2. Biotechnology Applications in Cotton: Concerns and Challenges

M. Rafiq Chaudhry
Head
Technical Information Section
International Cotton Advisory Committee

Introduction

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 International Cotton Advisory Committee (ICAC) Secretariat estimates that 36 percent of world cotton area was planted to biotech varieties in 2006/07, and this area is expected to produce 45 percent of world cotton for the period. 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.

What is limiting the expansion of biotech cotton area in some countries is the requirement for a refuge crop. Moreover, if the adoption of biotechnology did not require regulatory approval, and if the technology were freely available like other technologies such as short stature wheat and rice, many more countries would have adopted biotech cotton by now. Nevertheless, biotechnology is the fastest adopted technology in the history of agriculture although it has also proved to be the most controversial.

Impact on Yield

Over the last 30 years, the world cotton yield rose on average at the rate of 2 percent or about 8 kg/ha per year. There have been periods of slow growth, and similarly, of faster growth. The world yield rose to a new record of 600 kg/ha in 1991/92, but there was no increase in the following 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. The 29 percent increase in world yield over the last 10 years is unprecedented in the recent history of cotton. Not all, but a significant proportion of this increase, comes from the use of biotech varieties providing better protection against pests.

To estimate the role of biotechnology in the increase of world cotton yield, many assumptions have to be made. A comparison of yields in Bt areas versus non-Bt areas is presented here. Cotton producing countries were divided into two groups: countries that produce Bt cotton (Argentina, Australia, Brazil, China, Colombia, India, Mexico, South Africa and the United States) and countries that do not yet produce Bt cotton.

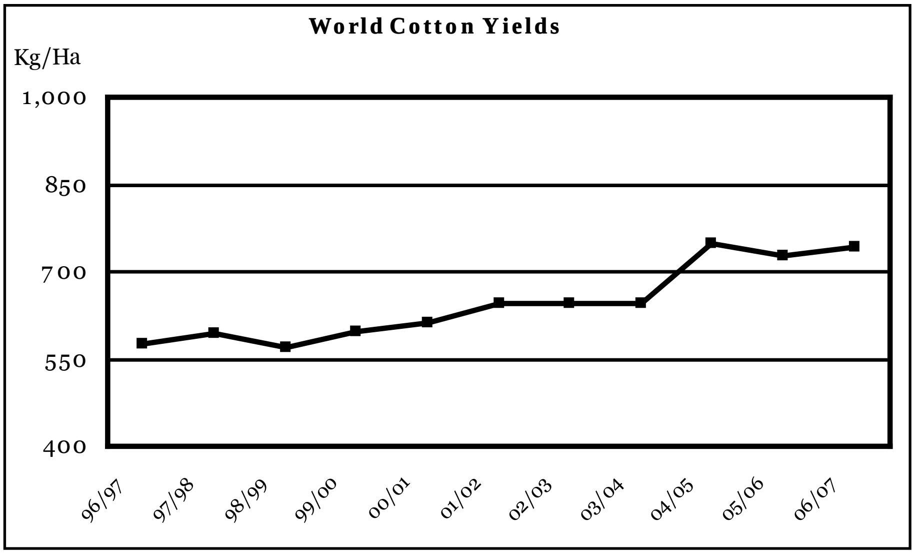


Table 1. Yield Performance in Bt Producing vs. Non-Bt Producing Countries

	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%	1.1%
1976/77 to 1985/86	6%	2%	3.5%
1986/87 to 1995/96	1%	1%	0.8%
1996/97 to 2005/06	3%	1%	2.7%

The data above indicate variable rates of yield increases with the rate for the period 1986/87 to 1995/96 slower than in the previous two decades. Further analysis shows that the slower growth rate was because there were no increases from 1992/93 to 1995/96. The Bt and non-Bt producing countries 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. Other countries adopted insecticides, although relatively late, and with applications often done incorrectly, including the use of threshold levels, spray machinery, proper chemicals, among others. The differences in yield in the last ten years indicate that countries adopting Bt had 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 its negative aspects 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 its positive aspects. 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 the Gene Action Technology

Many biotechnological tools are available to utilize the genetic variability from within species, across species and beyond species. Bt cotton was developed utilizing a gene from the soil bacterium *Bacillus thuringiensis*. The Bt gene codes for a specific protein, Cry 1Ac, which kills 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. With genetic engineering tools, different switches can be attached to desired genes, directing them to work in a special tissue or to 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 1993, three years before the biotech cotton varieties were commercialized. The technology, patented in 1998, consisted of a three-gene system that forced plants to produce a toxin lethal to their own seeds. Through the technology protection system, 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 toxin was produced late in the season, so that the seed did not lose its commercial value for oil extraction and livestock feed. Meant to stop the illegal spread of biotech seeds by making it impossible for farmers to plant the seeds the next year, the technology was not commercialized due to objections from farmers and other cotton industry members. However, similar tools could be employed in the future in different forms that could work against growers, processors and even the users.

Development of Resistance to Bt Toxins

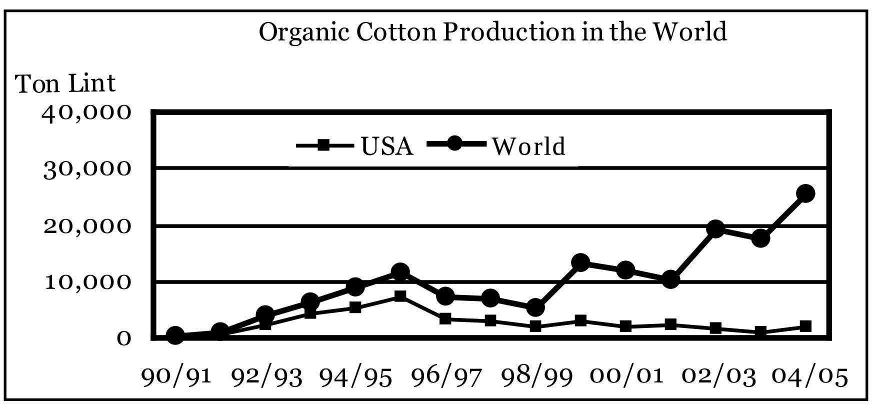
Once a Bt gene is inserted into a variety, the Bt toxin is produced throughout the cotton plant during the entire growing season. Consequently, target pests are continuously exposed to high levels of the toxin, a situation likely to elicit resistance faster than the intermittent exposure to conventional 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 the occurrence of resistance if farmers incorporate resistance management strategies into their cotton production systems. Without effective management plans, the efficacy 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 crops 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-tolerant biotech crops encourage the use of herbicides. According to James (2006), the herbicide tolerance character has consistently been the dominant trait since the commercialization of biotech crops. In 2006, the herbicide resistant trait was present in 70 percent of the 102 million hectares planted to biotech crops in 22 countries. Of the total area, 19 percent had the Bt gene while the remaining area was devoted mostly to stacked traits of Bt and herbicide tolerance. The herbicide tolerance trait in cotton is popular in Australia and the United States. In the United States, over 95 percent of the biotech area in 2006/07 was planted to herbicide resistant biotech cotton.

Herbicide resistant biotech cotton has changed the weed control systems in Australia and the United States. Weed control prior to Roundup Ready cotton involved multi-dimensional approaches from several angles to achieve the best control. These included pre-plant incorporations (PPI); applications at planting (PRE); post-emergence directed (PDIR) applications when the cotton reached 3 to 4-inches in height or once a height differential was established between cotton and weeds; cultivation; non-selective herbicides under hoods; lay-by 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 tolerant biotech system include broad spectrum weed control, convenience, simplicity, increased efficacy and crop safety and reduced labor, which is expensive in Australia and the United States. 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 soil 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 of the most popular herbicide (the low cost, easy to use and broad spectrum glyphosate) used on cotton. Roundup Ready Flex cotton was introduced in the United States 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 United States 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 agency that the cotton has been produced following the organic cotton production requirements set under the U.S. National Organic Standards Act. It primarily requires the use of 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 United States. With 88 percent of the US 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, producing 44 percent of world organic cotton 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 products during handling, ginning and processing. This is in addition to maintaining distances between fields to 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.

The restriction on spraying microbial insecticide (insecticides also made from *Bacillus thuringiensis*) on biotech varieties has had a negative effect on organic cotton production. Biotech use has significantly diminished the market for Bt insecticide and has proved to be a disincentive for producers to continue manufacturing the microbial insecticide. Because of this, 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 non-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 percent was produced in India and very little in the United States. In India, the increasing area planted to biotech cotton could affect organic cotton production.

Labeling and Consumer Rights

Cotton is a fiber crop, but approximately 40 million tons of cottonseed produced annually 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. 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, Argentina, Brazil, Canada, India and the United States, account for 92 percent of the 102 million hectares planted to biotech crops in 2006/07 (James, 2006). Three other countries, China (mainland), Paraguay and South Africa, account for another 6 percent of the biotech crop area in 2006 while the remaining 2 percent was in 14 other countries. It means that only a few countries have so far had extensive experience of planting biotech cotton. 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 11 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.

Illegal Biotech Cotton Use and 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 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 also 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 also 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 piracy 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 percent 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 was observed by Xue (2002) and this is 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 mired, *Creontiades dilutus*, which has increased significantly in Australia and China (mainland). In the United States, the tarnished plant bug (*Lygus lineolaris*) has become a reason for high concern.

Table 2. 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)

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. This changes 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 Cotton 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 byproducts 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 have been killed.

Human Health and Environment

If a genetically engineered plant produces a new protein, there may be some risk that the new protein could be an allergen to humans. 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 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.

Technological Limitations

Breeding, the art and science of developing new varieties, has been practiced for centuries, and genotypes and cultivars drastically different from their wild ancestors and relatives have been developed. Developments made in agronomic performance, including higher yield and better fiber quality in cotton, have contributed to productivity and quality improvements. While breeding can bring drastic changes, biotechnology applications have so far 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 still 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 a 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 varies from country to country 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.

The Cost of Technology

Agricultural technological innovations like the green revolution progressed in various stages, with each new stage requiring new costs in technological development and acquisition. Further, if the technology is acquired through the seed, the cost is paid only once, except in the case of hybrid corn seed or commercial cotton hybrids in India. This condition, however, was not dictated by technology developers but was a genetic issue where nothing could be done except to produce plant seeds every year. But these costs are nothing compared to the cost of biotechnology products. For biotech crops, farmers have to pay for insect- and herbicide-resistant technology every year, making it even more expensive. The high cost of biotechnology is limiting the use of this technology in many countries. Argentina commercialized Bt cotton in 1998, but so far Bt cotton varieties cover less than 25 percent of the area planted to the crop. 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 New 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 cotton, but new forms of biotech cotton (other than insect- and herbicide-resistant varieties) 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 quit 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 that are 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 the 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 in many European countries. Unfortunately, the year when biotech varieties were introduced in India coincided with the detection of a new disease. The disease, commonly called "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 that created doubts and confusion in the minds of farmers and the public.

Need for Public Participation

The Cartagena Protocol which was adopted in January 2000 came into effect in September 2003, and by end of 2004, 111 countries had already ratified it. 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: on available products and on biotechnology products in the pipeline or those that are 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).

3. BIOSAFETY REGULATION: A COUNTRY MODEL THAT IS PRACTICAL, RESPONSIBLE AND EFFECTIVE; LEARNING FROM THE EXPERIENCE OF OTHERS

Willy De Greef, IBRS
Executive Director
International Biotech Regulatory Services (IBRS)
The Plant Biotechnology Institute for Developing Countries (IPBO)

Technology and innovation do not develop on their own; they are only successful after their results are generally accepted and if they meet a societal demand. Society wants to be reassured about innovation: does it work? Is it as safe as claimed? Does it meet societal values and beliefs? The regulatory history of GMOs provides a good example of how not to regulate or generally organise the governance of innovation. From the start, GM crops raised questions about their safety for human health and the environment, their socio-economic impact (e.g., small vs. large farmers), their impact on food security and agricultural trade, and even their moral acceptability.

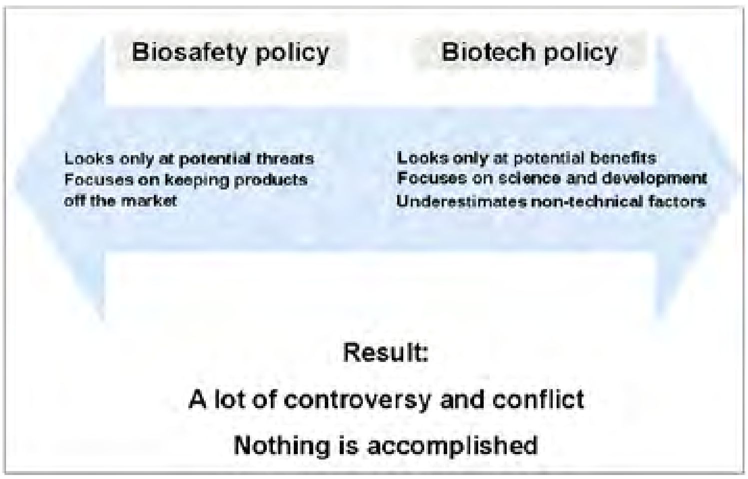
All these concerns were telescoped in a regulatory regime that **officially** deals only with biosafety, leading to a poor fit between concerns and the way they are dealt with, massive confusion in application of biosafety regulations, and a severe mismatch between biotech policy and biosafety policy. Although there are large differences between regulatory regimes, this general observation raises the question whether there are actually GM regulatory regimes that can be considered workable today.

The most important inefficiency relates to the apparent independent development in most countries of biotechnology policy and biosafety policy. In an effective regulatory system for innovation, one would seek to promote a situation in which safety and other societal issues are integral parts of innovation policy. This principle has been abandoned early in the evolution of agricultural biotechnology, at least in part because of an ideological disagreement between Europe and the United States on the role of industrial and innovation policy as part of innovation. While the United States has a strong bias towards letting the markets decide about the usefulness of innovation and its products, Europe has an equally strong tendency to try to harness innovation in government policies. This fundamental difference led to parallel (and often opposite) policy making, separating biosafety and biotechnology.

All this leads to a world of parallel realities. The annual ISAAA reports on the commercial planting of GM crops show, data in hand, that GM crops are one of the most rapidly spreading innovations in the history of agriculture. Significantly, it has been shown in many countries that once farmers have had the opportunity to grow the crops, there is almost no going back because the economic advantages of the crops on the farm easily outweigh their higher costs.

The most successful introductions include the largest agricultural economies in both the developed and developing world, with the notable exception of the European Union. In the EU and in most of Africa, GM crops are still considered to be inherently dangerous, in and by themselves, purely on the basis that rDNA technology has been used in their creation. This "reality" is not open anymore to factual information, at least at the level of the policy debate. It is notable that at the level of European scientific risk assessment bodies (most prominently the European Food Safety Authority, EFSA), the assessments of the safety of these crops is not much different from that in the countries that have approved their general release. It is at the subsequent level of policy decision making that non-science based safety concerns tend to stop their deployment. From experience, between those two opposite decision making mechanisms, there is no proper base for a positive and open dialogue.

Fig. 1. The mismatch between biotech and biosafety policies



At some points this parallel reality creation in the EU becomes manifestly absurd. For example, at a hearing of the European Parliament in October 2006 about GM crops and their safety issues, one Member of Parliament could openly state, without being challenged, the "fact" that there is no need to reconsider release of GM crops in the EU, because "it is well known that the growing of these crops had imploded in the United States in 2006." This despite the fact that the USDA published its final statistics of GM crop growing that clearly showed 2006 as a very successful year, with large increases in market penetration for all three widely grown crops: corn, soybean and cotton (Fig. 2)

Fig. 2: Percentage GM of total plantings in the USA.: corn, soybean, cotton (source: USDA, 2006)

	2000	2001	2002	2003	2004	2005	2006
Maize	25	26	34	40	45	52	61
Cotton	61	69	71	73	76	79	83
Soybean	54	68	75	81	85	87	89

Learning from these contradictions, it is possible to make some informed estimates of what a workable regulatory system could look like. First and foremost, it has to address the real concerns of policy makers and the public, deal respectfully with opposing views, and be pro-active in its "points to consider." It also has to acknowledge different concerns on their own merits: look at safety with safety experts, look at economics with economic experts, and discuss acceptance on its own merits. It has to be an integral part of the innovation policy, integrating **all concerns and opportunities**, while addressing them each within their own reference frame. Finally, it has to generate decisions that are respected by all stakeholders.

Finally, it has to be the result of a comprehensive **risk-benefit** assessment. Current regulatory regimes tend to focus on the risk side of innovation, with little or no attention to their economic, social and/or environmental benefits. This leads to a drive towards trying to prove zero risk, which is impossible in a science-based risk assessment. At the same time it ignores the fact that innovations such as GM crops have massive capabilities to improve the economics of agriculture and reduce its environmental impact. In this way, the perfect becomes the enemy of the good.

Today there is no national regulatory system for GM crops that meets all these requirements, although some systems have elements of the "ideal regulatory system." It has to be recognised though, that first and foremost, regulations are influenced by legal and regulatory traditions in countries and can widely differ. For that reason alone, a "one size fits all" approach, which is the cornerstone of international efforts at harmonisation, does not work in practice.

This does not mean that there are no elements that can be harmonised. While decision making procedures are almost always dependent on the governance system in sovereign countries, and therefore not readily amenable to change, the **technical elements** of systems, which bring together the relevant scientific risk assessment information, can and are based on common international standards, as repeatedly demonstrated by the wide acceptance of technical guidelines emanating from expert bodies in Codex Alimentarius and OECD.

It is recognised that a workable biosafety system needs three major components: risk assessment, risk management and risk communication. A respected system is strong in these three areas and coordinates between these components. It learns from experience and evolves on the basis of new information. Crucially, a working risk governance system deals not only with scientifically demonstrated hazards, but also with **risk perception**. GM crops have shown that much of the fear and confusion concerning safety issues is based on perceptions of risk that have no factual basis. The **fear** of the affected stakeholders and decision makers, however misguided, is very real, and an effective risk governance system will respect that fear and find a way to address it.

To make it work at the policy level, a biotechnology innovation policy has to be in sync with agricultural, health and environmental policy. It has to develop the regulatory framework so as to enable and not contradict the policy, and has to develop human resources to execute both the policy and the regulatory framework. At the implementation level, it has to ensure that the regulatory body includes all the affected government departments; that it provides adapted review for each development stage of research, field trials and large-scale release; that it gives a designated space for safety, economics and acceptability; and that it provides good technical and administrative support. Above all, it has to be very good at communicating with all relevant actors and stakeholders.

4. Biotechnology: A Look into the Future

James McD. Stewart
University Professor,
Altheimer Chair for Cotton Research & Development,
University of Arkansas, Fayetteville, AR 72701

...perception is reality. Malcolm Kane, Head of Food Safety, Sainbury's Supermarkets Ltd. (1980-1999)

A person who does not learn the lessons of history is doomed to repeat them. However, **"What experience and history teach is this – that nations and governments have never learned anything from history, or acted upon any lessons they might have drawn from it."** G.W.F. Hegel, German philosopher (1770-1831).

Two issues are covered in this regional consultation. The first, Genetically Modified Cotton for Risk Assessment, potentially can have a profound effect on the second, Opportunities for Small- Scale Cotton Growers. I make this statement because regulations promulgated in the name of "biosafety" can, in effect, be barriers to implementation of otherwise beneficial biotechnical advances. This can happen when only the socioeconomic perspective is considered in the assessment process. In 1991, I wrote that "Issues of concern to a society tend to be based...on perception..." rather than upon reality. Today, 16 years later, this is still true. As Michael Kane (2001) stated, "...perception is reality." At that time I did not anticipate that genetic engineering would be negatively perceived by some once it was understood how the process works from a scientific perspective. At the time of that review (five years before the first commercial biotech cotton) a process of risk assessment was in place in the United States that emphasized a scientific approach. This led to approval and the rapid adoption of biotech cotton by producers beginning in 1996.

In the ensuing years, various groups, some being extremely vocal and adept at influencing public opinion, raised objections to production of biotech foods and possible negative effects of biotechnology in general. As an example, my wife told me that she was not going to eat "rat genes" in her lettuce. When I queried her, she said that she had "heard" that rat genes were being put into lettuce but was unable to tell me the source. When I tried to explain to her that, even if it were true, a gene is only a sequence of DNA common to all living organisms. In other words, I used scientific reasoning to establish an argument against an emotional reaction. As you might expect, my "scientific reasoning" fell on deaf ears. Perception is reality.

Biotech cotton receives less scrutiny than food crops that have been genetically engineered because traditionally, the fiber is made into textiles that are not eaten. Perhaps it is through lack of knowledge that extensive use of biotech cotton as a feed for dairy and beef cattle does not receive extensive notice. Also, one does not hear extensive complaint about the use of cottonseed oil from biotech cotton, perhaps for the same reason (although the amount of protein in cottonseed oil is extremely low).

One of the early complaints of biotech cotton concerned the perception that it would benefit only the large-scale farmers who could afford the increased cost of seed. The argument followed that this would increase the difference in the relative well being of poor vs. rich producers. By extension, this was also applied to developing countries vs. developed countries. In 1991, it seemed to me and I wrote that the technology would be of more benefit to the small-scale farmer than the big producer. History has since shown that extensive benefits from biotechnology have accrued to the small-scale producer. Many cotton producers in India and South Africa already enjoy these benefits (James, 2006). Perhaps because of the success enjoyed by these producers, today you do not hear this argument very often. In reality, the greatest disparity seems to be between those countries that have adopted biotechnology and those that have not.

Thus far, I have dwelt on the past and present situation with regard to biotechnology. My charge is to take a look into the future and try to offer prognostications concerning the role of biotechnology. Because of the obvious benefits to the cotton producers who have already adapted biotech cotton, one can predict that the application of biotechnology will continue to expand into those areas and countries where it is not now grown. However, concerns about the safety of GMO have slowed adoption and potentially could limit its spread into the areas where it is most needed. Hopefully this consultation meeting will help provide partial, and perhaps full answers to lingering questions concerning any environmental and socioeconomic risks associated with biotech cotton.

One of the issues that remains today, and probably will remain in the future, concerns the question of risks related to the release of biotech cotton into the environment. Of course, the question most at hand relates to the effect of biotech cotton expressing a Bt toxin or an enzyme that confers resistance to a particular herbicide, since these are the only biotech products that are currently commercially available. The history of the last 10 years tells us that the first generation biotech products will be deemed not to have a negative effect on the environment and will be widely grown in areas where they are currently not grown. The reasons why they are not currently grown is probably related to lack of a coherent set of approval mechanisms (country choice) or the lack of a viable method for protecting intellectual property rights (provider choice). As these various countries institute regulatory mechanisms and intellectual property rights, the technology will be made available through international trade. Part of the equation for protection of intellectual property is the establishment of a viable planting seed industry for reliable delivery of the seed to the producer.

For those countries with the capacity to develop their own biotech cotton varieties through public or private funds, the two elements of regulatory oversight and IP protection are still necessary. Pakistan is an example of this. Although it has the capacity to produce biotech cotton, only recently has its regulatory and IP systems been put into place. India, on the other hand, established its system more than 5 years ago, and biotech cotton is now widely grown in that country.

One might ask, “Why is a regulatory system necessary if biotech cotton is not harmful to the environment?” To answer this question, one has to realize that regulation of biotechnology applies to all transgenic plants – not just to cotton. In addition, the regulatory rules must consider future genes that may be genetically engineered into cotton. As an extreme example, assume someone were to genetically engineer the botulinum toxin gene into cotton. As you know, the botulinum protein is a very powerful neurotoxin. While cotton genetically engineered to express the gene might be grown as a specialty crop for isolation of the protein (see below), because of the potential harm of the protein to humans, its production would have to be in isolation to prevent gene flow to other cotton. A viable regulatory system would require that the biotech cotton be grown and handled in such a way as to prevent any possible gene escape or any harm to humans.

To be commercially viable the cost of biotech cotton seeds must be lower than the cost of insect control practiced in that region. In this way, both the developer of the biotech cotton and the producer will receive benefits. However, the late entry of some countries into the use of biotechnology in their agricultural enterprises, and especially cotton, places those counties at somewhat of a disadvantage in a global market. The cost of cotton production without the aid of biotechnology is relatively high because of losses to (or, control of) insects. In the interim, as more countries adapt to the reality of biotech cotton, the yields increase, as do the world stocks of cotton. Because of the increase in world cotton, stocks available to the textile industry, the price received by the producing country (hence producer) will remain relatively low. Thus, the producer of non-biotech cotton will be at a distinct disadvantage.

Traditionally, farmers are encouraged to produce cotton because it is a "cash crop" that provides foreign currency to the exporting country. However, in the absence of a domestic market for within country produced cotton, the cotton producer will be subject to the global economy. This is very evident in the countries that historically have been dominant in cotton production and utilization. Because of the increased yield of biotech cotton, India will probably surpass the United States in total cotton production to become the number two cotton producer behind China, by virtue of the number of acres produced with increased yield. Because of the viable textile industries in both China and India, consumption of cotton will also increase as the economic status of these two countries increases. Hopefully, this will relieve some of the pressure on world cotton supplies.

Opportunities for small-scale cotton growers

The first commercially viable products in biotech cotton have been those that decreased the inputs required to manage the crop. The cheapest method to manage any insect or disease organism is through genetic resistance. By genetically engineering the Bt gene into cotton to resist lepidopterans, the cost of controlling these insects using chemicals decreased dramatically. The developing companies recoup their investment by transferring part of the chemical management cost into the cost of the seed. In the case of genetically engineered herbicide resistance, in developed countries where labor is expensive or unavailable, the "technology fee" for the seed is less than for seed conferring insect resistance because part of the cost of development is recouped in sales of herbicide. In areas where hand labor for weeding is inexpensive and readily available, as in the developing countries, it is not likely that herbicide tolerant biotech cotton will be successful.

As a result of biotechnology, farming systems have evolved. At the beginning of the green revolution, the mindset of producers had to change in order for technology to be incorporated into their farming methods. This involved planting of genetically advanced seeds, planting at different plant densities than traditionally done, chemical control of pests, changes in the application of fertilizers, etc. The implementation of biotechnology as an innovative method to improve production also requires a change in the mindset of all stakeholders including the developers, producers and, perhaps for the first time, the consumers. Crop management must be accompanied by changes in cultural practices for success to be insured. Implementation of the new technology will depend on the following: 1) Adequate education and training of producers to ensure that there is comprehension of the new technology. For example, engineered pest resistance does not mean that the crop can be planted and ignored until harvest. If anything, scouting for pests must be intensified; 2) For the technology to be useful, all of the genetic material must be adapted to the local conditions. That is, the engineered trait must be in a locally adapted variety; 3) Due attention must be given to the possibility that pests will develop resistance to the engineered resistance. Every effort must be made to delay that resistance so that the usefulness of the technology is not lost; and 4) Ultimately, the technology must provide benefits not only to the producers and developers, but also to the consumers of the raw product that can be passed on to the ultimate consumers.

Both herbicide tolerant and Bt cotton are considered as first generation products and are directed toward reducing the cost of inputs to manage the crop. Because reduction of input costs is of great benefit to producers in terms of cost of production, biotech developments have been rapidly incorporated into farming schemes. On the other hand, much of the potential benefit has been transferred to the companies developing the products at the expense of the chemical industry. While farmers have benefited from the biotech developments through increased yield and reduction in cost of managing the crops, consumers have benefited only to a lesser degree (through lower costs for textiles) because the raw product (cotton fiber) constitutes only a small part of the cost of producing and distributing a garment. A major criticism of those opposed to the biotech revolution is that producers receive only a fraction of the potential benefits and the consumer receives very little.

To address this issue, the second generation genes that will be available to the producer should probably be directed toward output traits, such as fiber quality and quantity, and abiotic stress resistance. These generally low-value traits, while extremely useful to producers, will not allow the biotech companies to charge high "technology fees" for seeds. In these cases, the strategy of the seed companies will be to maintain or gain "market share" for their seeds. Other low input traits (e.g., fungal resistance, viral resistance) that may have extreme importance in a relatively small area, fall into this same category. These will have to be developed locally or regionally (depending upon biotechnological capacity). While "technology fees" at first appear to be high, as competition increases these can be expected to decrease so that all the technology is within the perceived means of all producers. ("Cash flow" could possibly deter some producers, although by adopting the technology they would ultimately earn more from the crop.)

A new area that is receiving attention is the use of plants to produce pharmaceuticals. Plants can be genetically engineered to produce some drugs cheaper than they can be obtained from traditional sources. Although the cost of meeting regulatory requirements may be high, the high market value of the drugs should make the effort worthwhile. Part of the regulatory process will be to have absolute assurance that the trait will not be transferred to other plants not possessing the engineered gene. Of course, there are many factors that determine what the crop of choice would be for production of a specific drug, and cotton will be only one of many choices. Because of the use of cotton fiber as a wound dressing, it seems logical that it would be the plant of choice for production of antimicrobial compounds in the fiber.

The cost of meeting the regulatory requirements has been, and will continue to be, a barrier to new biotech developments by academic scientists. Because of this, there has been a shift away from genetic engineering with a concomitant increase in the use of molecular markers to identify useful traits in crop germplasm. Cotton is fortunate in possessing a relatively large genetic pool from which to draw new genes (Stewart, 1995). Extensive effort is being devoted to mapping of the cotton genome and close relatives. Plants resistant to various pests and stresses that are derived from these efforts will avoid the high costs of regulatory requirements since they will be developed through "natural" hybridization. A pertinent example of this is the development of resistance to the leaf curl virus in G. hirsutum (4X) by introgression of resistance from G. arboreum (2X). While resistance can probably be developed through genetic engineering of cotton with appropriate genes that confer resistance to CLCV, in fact, it may be faster and certainly less expensive to introgress the resistance from the diploid species (G. arboreum), especially if a molecular marker can be associated with the area of the chromosome conferring resistance. As the molecular map of cotton evolves, selection of markers associated with particular traits will become easier, as will transfer of useful traits from exotic germplasm to elite cultivars.

In the future, biotechnology should be able to shift existing production systems to more environmentally friendly systems, especially in developing countries. (As a negative example, extensive deforestation is occurring in the Bolivian Amazon plain to make way for soybean production. Ten years ago deforestation in that region was occurring for cotton production.) Biotic resistance is just one of many traits needed to provide cotton crops that will yield more on less land. Some of the traits that are currently receiving attention are: 1) increased light harvesting efficiency, 2) drought tolerance, 3) high and 4) low temperature tolerance. Each of these are steps toward producing more and better cotton in a sustainable way. Also, one could hope that the output traits derived from biotechnology will be viewed favorably by the general public since they will not imply the plant is producing a "toxin," as is now the case.

1. Any feature 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 functional for a longer period of time. This seems to be a relatively straight forward method for improving light interception. Photosynthetic efficiency is an area that has received much interest but where little progress has been made. Rubisco has affinity for both CO_2, which results in carbon fixation, and for O_2, with leads to carbon loss through photorespiration. A slight increase in the affinity for CO_2 relative to O_2 would have a significant impact on carbon fixation.

2. Drought tolerance is a complex environmental parameter that is often confounded by heat stress tolerance, and also (in the case of cotton) chilling stress tolerance. Much work has been done on model plants regarding gene expression in response to this abiotic stress. We have identified a number of genes that appear to be related to increased tolerance to water-deficit stress, but we have not reverse-engineered any of these genes to verify a functional roll in tolerance. Genes found in other plants (such as Arabidopsis) to be regulated by water-deficit and other abiotic stresses have also been found to be similarly regulated in cotton (e.g., DREB; Lui, 2002). Some of these genes are reported to increase tolerance to water-deficit and other abotic stresses (such as salt-stress). Because tolerance to biotic stress is a complex phenomenon, a single gene used to transform another plant is not expected to provide much increase in tolerance.

3. Heat stress can potentially be a limiting factor in cotton production in many parts of the world. Multan, in Pakistan is but one example where the average maximum temperature during June exceeds 42 0C. Wise et al. (2004) reported that electron transport reaches its limit in Pima cotton grown under field conditions in USA southwestern desert. Deridder and Salvucci (2007) found that high temperature initially made Rubisco activase unstable, but that the enzyme stabilized with time. This suggests that chaperon-type proteins probably stabilize the rubisco activase, and that these proteins could provide a level of protection to the vital biochemical functioning of heat-stressed cells. Genes coding for chaperon-type proteins could be genetically engineered for constitutive expression in cotton to increase tolerance to heat. Since these proteins play a role in enzyme protection and even in the refolding of denatured proteins, they would be expected to give a level of increased tolerance to most abiotic stresses.

4. Work on chilling-stress in cotton goes back many years (my graduate research), but as yet there has been no breakthrough in a viable approach to increase resistance to chilling-stress. Work at Texas Tech University suggests that maintaining a highly reductive environment improves tolerance to chilling-stress (Payton et al., 2001). Transformation of cotton with superoxide dismutase increased its tolerance to chilling temperatures. Primarily, the antioxidants aid in removing damaging free radicals generated due to poor membrane function, especially when chilling temperatures are combined with high light intensity. The accumulative information indicates that temperature membrane transition from a gel to a solid at around 12 0C in cotton 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 increases sensitivity to heat stress.

5) Salt tolerance. Many of the tolerances to abiotic stress engage in "cross-talk", that is, the tolerance mechanisms draw upon a sub-set of genes that function to improve tolerance to environmental stresses. For example, because of their protein-protective nature, the chaparonins function in any abiotic stress where proteins potentially can be made inactive. As cotton is considered to be relatively salt-tolerant, its cultivation might be extended into areas when other crops could not grow because of the high salinity. Many plants are considered to be halophytes (plants that will grow under high salt concentrations). Several genes have been identified from these plants that seem to function in salt tolerance and have great potential in genetic engineering. A Na^+/H^+ anti-port enzyme which excludes Na from the plant cell may have potential for improving the salt tolerance of cotton.

6) Fiber quality is an area that everyone recognizes as a component of production, but few workers have sufficient knowledge of the molecular biology of the fiber to speculate what genes might contribute to fiber quality. Although the process has been slow, the biology of the fiber is being to unravel. Of particular note are the claims that single genes have dramatic effects on fiber yield and quality. Dr. Candace Haigler et al. (2000a) transformed cotton with a sucrose phosphate synthase, while Thea Wilkins transformed extensin into cotton. In each case, transgenic plants expressing the gene are reported to have had longer stronger fiber and increased yield (Haigler et al., 2000b; Wilkins, personal communication). It seems unusual that single genes would have a dramatic effect on a range of quantitative traits.

Each of these are steps toward producing more and better cotton in a sustainable way. Also, one could hope that the output traits derived from biotechnology will be viewed favorably by the general public since they will not imply the production of a "toxin" in the plant, as it is now the case.

References

Chang, X.-G., Y.-X. Hou, Y.-L. Guo, et al. (2002). In vitro expression and characterization of a GhDREB transcription factor containing AP2 domain in Gossypium hirsutum. Cotton Science 14S:62-63.

DeRidder, B.P., and M.E. Salvucci. (2007). Modulation of Rubisco activase gene expression during heat stress in cotton (Gossypium hirsutum L.) involves post-transcriptional mechanisms Plant Science 172:246-254.

Haigler C.H., A.S. Holaday, C. Wu, B.G. Wyatt, G.J. Jividen, J.G. Gannaway, W.-X. Cai, E.F. Hequet, TT. Jaradat, and D.R. Krieg. (2000a). Transgenic cotton over-expressing sucrose phosphate synthase produces higher quality fibers with increased cellulose content and has enhanced seedcotton yield (abstract no. 477). In Proceedings of Plant Biology 2000, July 15-19, San Diego, CA. American Society of Plant Physiologists, Rockville, MD.

Haigler, C.H., E.F. Hequet, D.R. Krieg, R.E. Strauss, B.G. Wyatt, W. Cai, T. Jaradat, N.G. Srinivas, C. Wu, G.J. Jividen. (2000b) Transgenic cotton with improved fiber micronaire, strength, length, and increased fiber weight. pp 483. In CP Dugger, DA Richter, eds, Proceedings of the 2000 Beltwide Cotton Conference, 4-8 January, San Antonio, TX. National Cotton Council, Memphis,

James, C. (2006). Global status of commercialized biotech/GM crops: 2006. ISAAA Brief 35. http://www.isaaa.org/ .

Kane, M., (2001). GMO regulations: Food safety or trade barrier? In: G.C. Nelson (ed.). Genetically modified organisms in Agriculture. Academic Press, NY. 344 pp.

Payton, P. R. Webb, D. Kornyeyev, R. Allen and A.S. Holaday. (2001). Protecting cotton photosynthesis during moderate chilling at high light intensity by increasing chloroplastic antioxidant enzyme activity. Journal of Experimental Botany 52:2345-2354.

Stewart, J.McD. (1991). Biotechnology of cotton: achievements and perspectives. ICAC Review Articles on Cotton Production Research No. 3. CAB International, Wallingford, UK. 54pp.

Stewart, J.McD. (1995). Potential of crop improvement with exotic germplasm and genetic engineering. Pp.313-327. In: G.A. Constable and N.W. Forrester (eds.). Proc. World Cotton Research Conf. 1: Challenging the Future. CSIRO, Melbourn, Australia.

Wise RR, Olson AJ, Schrader SM, Sharkey TD. (2004). Electron transport is the functional limitation of photosynthesis in field-grown Pima cotton plants at high temperature. Plant Cell Environ 27: 717–724.

5. Regulatory Procedure for Genetically Modified Crops in India

CD Mayee
Chairman, Agricultural Scientists Recruitment Board (ASRB)
Pusa, New Delhi-110012

Regulations for risk assessment of genetically modified (GM) crops are essential to gain experience and familiarity with specific crop-transgene combinations. In India, regulatory procedures for GM crops evolved with the development of the first GM product, Bt cotton. The Government of India established statutory bodies such as 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 the District Level Coordination Committee (DLCC). In accordance with the Rules 1989 of the Environment Protection Act 1986, the Government of India empowered the Ministry of Environment and Forest (MOEF) and the Department of Biotechnology (DBT) to implement the rules and regulations governing GM crops. The first four committees are involved in the pre-approval regulations, and the latter two, acting at the state and district levels, are the ones responsible for monitoring the post-approval implementation of GM crops. These committees are designed to ensure that experts from the fields of environment, health, science, agriculture and law, are all involved in the pre- and post-evaluation of GM crops.

Bt cotton is the first GM crop to be introduced in India in 2002, and since then evaluation mechanisms have been further refined. The Ministry of Agriculture and the Indian Council of Agricultural Research (ICAR) are involved in the agronomic evaluation of the products. It is a very significant development in India that along with biosafety and environmental safety considerations, the economics of the product for its adoptability are also considered in the entire process. Currently, four events (Mon 531 and Mon 15985 belonging to Mahyco Monsanto Biotech Ltd, GFM event of Nath Seeds, and Event-1 of JK Seeds) have been approved for cotton, with a view to diversify the base of Bt cotton hybrids in India. Nearly 62 hybrids were approved for commercial cultivation in all the three cotton-growing zones in 2006. The impact of Bt technology has become visible in the area devoted to cotton productivity. Between 2002 to 2006, the area under Bt cotton increased from 45,000 ha to 3, 800,000 hectares, and simultaneously the cotton production rose from 14 million bales (170 kg/bale) to 25 million bales. Cotton productivity has risen from 310 kg lint/hectare to 500 kg lint/hectare. This white-gold silent revolution witnessed by India is a culmination of the entire process of regulations developed by its government.

Now that the country is on the path of adoption of biotech crops, more than a dozen crops involving different traits are targeted in research programs in public and private sector institutions. The Government of India has ratified the Cartagena Protocol in January 2003, and is committed to the biosafey of GM crops.

6. Biotech Cotton Trade Socio-Economic and Market Acceptance Issues

Mrs Jolly.K. Sabune
Managing Director
Cotton Development Organization

1. Introduction

1.1 The Term "Biotech Cotton"

The term "Biotech Cotton" coined by the ICAC refers to an expanded wide range of products in cotton which are facilitated by means of biotechnology (ICAC 2004a). This article, however, will refer only to two categories of biotech cotton. These are cottons whose genetic compositions have been modified through biotechnology for resistance to bollworms and for tolerance to herbicides for the control of Lepidopteran insects and weed pests, respectively.

1.2 The Bt Bollworm Resistant Biotech Cotton

Biotech cotton has been produced commercially since 1996 after its introduction by the Monsanto Biotechnology firm (ICAC 2000). This was after Perlak *et al.* (1990) introduced the *Cry1Ac* gene into cotton plants from a soil borne bacteria *Bacillus thuringiensis var kurstaki (Bt.k)* strain HD 73. The gene produces an endo-toxin protein in the transformed plants which offers levels of resistance to cotton bollworms. A second gene *Cry2Ab* was later incorporated by Monsanto to form Bollgard II™ cottons. It was released in 2002 for offering higher and broader levels of resistance to the bollworms and for the management of bollworm resistance to the Bt toxins (www.agbios.com) Another product announced in the year 2004 by Dow Agrisciences was a dual Bt gene product named "Wide Strike". It contained *Cry1AC* and *Cry1F* genes (Pellow *et al.*, 2002). Again in the same year the Syngenta firm announced a "VIP" vegetative toxin gene from Bt (Shotkoski, *et.al.*, 2003).

1.3 The Herbicide Tolerant Biotech Cottons

Herbicide tolerant biotech cottons were first commercialized in 1997 by the Monsanto Multinational Company. The transgenic cottons tolerant to a broad spectra herbicide 'Roundup" with glyphosate as its active ingredient came to be known as Roundup Ready (R) (RR) cottons (Monsanto 2002). The setback with the first generation of RR cotton was the limited window of its tolerance to the herbicide of only up to four leaf-stage of the cotton plant. Alternative research by Bayer Crop Sciences biotech company, came up with the Liberty ® Link cotton tolerant to the herbicide "gluphosinate" (rather than glyphosate) up to a 10 leaf-stage, a longer application window.

The Monsanto group has now developed a second generation of biotech cotton known as "Roundup Ready ® Flex" which tolerates the Roundup (glyphosate) herbicide at all stages of plant growth (i.e from germination up to harvest). The RR flex cotton was approved for commercial production in 2006/07. It utilizes a cp4 epsps sequence that expresses for the CP4EPSPS protein, which with an improved promoter sequence, can tolerate the glyphosate herbicide for a longer period than the first generation of RR cotton (ICAC, 2006 c, Croon *et al.*, 2005 and ICAC 2004 b).

This article attempts to bring out salient issues on Biotech cotton trade, socio-economic and market acceptance aspects with emphasis on the small-holder producers in developing countries.

2. The Projected Trends in Global Biotech Cotton Production and Trade

2.1 Global Cotton Trade

The ICAC projected the cotton trade (for both conventional and biotech) to be 9.5 million tons in the 2006/07. This would be a fifth consecutive record. This trade would exceed the 2001/02 volumes by 50 percent. The surge in cotton trade during the period between 2001/02 and 2005/06 was attributed to the rise in world mill use in China (mainland), Pakistan, Turkey and India, four major textile countries that depended on imports of cotton. They accounted for 23 percent of world imports in 2001/02 and for the estimated 57 percent in 2005/06 (ICAC 2006a).

2.2 Global Biotech Production and Trade

The biotech cotton production and trade is also expanding. It is recorded that in 2005/06, biotech cotton accounted for 29 percent of world cotton areas and 38 percent of world production, an increase from the 2004/05 figures of 24 percent and 33 percent, respectively. The nine major biotech producing countries in 2005/06 included the United States, Australia, China (mainland), India, South Africa, Argentina, Colombia, Indonesia and Mexico (ICAC 2006 a and b).

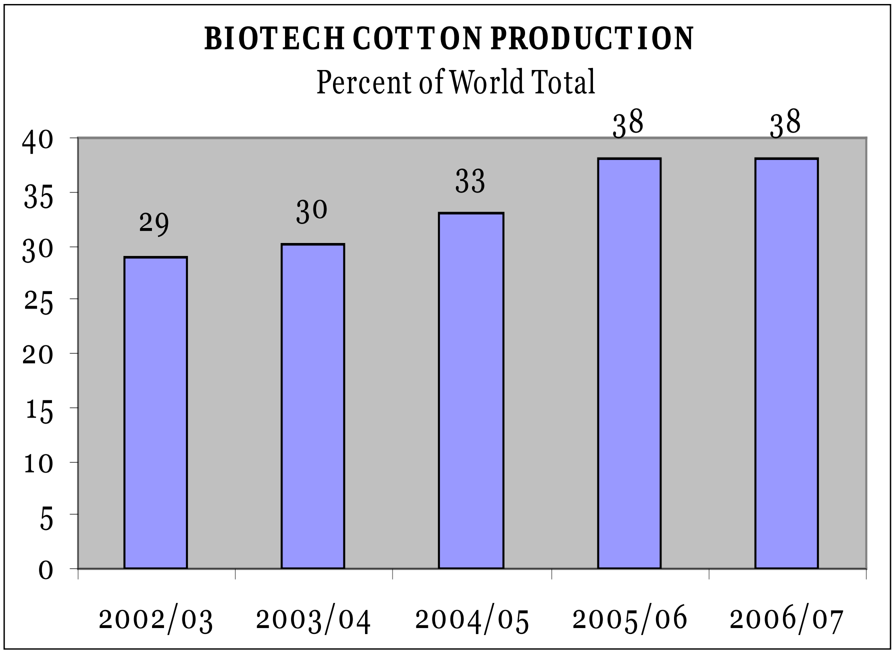
It is estimated that in 2006/07, biotech cotton will account for 31 percent of world area and 38 percent of world production. Based on production ratios of biotech cotton in exporting countries (United States., Australia and India), it was estimated that biotech cotton accounted for 35 percent in world exports in 2004/05 and 39 percent in 2005/06 (ICAC 2006b).

3. Socio-Economic Impacts of Biotech Cotton in Developing Countries

3.1. Commercial Biotech Cotton Production in Developing Countries

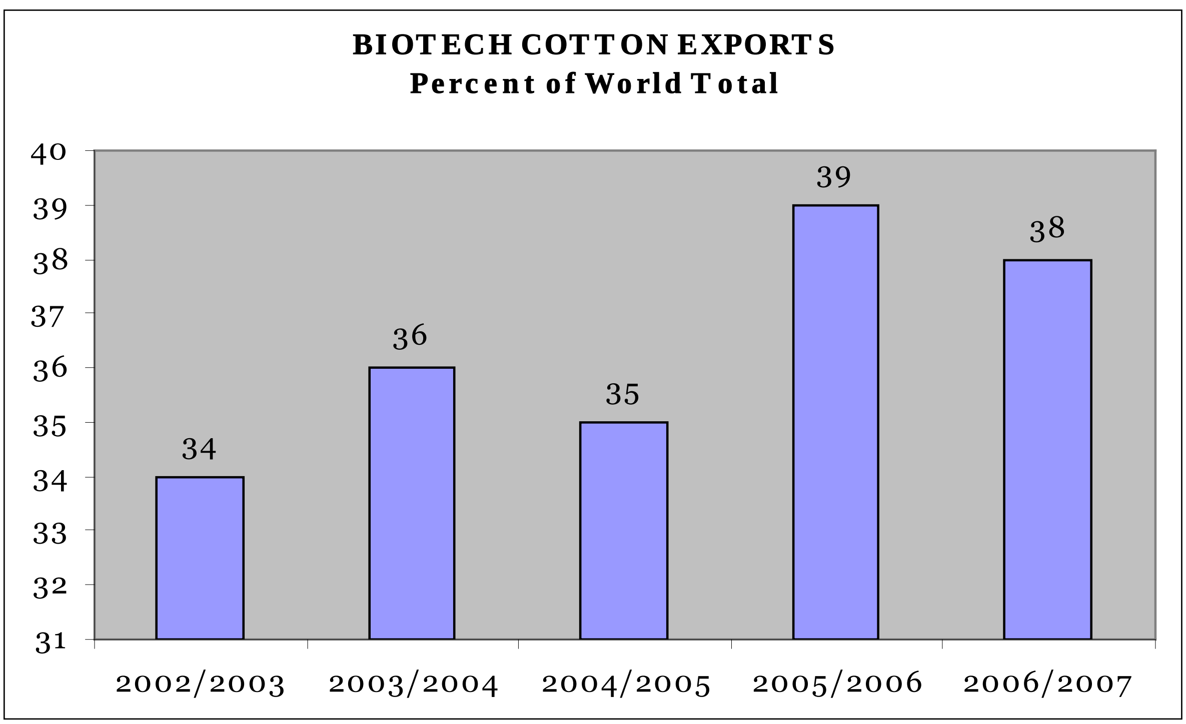
Developing countries that are already planting commercial biotech cotton include China, India, Argentina, Mexico and South Africa. Other developing countries with small-scale cotton production systems are coming on board but still at levels of biotech cotton testing and transformation of traditional varieties, as in the cases of Uganda and Zimbabwe, respectively, (Serunjogi, 2007 and Yogeshkumar, 2007), and West African countries such as Mali, Burkina Faso and Chad, which are still in research phases for developing and testing (Deat, 2006).

Figure 1. Production



Source - ICAC 2006(a)

Figure 2. Exports



Source - ICAC 2006(a)

A number of reviews have recently been made on the determinant factors for the slow adoption of transgenic crops in developing countries. The level of profitability ultimately determines whether the farmers will adopt and retain a new technology although a number of other factors also affect adoption. The economic studies in developing countries found positive but highly variable economic returns from adopting transgenic crops (Raney, 2006), hence emphasizing the need for careful analysis of case by case while addressing a country's needs for biotech cotton.

Raney (2006) reported results of comprehensive economic studies of farm-level impacts of Insect Resistant (IR) Biotech Cotton in Argentina, China, India, Mexico and South Africa. (Table 1).

Table 1: Performance Advantage of Biotech over Conventional Cotton Expressed as a percentage.

	Argentina	China	India	Mexico	South Africa
Yield	33	19	34	11	65
Revenue	34	23	33	9	65
Pesticide costs	-47	-67	-41	-77	-58
Seed cost	530	95	17	165	89
Profit	31	340	69	12	299

Source: Raney, 2006

Each of the studies in Table 1 was based on data from two or three seasons of commercial farm production. The figures are average percentage differences for all farmers over all seasons covered in the study. While the averages concealed the high degree of variations among the farmers and between seasons in a given country, they showed the variations among the countries. There were overall positive results. Farmers who adopted the biotech cottons had higher yields, due to less pest damage, higher revenue and lower pesticide costs. Those factors compensated for the higher prices of the transgenic seeds and hence gave significant profits to biotech cotton-adopting farmers.

3.2 Small-Scale Producers of Biotech Cotton in Developing Countries

The Raney (2006) review shows positive benefits from using biotech cotton. It is, however, important to note the variations in yield, costs of inputs (seeds) and hence, the profits across the countries. This emphasizes the need for careful analysis country by country of the socio-economic factors for deriving meaningful potentials of the biotech cottons. This is especially necessary in cases of small-holder subsistence farmers. These socio-economic factors will determine whether the small-scale grower would be able to adopt biotech cotton production or not. In Uganda, other than the lowered costs of production, increased productivity and incomes, benefits expected by biotech cotton-adopting farmers include the alleviation of gender concerns. In cotton production systems, the women and the youth are responsible for the heavy and time consuming hand hoeing to control weeds while the mature males are more involved in the marketing aspects. The use of herbicide tolerant biotech cotton would reduce the burden of weeding. With particular reference to Uganda, the other factors of consideration would include *inter alia*:

3.2.1 Guarding Against Disruption of Conducive Low-Cost Input Systems

In Uganda the majority of farmers' cotton plots range from 0.5 to 2.5 ha in size although there are new efforts by the Cotton Development Organization (CDO) and the Uganda Cotton Ginners and Exporters Association (UCGEA) to cluster plots into cotton blocks of 500 acres and over through the formation of farmer groups (NARO-CDO, 2005). A seed replacement wave system is currently in practice (Serunjogi *et al.* 2001) that allows movement of the conventional line variety seeds from a small production area in one season to a larger zone the following season through an informal seed scheme. The seeds are affordable and the main costs are incurred in processing (ginning, delinting and chemical dressing) and transportation. These costs are subsidized by the private sector, particularly the UCGEA. The high cost of transgenic seeds would be prohibitive in such a system where there are no provisions of credits for inputs. The government would not subsidize the cost of seeds under the liberalized trade systems (Sabune, 2005).

3.2.2. The Limited Scope of Biotech Cotton on Pest Control

Another setback in small-scale biotech cotton production systems stems from the need for a number of chemicals to control major insect pests other than the bollworms and weeds, which include the sucking and leaf chewing insect pests: *Aphids spp*, Lygus and stainers (*Dysdercus spp*) in Uganda. Protection of the Bt cotton requires the small-scale grower to purchase and apply small portions of appropriate chemicals. There is therefore, a need for further biotech research aimed at expanding the scope of control by biotech cotton to include other major insect pests and even to alleviate stresses due to drought and nematodes. These stresses are prevalent in the rain-fed and sandy, low soil fertility production systems, respectively.

3.2.3 Loss of Intrinsic Attributes in Traditional Varieties

The small-scale cotton producing systems in developing countries are further characterized by insufficient biotechnology research programmes under publicly funded National Agricultural Research Systems (NARS). Such systems would usually depend on multinational firms for sources of biotech options. The adoption of foreign transgenics would deprive such countries the intrinsic attributes of the traditional varieties that have been improved over the decades through conventional breeding efforts. Such attributes in the Uganda Albar varieties *Gossypium hirstum L.* include *inter alia*: 1) resistance to Jassid pests through selection for hairy (pubescent) varieties; 2) resistance to diseases like the bacterial blight caused by *Xanthomonas campestris pv malvacearum*; and 3) the good fiber and spinning quality that have earned Uganda cottons premium prices in international markets (Serunjogi *et al.*, 2004a and 2003). Further, yield component characteristics of large boll and seed sizes and high ginning out-turn (GOT) desired by farmers and ginners, respectively, would also be forfeited. Moreover, adoption of foreign transgenics could lead to poor crop performance, yield and quality due to low adaptation to the new environments (soils, moisture, sunshine and diseases).

3.2.4 Intellectual Property Rights Management Issues

In order to avoid the loss of good attributes in traditional varieties mentioned above, it is ideal to have the biotech genes incorporated into the developing country's traditional varieties. The transformation can be done in multinational firm laboratories or through procurement of appropriate transformed varieties for backcrossing to the local varieties. India used the latter arrangement in the development of its successful biotech hybrids (Chaporkar, 2007). Whatever the arrangement adopted, the recipient developing country should still have appropriate Intellectual Property Rights (IPR) systems in place. This would facilitate the drawing up of appropriate agreements regarding technology fees due to the technology provider and royalties for both parties (technology recipient and provider) from the subsequent sales of transformed seed.

4. Market Acceptance Issues

4.1 Alleviated fears of Biotech Cotton Based on Environment and Human Health Risks in the United States and Europe Markets

On the onset, the adoption of biotech cotton production was much impeded by rejection in marketing circles especially in Europe, UK and Germany (Gillen, 2002). The rejection arose from fears of transgenic cotton and its byproducts in regard to unknown effects on the environment, local fauna (including beneficial insects), approaches, and on livestock and human health. (Serunjogi, 2004b). Such fears led to a possible rejection of biotech cotton by developing countries like Uganda and by the traditional cotton markets in Europe.

It is now noted that the initial fears about biotech cotton have waned. The European Union markets have accepted biotech cotton and its byproducts (ICAC 2004a). Gillen (2002) had earlier explained that the acceptance of biotech cotton in the United States was made possible partly through the effective communication to the environmental groups, political communities and to the consumers by the biotech firms.

The communication included *inter alia,* facts on the benefits to the environment and human health through substantial reduction in use of pesticides. Further, according to Gillen (2002), consumers in the United States had been satisfied by the sound science-based analysis concerning the benefits from biotech crops. The consumers also came to trust the regulatory processes which were focused on environmental impacts and consumer safety.

4.2 Alleviated Fears on Biotech Cotton By-products

Further fears on the use of biotech cotton byproducts have been alleviated by studies which proved the non-allergenicity and non-toxicity of biotech cotton DNA and proteins. The studies also proved that cotton cooking oils are free of DNA and proteins, and that there is no evidence of cross-transfer of biotech DNA into human and livestock DNA. The possible toxification, for instance, from the gossypol content of livestock feed cakes is excluded through the extensive processing phases, including detoxification of cotton seed meals by incubation with the fungus, *Candida tropicalis*. Textile products from biotech cotton undergo cleaning at ginning, yarning, knitting, weaving, bleaching, finishing and dyeing stages of manufacturing (Yogeshkumar, 2007 and Neil, 2002).

4.3 Market Acceptance of Biotech Cotton Fiber Qualities

Another important aspect in the market acceptability of biotech cotton lint concerns its fiber and spinning quality. The potential for high market acceptability of biotech cotton lint stems from the fact that the transformation of the traditional varieties for insect resistance and or herbicide tolerance will not alter the fiber characteristics and spinning qualities desired by traditional markets. What is essential is to make appropriate crosses and back crosses for retention of the quality types in the traditional parent lines. This approach has been used in India for development of transgenic hybrid with a wide range of fiber qualities. The Maharashtra Hybrid company of India has developed 75 Bollgard cotton hybrids with fiber qualities in the medium staple (3 hybrids); Long-staple (70) and extra-long staple lengths (2) (Chaporkar, 2007). Additionally, adoption of herbicide resistant biotech cottons have led to improved fiber quality and market acceptance through reduction of trash and weed-seed contaminants in the seed cotton and resultant lint.

4.4 Exceptions to Biotech Cotton Acceptance: the Organic Cotton Concept

A challenge to the adoption of biotech cotton in Uganda is the promising niche market for organic cotton. Organic cotton is produced without the use of synthetic fertilizers and pesticides. Organic cotton lint has an average price of 100 US cents/Lb^{-1} while non-organic cotton lint fetches only 50-60 cents/Lb^{-1}. Embracing biotech cotton in all cotton producing zones in Uganda would disrupt the organic cotton opportunities since the certification standards for organic cotton exclude biotech cotton. Disruption of Uganda's organic cotton market opportunities would be a big blow to the country's economy. Landlocked Uganda exports 97 percent of its cotton lint in raw form, exposing its small-scale growers to price fluctuations in the international market. The incentive price pegged on organic cotton will provide very good income-earning opportunities for the farmers.

5. Discussion and Conclusions

5.1 Biotech Cotton Acceptable on Trade and a No Price Differential

In practice, local and international markets do not identify biotech contents in cotton fiber, textiles and byproducts but lay more premium on product properties based on cotton fiber characteristics. There are no price differentials between biotech and non-biotech cotton fibers or textiles. Challenging the widespread adoption of biotech cotton, however, is organic cotton, a high premium product that has great potential as a niche market. Certification standards for organic cotton should, in the future, be eased to include biotech cotton.

5.2 Implications of Increased Biotech Cotton Production on World Trade and Prices

The production of biotech cotton is evidently on the rise as evidenced by more and more developing countries joining the bandwagon. The ICAC (2006 a and b) projects a world cotton area in 2010/11 of 35.7 million hectares, half of which will be under biotech cotton production in over 15 countries. The yields are likely to go up under biotech cotton, especially in developing countries where plant protection programmes are not yet established. The increases in production may have an effect on the international prices which are expected to average 50-60 US cents/Lb^{-1} of lint between 2001/02 and 2009/10 from an average 72 US cents/Lb^{-1} in the 1990s and 73 US cents/Lb^{-1} in the 1980s. With expected production growth, the lint prices may fall if the world stock:use ratio were to rise. Mechanisms to buffer against a drop in international prices include an increase in mill use to reduce the world stock:use ratio, reductions in competition through the use of synthetic fibers and distortions from massive subsidies granted to cotton produce by industrialized countries.

References

Chaporkar, C.B. 2007. G M Cotton Experience in India. Maharashtra Hybrid Seeds Company. In proceedings of the Zimbabwe National Cotton Association Biotech Cotton Consultative Workshop Harare, 08 February, 2007. Theme: Poverty Alleviation: Increased Cotton Production through new Cotton Seed Technologies.

Croon, Kent A., Rob, A. Ihrig and J. Walt Mullins. 2005. Roundup Ready Flex cotton technology. *Proceeding of the 2005 Beltwide Cotton Conferences*. National Council of America, Memphis, TN, USA..

Deat, M., 2006. Statement of CIRAD. The Socio-economic and Environmental Impact of Cotton in West and Central Africa. In Statements 65th Plenary Meeting of the International Cotton Advisory Committee Goiania. Brazil September 2006.

Gillen, Neal P. 2002. Impact of Transgenic Cotton on the International Cotton Trade. In papers presented to the Technical Seminar and Meeting Committee on Cotton Production Research "The 21st Century Cotton Industry: Growth Through Private Investment". The 61st Plenary Meeting of ICAC, Cairo Egypt October 2002.

ICAC 2006(a). Developments in World Cotton Trade. In World Cotton Trade 2006-07. International Cotton Advisory Committee September 2006.

ICAC 2006(b). The outlook for cotton supply in 2006/07. International Cotton Advisory Committee. September 2006.

ICAC 2006(c). Herbicide Resistant Biotech cotton. The ICAC Recorder: Vol. XXIV No.3 September 2006. The International Cotton Advisory Committee.

ICAC 2004(a). A Report of the Second Expert Panel on Biotechnology of Cotton. International Cotton Advisory Committee, November 2004.

ICAC 2004 (b) Update on Genetically Engineered cotton. The ICAC Recorder, Vol XXII, No. 2 June 2004.

ICAC 2000. A Report of the Expert Panel on Biotechnology of Cotton. Advisory Committee, November 2000.

Monsanto 2002. Safety Assessment of Roundup Ready ® Cotton Event 1445, September 2002. http://www.monsanto.com/monsanto/content/scitech/prod safety/roundupcotton/pss pdf.

NARO-CDO (2005). A report on Agronomical Constraints on Cotton Production in Uganda in 2003-2004 season. Action and Recommended Interventions, March 2005. Abridged Version.

Pellow, J., Huang, X., Anderson, D. and Meade, T. 2002. Novel Insect Resistance Traits from DOW Agrosciences. Proceedings of the Beltwide Cotton Confernce 2002.

Perlak. F.J., Deaton, R.W, Armstrong, T.A., Fuchs, R.L, Sims, S.R., Greenplate, J.T., and Fishaff, D.A 1990. Insect Resistant Cotton Plants. **Biotechnology 8**, 939-943.

Sabune, J. K. 2005. The Cotton sector in Uganda. Progress Made in Sector and Recommendations for Achieving further Progress. Paper presented at the 64th Plenary meeting of ICAC, Liverpool UK.

Serunjogi, L.K. 2007. Developments Towards Testing of Biotech Cotton in Uganda. In proceedings of the Zimbabwe National Cotton Association Biotech Cotton Consultative Workshop Harare, 08 February, 2007. Theme: Poverty Alleviation: Increased Cotton Production through New Cotton Seed Technologies.

Serunjogi, L.K ., Areke, T.E.E, Naluyimbe.R., and Aru.C., 2004 a.Challenges and Success on Cotton Variety Development Under Changing Policies, Stakeholders' Needs, Production Environments and Market forces in Uganda. **Uganda Journal of Agricultural Sciences 9**, 750-757

Serunjogi, L.K. 2004b., Why Fear Biotechnology. In papers presented at Technical Seminar at the 63rd plenary meeting of the International Cotton Advisory Committee Meeting, Mumbai, India, November 2004. How to improve yields and Reduce pesticide use: pp. 21-26.

Serunjogi, L.K., Areke, T.E.E, Odeke W., Ocan, J.R.,Naluyimbe.R., and Seruwagi., 2003 Varietal Development for Varied Stakeholders' Needs in the Liberalized Cotton Industry in Uganda. **Uganda Journal of Agricultural Sciences 8**, 55-66.

Serunjogi, L.K., Elobu P., Epieru, G., Okoth, V.O.A., Sekamatte, M.B.,Takan J.P., and Oryokot, J.O.E, 2001. Cotton (*Gossypium Sp.*) in Agriculture in Uganda Volume 2: Crops pp 322-375 (Ed) Mukiibi J.K. Fountain Publishers/CTA/NARO).

Shotkoski, F., Chen, E., Mascarenhas, V.J and Boykin, R. 2003. VIP. A novel insectificidal Protein with Broad Spectrom Lepidopteran Activity. Proceedings of the Beltwide Cotton Conference 2003, pp 89-93

Terri Raney 2006. Economic Impact of Transgenic Crops in Developing Countries. Current Opinion in Biotechnology 17, 1-5, - A Themed Issue on Plant Biotechnology Edit. Nam-Itai Chua and Scott V Tingey © 2006 Elsevier

Yogeshkumar. S. Naik. 2007. Safety Assessment of Genetically Modified Foods. In proceedings of the Zimbabwe National Cotton Association Biotech Cotton Consultative Workshop Harare, 08 February, 2007. Theme: Poverty Alleviation: Increased Cotton Production through new Cotton Seed Technologies.

7. Concerns, Risks and Issues Regarding Adoption of Bt Cotton - Focus on Implications of IPRS and Need for Awareness Raising and Dialogue

Derek Eaton
Researcher, International Trade & Development
Agricultural Economics Research Institute (LEI)
Wageningen University and Research Centre, the Netherlands

Introduction

Concerns, risks and issues around Bt cotton can be divided into three general areas:
- Biosafety, including plant and animal health, and food safety
- Performance & economic impact
- Institutional framework (role of private sector), including use of intellectual property rights (IPRs)

The broader background behind these concerns in Europe originates partly in the diminished trust in the regulation of overall food safety. Many people are not really convinced that genetic modification of food plants is safe, and more importantly, are not sure whom they should trust as an authority. The safety of the technology is being discussed by other presenters. But interpretations by many consumers of messages concerning the safety and risks are also affected by broader concerns surrounding the benefits and costs of this new technology. This presentation reviews recent discussions concerning the performance and economic impact, and discusses associated concerns regarding the institutional organization of the development and diffusion of Bt cotton, including the role of proprietary technology. The final section discusses how these concerns relate to overall assessments of the acceptability of such a technology.

Performance and Economic Impact

Proponents of genetic modification often base their case on the economic performance of crops such as Bt cotton, which have been widely adopted in a number of countries, including the United States and China. Opponents also seem to be armed with studies demonstrating poorer performance (see for example, GRAIN 2007). As with any new technology, in particular a crop variety, it is not surprising to find mixed results concerning the agronomic performance and economic impact. The new technology works better in some circumstances than in others, and some farmers are in a better position to profit from it than others, because of differences in natural resources, access to credit and other inputs, or simply due to farming capability.

A number of studies have been undertaken to assess the performance of Bt cotton in various countries and regions. Smale *et al.* (2006) recently reviewed 56 such studies over the period 1996/2006[1], all ofa which had been subjected to a peer review, and concluded that "the overall balance sheet, though promising, is mixed. Economic returns are highly variable over years, farm

[1] Of these, 42 were conducted in only three countries: China, India, and South Africa.

type and geographical location. They depend on initial practices, pest infestations, seed costs, and other attributes of farmers and farm production. Thus, findings cannot be generalized" (see Table 1). Smale and colleagues (2006) highlight the difficulties in assessing the economic impact of new varieties due to difficulties in controlling other factors (or in other words, defining what the counterfactual situation is), as well as indirect effects, such as price changes. Most importantly, they emphasize that most studies examine a time period that is relatively short compared to the time needed for many changes resulting from new varieties to be seen, as was the case with the Green Revolution (see for example Lipton and Longhurst, 1989).

Table 1: Summary of economic impact studies on Bt cotton in selected developing countries

Country	General	Institutional Setting
Argentina	- High price for Bt; low adoption - Medium- & large-scale farmers	- Private sector
China	- Wide coverage & diverse conditions - Varying success - Existing pesticide use high	- IPRs not strongly enforced - Private and public sector involvement - Higher (state-set) prices for cotton
India	- Very diverse conditions - Varying success - Objectivity of studies?	- Nontransparency in seed market; few IPRs - Non-integration of input and output markets - First private sector
Mexico	- Effective in specific region	- Private sector - Integrated input package - IPRs enforced through ginnery
South Africa	- Area of lower potential - Existing pesticide use not high - Initially positive impact	- Private sector - Integrated input package

Source: Adapted from Smale *et al.* (2006)

Thus aside from the methodological difficulties of assessing economic impact of Bt cotton, it can be argued that discussion is not necessarily furthered by the selection of results from a specific study or studies as illustration for one position or another. In other words, mixed results are to be expected, even at the farm level as estimated by comparing partial farm budgets. That both proponents and opponents of the technology tend to use specific results that support their position, while ignoring others, seems to reflect other concerns and perspectives on agricultural development, in particular the changing organization of agricultural research and development.

Concerns about Bt cotton, as with many other GM crops, are frequently raised with respect to the changing institutional framework in which these crops are developed by private sector companies, instead of the "traditional" public sector. Indeed, Smale *et al.* (2006) also hypothesise that there is a pattern between the impact observed to-date in the studies they reviewed and the "institutional and marketing arrangements for supplying the technology and marketing the product." The suggestion being made is that farmers benefit more from Bt cotton when it is supplied by the private sector due to lower prices and fewer (enforced) restrictions on use of Bt cotton seed. In the case of Bt cotton, China and India are examples where public agricultural research organizations have also invested in the development of Bt cotton varieties, without any dependence on proprietary technology of the private sector. In the United States, where Bt cotton was first developed, private sector development of Bt cotton has been paralleled (some would argue enabled) by increasing scope of intellectual property rights in the seed sector.

Intellectual Property Rights

A major concern surrounding the development of Bt cotton, and genetically modified crops in general, is the increasing possibility to protect such technology through the use of intellectual property rights (IPRs). This refers to both protection of the variety itself and also possibly to the protection of tools and techniques used to develop genetically modified varieties. As misunderstandings concerning the specific issues around IPRs are common, it is useful to summarize obligations for developing countries and emerging experiences, as a World Bank publication (2006) has done.

Under Article 27(3)b of the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) of the World Trade Organization (WTO), all WTO member countries are required to offer certain forms of IPR protection for plants and plant varieties, as well as biotechnological inventions. More specifically, countries must offer either plant breeder's right (PBR) and/or patent protection for plant varieties, as well as patent protection for biotechnological inventions. Most developing countries had not yet offered such protection at the time the TRIPS Agreement was negotiated as part of the Uruguay Round, but many have since passed legislation allowing for PBR protection, followed by the establishment of an authority to administer the granting of PBRs for specific varieties at the request of a breeder. Many such countries have chosen to develop a PBR system that conforms with the requirements for membership to the Union on the Protection for New Varieties of Plants (UPOV), established originally to harmonize European PBR systems. The scope of protection required under UPOV is fairly wide though, and some countries have chosen to model their PBR system on an earlier version of the UPOV treaty from 1978, and possibly to incorporate issues such as protection for farmers' varieties or landraces. Countries that are classified as "Least Developed" have been granted an extension until 2013 to fulfill the requirements of Article 27(3)b. Notably, hardly any countries have chosen to offer the even broader protection afforded by patents to plant varieties, arguably quite inappropriate for developing country agriculture, unless requested to do so in the framework of a bilateral trade agreement with the United States.

By choosing to offer PBR instead of patent protection for cotton varieties, countries allow breeders to continue using each other's varieties freely (breeders' exemption) and usually for farmers to save seeds if they wish. With Bt cotton, there is the added complication of the Bt gene construct inside the variety that can be protected by a patent. The overlapping protection between a patented gene construct inside a variety covered by PBR is an issue that will need to be addressed in the future. Member states of the EU have established guidelines under which the limitations to the holder of a PBR would continue to apply in such a situation (implying a limitation on typical patent rights, including the manner in which these have been applied in the United States). But there is still little indication as to how this will work in practice, and it is an issue that will probably arise later in the TRIPS Council, and possibly also in the context of the negotiation of a patent law treaty within the World Intellectual Property Organization (WIPO) framework, as opposed to the WTO.

While many developing countries have passed legislation for IPRs such as PBRs, most of them are struggling to implement these systems and offer enforceable rights for plant breeders. There are, therefore, few examples of effective systems, as emphasized by the World Bank (2006). This is partly a reflection of weak overall institutional capacity in many countries, particularly acute in an area demanding specific technical expertise, as well as organizational effectiveness, in addition to the less-developed judicial system to support the enforcement of such rights and associated contracts. The challenges are also one of trying to introduce a long-term change in people's customs and habits, in this case how farmers and seed suppliers regard seeds, and any norms concerning rights and responsibilities around their use and exchange. The development of PBRs in Europe has for instance been a long-term and gradual process, with the first discussions and political debate lasting at least a generation until the first form of limited protection was offered. This process began approximately 100 years ago in western Europe.

IPRs in plant varieties present challenges to a range of stakeholders. Attention often focuses on farmers, including those who operate as seed suppliers for their neighbours. But breeding and multiplication companies in developing countries also need to learn to work with the new alignment of rights and responsibilities. Perhaps most difficult are the challenges for the public agricultural research organizations, where a "culture of sharing" has long prevailed. Scientists and plant breeders in the public sector in developing countries are often not accustomed to proprietary rights over varieties or breeding technologies. The introduction of IPRs risks causing a reorientation of research strategy among crop research institutes that may be driven more by shorter term financial goals, rather than a broader agricultural development strategy (Tripp *et al.*, 2007).

While IPRs have not yet had much discernible impact in the seed sector in developing countries, cotton is an example of a crop where such protection does affect investment opportunities and decisions. Cotton is a large commercial crop, with seed in most countries consisting of open-pollinated varieties (OPVs). This provides a potentially attractive market for private sector seed companies, particularly since there are often possibilities for reducing the incentives of farmers to save and re-use seed given the technical and marketing characteristics of this cash crop. On the other hand, there has been considerable public sector investment in many countries, including the large producers such as China, India and Pakistan. These countries have all chosen to apply this accumulated expertise to the development of public sector Bt cotton varieties, despite the availability of Monsanto's varieties. It appears from the review by Smale *et al.* (2006) that this strategy may yield more benefits for some farmers, as there is more choice and the public sector variety is available at lower cost (and with fewer restrictions).

Concluding remarks

The availability in some countries of "public sector Bt cotton" may have defused the debate between proponents and opponents of Bt cotton to some extent, but not entirely. The experiences though in Bt cotton illustrate that the acceptability of GM technology in general is much broader than a discussion on food and environmental safety. Stakeholders have a variety of concerns related to social consequences of new technologies. For genetically modified crops, a major concern is the increasing development and delivery of seed technology by the private sector with the perceived risk that some farmers will now benefit more than others. More generally, there is a perceived risk that it will be more difficult for society to influence the nature and course of technological change in agricultural systems. In many countries, food and agriculture have a social and cultural importance that goes beyond the simple function of food provision. Summarizing results from the EU-funded Ethical Tools project, Beekman and Brom (2007) note that "the debate about the use of GMOs in agriculture and food production is for many people not just confined to the acceptability of the consequences of the application of this specific technology; it is also a debate about the future of agriculture, rural communities, landscapes and cultural identities. It should be clear that a debate about such comprehensive issues is not merely a factual discussion." For many scientists and technologists, the idea that the acceptability of Bt cotton, and GM crops in general, may not only be a "right/wrong" issue, as in the case of food and environmental safety, may be challenging, requiring a broader perspective.

References

Beekman, V. and F. Brom, W. A. (2007). "Ethical Tools to Support Systematic Public Deliberations About the Ethical Aspects of Agricultural Biotechnologies", *Journal of Agricultural and Environmental Ethics*, 20(1): 3-12.

GRAIN (2007). "Bt cotton: the facts behind the hype". *Seedling*, January, pp. 18-24. (www.grain.org)

Lipton, M. and R. Longhurst. (1989). *New Seeds and Poor People.* London: Unwin Hyman.

Smale, M., P. Zambrano, and M. Cartel. (2006). "Bales and Balance: A Review of the Methods Used to Assess the Economic Impact of Bt Cotton on Farmers in Developing Economies", *AgBioForum*, 9(3): 195-212.

Tripp, R., N. Louwaars, and D. Eaton. (2007). "Plant Variety Protection in Developing Countries. A Report from the Field", *Food Policy*, 32(3): 354-371.

World Bank (2006). *Intellectual Property Rights: Designing Regimes to Support Plant Breeding in Developing Countries.* (By Rob Tripp, Derek Eaton and Niels Louwaars). Washington DC: World Bank, June 2006. http://siteresources.worldbank.org/INTARD/Resources/IPR_ESW.pdf

7. Biotechnology Research Limitations

Lastus Katende Serunjogi
Cotton Breeding Consultant
Cotton Development Organisation

1. Introduction

The scope of biotechnology is large (ICAC, 2002). Biotechnology is a collection of technologies that exploit the attributes of cells such as their manufacturing capabilities. It utilizes biological molecules, such as DNA and proteins to satisfy human needs. Biotechnology includes experimental techniques for evaluating and manipulating genetic materials of organisms including molecular analysis, hybridization (even among least related parents), organ and cell culture, plant regeneration, microbial biochemistry, and molecular biology and genetics. The uniqueness of biotechnology is that it can be applied to all classes of organisms which include viruses and bacteria, and plants and animals. Biotechnology is becoming a major tool of modern agriculture, human and veterinary medicine, industries, use of bio-resources and of environmental management. (Zeweldu, 2006)

Biotechnology experimentation or research can be classified into two major categories. The first is research into the development of appropriate methodologies, procedures, protocols and tools to manipulate organisms and derive the desired products. The second category of biotech research is the identification and isolation of novel traits or genes for use in making desired genetic changes (transformation) in the organisms of interest. Biotechnology research is globally conducted under two systems of funding. These are state or public and private firm funded biotech research. It should be noted that the source of funding of biotechnology research has a lot of bearing on the modes and ease of access of the end users to the biotech products. The two funding sources yield public and private biotech goods, respectively. CIRAD (2004) suggested that while publicly funded research could address all aspects of biotech research, it should concentrate on adopting approaches which take public demands and environmental impact of potential biotech research products into consideration. The ethical priorities would thus differ from those of private biotech research which are geared specifically towards promoting the commercial aspect and profit potential. CIRAD (2004) concluded that public biotech research should be dissociated from commercial considerations.

Whatever the source of biotech research funding, there are constraints or limitations which affect smooth progression towards achievement of the anticipated product. This article aims at pointing out these limitations in the contemporary biotech research and in the envisaged future biotech product innovations. While the applications of biotech research are wide, this article will dwell on the limitations in areas of biotech cotton research. The term "biotech cotton" will be used in this article to refer to the wide range of products in cotton which are facilitated by means of biotechnology (ICAC, 2004a). Emphasis will be placed on two categories of biotech cotton innovations. These are cottons whose genetic compositions have been modified through biotechnology for resistance to bollworms and for tolerance to herbicides for the control of Lepidopteran insects and weed pests.

2. Contemporary Research on Biotech Cotton

2.1 The Bt Biotech Cotton Research

Biotech cotton has been produced commercially since their introduction in 1996 by the Monsanto Biotechlogy firm (ICAC 2000). This was after Perlak *et al.*, (1990) introduced the *Cry1Ac* gene into cotton plants from soil borne bacteria *Bacillus thuringiensis var kurstaki (Bt.k)* strain HD 73. The gene produces an endo-toxin protein in the transformed plants which offers resistance to cotton bollworms. A second gene *Cry2Ab* gene was later incorporated by Monsanto to form Bollgard IITM cottons. It was released in year 2002 for offering higher and broader levels of resistance to bollworms and for the management of the bollworm resistance to the Bt toxins (www.agbios.com). Another product announced in the year 2004 by DOW Agrisciences was a dual Bt gene product named "Wide Strike". It contained *Cry1AC* and *Cry1F* genes (Pellow *et al.*, 2002). In the same year, the Syngenta firm announced a "VIP" vegetative toxin gene from Bt (Shotkoski *et al.*, 2003).

2.2 The Herbicide Tolerant Biotech Cottons Research

Herbicide tolerant biotech cottons were first commercialized in 1997 by the Monsanto Multinational Company. The transgenic cottons tolerant to a broad spectra herbicide "Roundup" with glyphosate as its active ingredient came to be known as Roundup Ready (R) (RR) cottons (Monsanto 2002). The setback with the first generation of RR cotton was the limited window of its tolerance to the herbicide which was only up to four leaf-stage of the cotton plant. Alternative research by Bayer Crop Sciences biotech company, came up with the Liberty ® Link cotton tolerant to the herbicide "gluphosinate" (rather than glyphosate) up to a 10 leaf-stage, a longer application window.

The Monsanto group has now developed a second generation of biotech cotton option known as "Roundup Ready ® Flex" which tolerates the Roundup (glyphosate) herbicide at all stages of plant growth, i.e, from germination up to harvest. The RR flex cotton was approved for commercial production in 2006/07. It utilizes a cp4 epsps sequence that expresses for the CP4EPSPS protein, which with an improved promoter sequence, can tolerate the glyphosate herbicide for a longer period than the first generation RR cotton (ICAC, 2006 c, Croon *et al.*, 2005 and ICAC 2004 b).

3. Envisaged Future Biotech Cotton Research

Hake (2003) outlined developments in cotton biotechnology tools and traits. The transformation of cotton using Agrobacterium was introduced in 1987 (Umbeck *et al.*, 1987). The approach enabled manipulation of single genes in comparison to whole plant genomes handled under the traditional plant breeding. The recent genomics-based biotech tools utilize marker aided selection (MAS). These rely upon laboratory and field experiments for identifying and validating close associations between genetic sequences (markers) and useful agronomic traits. The MAS biotech tools enable quick evaluation of large segregating populations for identifying those with desired traits, say for disease resistance. The MAS biotech tools are also highly valuable in identifying novel and useful traits from wild relatives that can be introgressed into modern crop varieties.

The roles of biotech cotton research on increased profitability and health, and on environment benefits have aroused further interest for new research tools and traits. Among the new areas being probed is the use of Inducible Gene Regulation (IGR) of biotech traits. This approach would target gene expressions in specific plant tissues, tissue ages and generations under various environmental stresses. This IGR approach would be in contrast to the current approach of constitutive expression of traits throughout all tissues and life of a transgenic plant (Hake, 2003). The IGR tools approach utilizes gene switches or promoters triggered off, for instance, by specific stress (heat, light, foliar chemicals, etc). As such, long term future biotech traits of interest would include drought tolerance, cold tolerance, salt tolerance, oil and fiber quality and yield enhancement.

4. Biotechnology Research Limitations

Much as the advances in biotechnology have benefited the human race, there are a number of limitations posed to contemporary and to future biotechnology research. These limitations and suggested alleviations in some cases can be categorized as follows:

4.1 Myths and Fears on Biotech Cotton

Among the setbacks surrounding biotechnology research are the myths and fears with regard to the biotech products. Right from the onset of modern biotechnology, research and initiatives supporting it have faced controversies and opposition from a range of potential benefactors such as policy makers, religious leaders, environmentalists, and the consumers or end users of the research products. Fears that have influenced biotech research in various forms stem from the following aspects *inter alia* (Garwe 2007, Serunjogi, 2004, and CIRAD 2004).

- Anticipated risks to health through ingestion of livestock products that fed on biotech cotton feed cakes and or use of biotech cotton textiles.
- Damage to environments through adverse effects on beneficial fauna, non-target insects in the case of Bt cotton, and creation of super weeds in the course of using herbicide-resistant biotech cottons.
- Political skepticism that biotech research in developed countries is a new form of economic imperialism through enhanced and sustained productivity and agro-processing that would lead to domination of international markets by developed countries. This perception of domination could be “confirmed” by policy makers in developing countries when approached by the local research scientists for funding the requirements of the fees associated with use of biotech technologies from private biotech firms.
- There is inadequate knowledge on intentions and appropriate use of biotechnology innovations. The example here is the Technology Protection System (TPS) known as “Terminator Gene” developed jointly by USDA and the Delta&Pine Land Company. While the trait was meant to protect the companies’ innovations, it was vehemently rejected in the developing counties where it was feared that it would disrupt the flexibility of farm seed saving in low input production systems. While it was patented in 1998, it was never commercialized (ICAC, 2002b and ICAC, 2000). Even though the technology was

abandoned, it sent harmful signals about the intentions of the biotechnologists. This led to negative decisions on the part of policy makers regarding sanctioning of biotech research or not putting in place enabling policy and legal framework for biotech research.

- Religion-based fears related to the impact of biotech research on the modification of food diets through transformation even between unrelated species and on the apparent trespass into the creation domain in the cases of cloning as in the Dolly sheep example.
- These fears have led to the necessity of undertaking costly side or basic research regarding management of risks to humans and the environment. This was necessary to court the product users, the would-be funders of the research and the policy makers, on the safety of biotech products. The additional research costs have been aggravated by the fact that while the studies on human health risks could be extrapolated across regions or globally through harmonized regulatory programs (ICAC 2004a), those on environment impact have to be duplicated, in the particular environments (laboratory simulation or in-situ field experiments) on a case by case basis (Garwe,2007 and ICAC 2004 a).
- It is, however, noted that the sound science-based research on impact studies and regulatory frameworks have alleviated the original fears and cultivated trust in biotechnology in the United States and many other countries. It has opened markets in European countries which were originally skeptical over biotech products (Serunjogi, 2004, ICAC, 2004a and Gillen, 2002).

4.2 Biological Systems' Limitations to Biotech Research

Other limitations to biotechnology research stem from deficiencies in the cotton plant biological systems which are being manipulated.

4.2.1 Limited Somatic Regeneration Capacity of Cotton Varieties

The case in citation is the failure of most cultivated cotton varieties to be regenerated from the cell/ tissue cultures after the transformation of the tissues. This has led to global research laboratories to entirely depend on the USA Coker 312 variety which has the capability of regeneration after transformation. This shortcoming on the biological systems brings out a number of limitations to biotech research including *inter alia*,

- The elite and improved local germplasm can not be readily used in the desired transformations but have to be put through long cycles of back crossing with Coker 312. This is necessary if the researcher is not to forfeit the intrinsic attributes in the local cultivars. Chapokar (2007) and Khadi and coworkers (2003) described the long procedures in the development of transgenic cotton hybrids in India.
- Payment of technology fee to the patenting agency for the use of Coker 312 by the recipient research program. The costs would eventually be translated into high costs of the resultant technology and could affect adoption rates, especially in the small-scale production systems in developing countries (Terri Raney 2006).
- The global use of Coker 312 as a transgenic gene donor could narrow down the world's biotech cultivar genetic diversity. This would be detrimental in cases of new races of diseases and pests. Low numbers of backcrosses would render the transgenic short of desired agronomical adaptation to the environment and fiber quality traits that would in turn affect adoption rates and traditional market requirements.

- The issues of cotton cultivar regeneration and limitations in somatic embryogenesis in the transformation systems are gradually being overcome. McNaugten and Rey (2000) described successful regeneration and transformation of apical meristem tissues of four South African cotton varieties *Gossypium hirsutum*. This was through manipulation of growth regulators in Murashige and Skoog basal media.

4.2.2 Development of Insect Resistance to Bt Toxins and Weeds to Herbicides

The phenomenon of pests developing resistance to pesticides has led to enormous amounts of research. The same phenomenon applies to the use of Bt genes to control Lepidopteran moths. The single *Cry1Ac* gene biotech cotton cultivars developed by Perlak (1990) were later upgraded to Bollgard (ii) with an added *Cry2Ab* gene in the quest for managing pest resistance to the Bt toxins. This phenomenon calls for researchers to be ahead of the pests and requires looking out for non-Cry genes for the control of the resistance. Khadi *et al.* (2003) described three categories of insect resistance management:

- Protein or gene pyramiding in cultivars for *Cry* and *Cry* plus other insecticidal genes.
- Toxic protein synthesis through specific tissue and or inducible expression including high or ultra high doses of the toxin.
- Field tactics including planting of refugia crops and practicing *Cry* gene crop rotation. They cited this approach to be more practical to the farmers.

Meanwhile, not much attention has been given to research on weeds developing resistance to herbicides under the Herbicide Tolerant cottons. The ICAC (2006) discussed how weed resistance to herbicides in biotech cotton was a real problem, but had not, however, received the same research attention given to insect or toxin resistance. Research efforts need to be directed to this limitation now to enlarge areas of immediate need for biotech research.

4.2.3 Limitations from the Narrow Scope of Cry Genes in Pest Control: the Essence of an IPM strategy

An additional limitation to biotech research is due to the narrow range of pest control by the Cry genes. While the Bollgard II biotech cotton can now control a range of Lepidopteran bollworms (*Helicoverpa armigera*, pink, and spotted bollworm) and even *Spodoptera* spp and armyworms (Chaparkar, 2007), it has no control effect on other major sucking and leaf chewing pests in the Uganda cotton systems. These include aphids, Lygus and Stainers, *Dysdercus* spp, (Serunjogi *et al.*, 2000). There is therefore a need for biotech research to look more widely for non-Cry genes for wider pest control. There is also a need for incorporating into the biotech research programme other components of Integrated Pest Management (IPM) and Integrated Weed Management (IWM) based on biological and cultural control methods. In essence, biotech research should be addressed by researchers as a component of the IPM and IWM strategy, and not as a “magic bullet” (ICAC, 2004). Further, future biotech research should include those on options for the control of diseases and nematodes.

4.2.4 Research Limitations due to the Nature of the Cotton Fiber

It would be desirable to extend the biotech cotton research to the improvement of the most important product of cotton, the lint. Biotech research efforts towards modifying cotton fiber quality on traits like fiber length, micronaire, colour and strength are under way. Progress is, however. hampered by the biological nature of the cotton fiber. Since the cotton fiber is a single cell, it has been difficult to modify it with functional substances. Further, disruption of the cotton's crystalline cellulose structure could compromise the quality parameters that confer desirable traits on the textile fiber.

4.3 Capacity Building for Biotech Research and Funding

Biotech research for the development of appropriate tools and their use in exploiting traits in various organisms for the benefit of mankind requires appropriate capacities in a range of connected institutions. Lack of adequate institutional capacity would limit research and technological development. The areas of limitation include:

4.3.1 Trained Staff and Infrastructure

Trained research scientists and technical teams are a prerequisite for a successful biotech research programme. The bio-physical scientists need skills in procedures and protocols for laboratory and field experimentation. Further, technical teams comprising bio-physical and social scientists are essential to train the farmers /biotech product end users. The technical teams are also needed to monitor and evaluate technology adoption issues for the planning of future research. The trained scientists need to have in place investments in infrastructure, facilities and supplies such as laboratories, glass/green houses, field and laboratory equipment, laboratory reagents and field chemicals, and application equipment. Additionally, the teams need logistical support for transport and communication. In countries with still developing economies, the costs for staff training and infrastructure are prohibitive. Solutions could be produced by the development of international or regional co-operations/networks which can enable sharing of resources for laboratories and personnel (Serunjogi, 2004).

4.3.2 Development of Policies and Regulatory Legal Framework including IPR Issues

Conducive policies and legal regulatory framework in biotechnology research and use are a requirement to assess biotech risks to health and the environment. The individual countries or regions also need them in developing, testing, applying and protecting biotechnological innovations. Lack of policies and frameworks would limit biotech research and application (Serunjogi, 2004 and Raney, 2006). The following issues are noted:

- The pace of development of policies and associated legal aspects may be delayed due to biased perception of policy makers on biotechnology. This becomes an impediment to the well-intentioned researchers in initiating research programmes or in collaborating with international laboratories.
- There are, though, a number of guidelines and options on the formulation of policies and regulations on biotechnology (Serunjogi, 2004). For example, there are international treaties and conventions which if a country is party to, could be ratified for preliminary use before being fully domesticated into national laws. These include *inter alia*, the United Nations Convention on Biodiversity (1992) and the Cartagena Protocol (2004) on biosafety. There are also examples of regional guidelines for countries intending to formulate bio-safety regulations, e.g.., the OAU (now African Union) Model on Biotech Regulations (OAU 2001).

- Intellectual Property (IP) management policies are essential at institutional and national levels for providing effective negotiations on appropriate use of biotech innovations by needy laboratories and for protecting the resultant technologies (Erbisch and Meridia, 2003).
- The formulation and implementation of the regulatory and IPR policies and their enactment into legal frameworks requires time consuming and costly inputs by multidisciplinary teams. Additionally, implementation requires creation of offices that will oversee, among others, biosafety regulations and intellectual property. All these have cost implications which pause limitations to biotech research in some developing countries.

4.4 Limitations to Biotech Research Due to Cost Implications

Sectors which are prerequisites for successful biotech research programmes require costly investments. In addition to costs on the training of the research scientists and putting in place conductive research facilities, costs are incurred in:

- development of biotech research within a national or private sector research agenda and implementation;
- development and institutionalization of biosafety regulations, intellectual property management policies and operationalisation under national laws and appropriate offices; and
- payment of technology fees and royalties in lieu of Intellectual Property Rights (IPR) to technology providers.
- The high costs of biotech research become prohibitive to individual research laboratories and a drawback to policy makers, in cases of publicly funded research. Additionally, the above costs *inter alia* tend to become built into the costs of the resultant biotech research products and could affect the rate of adoption of the technologies, especially in the small-scale and low-input farming systems in developing countries. Roney (2006) discussed the implications of these issues in developing countries.

5. Conclusion

The limitations to biotech cotton research are many, their magnitudes varying with the level of development on cotton/biotech research in a given country or firm. An influencing factor is the source of research support, whether through public or private sector funding. Some suggestions to alleviate this include *inter alia*:

- conducive collaborations between the public and private sectors on funding and technical issues and
- regional co-operation on research material exchange and on formulation of biosafety regulatory systems

International or regional co-operations/networks enable sharing of resources for genetic material exchange, laboratories, personnel and for formulation and implementation of regulatory frameworks. For example, the East African Regional Program and Research Network for biotechnology, biosafety and biotechnology policy development (BIO-EARN) has been guiding processes of developing biotech regulations in the East African countries of Ehtiopia, Kenya, Tanzania and Uganda (Anon, 2003). Further efforts under the planned creation of the East African Federation have seen to a creation of an East African Community Partner States' Technical Committee of Experts. The Committee is charged with the development of a harmonized EA regional policy, and legal and regulatory framework on biotechnology (Anon, 2006).

References

Anon 2006. East African Community Consultative Workshop for Development of A Regional Biosafety Policy. In Bio Vision Newsletter Vol 2, September 2006. Uganda National Council of Science and Technology. www.biovision.

Anon 2003. BIO-EARN. Biotechnology for development. A presentation of the East African Regional Program and Research Network for Biotechnology, Biosafety and Biotechnology Policy Development. Stockholm Environment Institute.

Cartagena Protocol on Biosafety, status of ratification and entry into force, 2004

Chaporkar, C.B.2007.GM Cotton Experience in India Maharashtra Hybrid Seeds Company. In proceedings of the Zimbabwe National Cotton Association Biotech Cotton consultative workshop. Herare, 08 Feb 2007. Theme; Poverty Alleviation. Increased Cotton Production Through New Cotton Seed Technologies.

CIRAD (2004). The role of public research in biotechnology for plant improvement CIRAD's standpoint.

Erbisch, F.N. and Maredia, K.M 2003. Intellectual Property Rights in Agricultural Biotechnology, 2nd Edn Biotechnology in Agricultural Series No. 28, CABI Publishing ISBN 0-85199-739-2

Garwe.D.2007.GMOs and the Environment in proceedings of the Zimbabwe National Cotton Association Biotech Cotton consultative workshop. Harare, 08 Feb 2007. Theme; poverty Alleviation. Increased cotton production through new cotton Seed Technologies.

ICAC 2006(C) Herbicide Resistant Biotech cotton. The ICAC Recorder Vol XXIV No .3 September 2006 .The International cotton Advisory committee

ICAC 2004. A report of second Expert Panel on Biotechnology of Cotton.International Cotton Advisory Committee November 2004.

ICAC, 2002.Commonly Asked questions about Transgenic cotton. The ICAC Recorder Vol XX No.2 June 2002.

ICAC 2000. Report of the Expert panel on Biotechnology in cotton. International Cotton Advisory committee November 2000

Kater Hake.2003.Cotton biotechnology; Beyond Bt and herbicide tolerance. In Proceeding World Cotton Research Conference-3, 9-13 march 2003, RSA (Ed) Swanepoel, A.pp 384-391

Khadi B.M,Kulkarni ,V.N,Kategeri,I.S, Vamaclevaiah,H.M,and Manjula Maralappanavar 2003.

Strength,Weakness,Opportunities and threats (SWOT) analysis of Bt cotton in India. In processing of the World Cotton Research Conference 3,9-13 march 2003 Cape Town RSA (ED)Swanepoel A.pp 394 -401

McNaughton C, and Rey M.E.C.2000. Development of an Efficient Regeneration and Transformation System for commercially Grown South African cotton cultivars. In proceedings of the World Cotton Research Conference-2 Athens Greece September 6-12 1998,(ED) Fred M. Gillham. Vol. 1 pp.304-306

Monsanto, 2004. Safety assessment of Roundup Ready (R) Cotton Event 1445, September 2002. http://www.monsanto.com/manosanto/content/scitech/prod.

Neal P. Gillen 2002. Impact of Transgenic Cotton on the International Cotton Trade. In papers presented to the Technical Seminar and Meeting Committee on Cotton Production Research "The 21st Century Cotton Industry: Growth Through Private Investment".The 61st Plenary Meeting of ICAC, Cairo Egypt October 2002.

Organisation of African Unity (OAU 2001). The OAU Draft Model Legislation on Safety in Biotechnology.

Pellow, J. Huang, X., Anderson, D., and Meade, T 2002. Novel insect Resistance Traits from DOW Agrosciences. Proceedings of the Beltwide Cotton Conference 2002.

Perlak, F..J., Deaton, R.W., Armstrong, T.M., Funhs, R.L., Sims, S.R., Greenplate,J.T, and Fishaff, D.A 1990. Insect Resistant Cotton Plants Biotechnology 8 939-943.

Serunjogi 2004. Why Fear Biotechnology. In papers presented at the Technical Seminar at the 63rd plenary meeting of the International Cotton Advisory Committee. Mumbai India, November 2004.How to Improve Yields and reduce pesticide use pp 21-26.

Shot'koski, F., Chen, E., Mascarenhas, V.J., and Boykin, R. 2003. VIP. A. novel insecticidal protein with broad spectrum Lepidopteran activity. Proceedings of the Beltwide Conference 2003. pp 89-93.

Terry Raney 2006.Economic impact of Transgenic crops in Developing countries. In current Opinion in Biotechnology 17,1-5. A themed issue on plant Biotechnology.(Edit) Nam-Hai Chua and Scott.V. Tingery.Elsiwvier Ltd.

Umbeck, Dr F, Johnson, G, Barton, K.A. and Swain, W.F.1987. Genetically transformed Cotton (Gossypium hirsutum L.) Plants.Bio/ Technology, 5:263-266

Zeweldu,T. 2006. Potentials of Biotech for Economic Development. Bio-vision Newsletter. June, 2006.Uganda National Council of Science and Technology www.uncst.go.ug

9. Biotechnology Research: Investing for the Future

Marc Giband
CIRAD (France)
EMBRAPA Algodão, Brazil

A decade after their commercial introduction in 1996, transgenic cotton varieties (also referred to as genetically modified – GM or biotech cotton) were grown on 13.4 million hectares in nine countries in 2006 (C. James, ISAAA, 2006). These figures do illustrate the great success of these varieties, and their appeal to cotton farmers worldwide. Nevertheless, a look at available figures may show that the potential of biotech cotton has not been delivered to all producers, including small-scale farmers, who could benefit from the technology.

Investing in biotech cotton …
Cotton is grown in more than 80 countries worldwide, only nine of which are growing biotech varieties on a commercial scale. Even though a number of other countries are experimenting on GM varieties and will probably be releasing them for commercial purposes in the near future, the percentage of countries actually growing GM varieties on a large scale is still low. Hurdles of different nature have been impeding the larger diffusion of the technology. Among these are legal, technical, and sometimes commercial considerations. Support to countries, which do not yet have a legal framework for the deployment of biotech cotton, in developing and adequately implementing such a framework would undoubtedly help in diffusing the technology. Similarly, help in training personnel in risk and economic assessment of GM cotton would allow an enlightened choice towards the acceptance of these varieties.

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

Of the nine countries that presently grow biotech cotton on a commercial scale, only three (the United States, Australia and South Africa) have approved both available traits, i.e. insect resistance and herbicide tolerance (and the combination thereof). All other countries only grow insect-resistant varieties, and in most cases, only a single “first-generation” (single gene) event is available. This limited offer does not always respond to the needs of cotton farmers who are faced with a larger panel of constraints. Newer events represent an advance over older ones in that they offer better pest control or allow a more flexible crop management.

A wider diffusion of presently available biotech cotton events, and the development and adoption of cultural practices better taking into account the local environments would probably allow more cotton farmers to make the best of GM varieties.

In addition to insect and weed control that are targeted by the presently available GM varieties, abiotic stresses are among some of the limiting factors that many cotton growers have to face, more so by the small-scale farmers in developing countries. It is hoped that future biotech varieties will target these more complex constraints that are faced by cotton growers. Resistance or tolerance to abiotic stresses generally involves mechanisms that are under a more complex genetic control, which make such a trait more difficult to achieve through a transgenic approach. Even though some progress is being made in this area, the availability to farmers of GM varieties with improved stress resistance or tolerance is still a future goal.

Present 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 the growers. Industry will primarily target solvable markets and traits of global interest, where they can expect a return on their substantial investments 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 to by the private sector. The strengthening of the local public sector is seen as a means of satisfying local needs, but experience seems to indicate that this goal may be difficult to meet in many cases. The question then remains of how to attend to these local needs in the short- to medium-term.

... and in cotton biotech

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 the 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 fibre 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 tap 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 the developers of GM varieties.

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

10. The Leaf Curl Epidemics: the Situation with Cotton Leaf Curl Disease

Rob W. Briddon
Plant Biotechnology Division, National Institute for Biotechnology and Genetic Engineering, Pakistan

Cotton leaf curl disease (CLCuD) is a whitefly (*Bemisia tabaci*) transmitted disorder of several malvaceous hosts, of which cotton is the most important. CLCuD is endemic across most of Pakistan and north-western India. The disease is also reported from Egypt, the Sudan, Nigeria, Malawi and South Africa. Affected plants exhibit characteristic symptoms like 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 between cotton varieties and also upon the age of the plant at the time of infection. Plants infected late in the season show only mild symptoms and do not suffer a significant yield reduction, whereas plants infected early are severely stunted, with tightly rolled leaves, and usually yield no harvestable lint.

Cotton is the main foreign exchange earner of Pakistan and production suffered heavily from an epidemic of CLCuD which initiated in the vicinity of the city of Multan in the mid 1980s and spread to virtually all cotton growing areas, as well as into western India. Altough the disease was noted infrequently across the Indian subcontinent prior to the 1980s, it was only a minor sporadic problem. The introduction and widespread use of high yielding, but also highly susceptible, cotton varieties such as S-12 and CIM70 has been suggested as the main factor in pushing this minor nuisance into an epidemic problem. *Gossypium arboreum*, the cotton species native to this region, is immune to CLCuD. Grown on a small-scale, it does not produce the high grade cotton lint desired by industry. 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. Cotton production was again at record levels by the late 1990s, exceeding the output prior to the epidemic. In 2001, there was a change in the prevalent virus population affecting cotton in Pakistan. Previously resistant cotton varieties began to show the typical symptoms of CLCuD infection, signalling a second, resistance-breaking wave of the CLCuD epidemic. This initiated in the vicinity of the town of Burewala (Punjab, Pakistan) and has since spread to most cotton growing areas of Pakistan and into India.

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 (Figure 2). Invariably, begomovirus-DNA β infections of cotton are also associated with a third component, known as DNA-1. This is a satellite-like molecule that plays no essential part in the aetiology of CLCuD (Mansoor *et al.*, 1999; Briddon *et al.*, 2004).

Figure 1. Typical symptoms of a cotton leaf curl affected cotton (*Gossypium hirsutum*). The leaves are curled (either upwards or downwards), have swollen and darkened veins, with enations that frequently develop cup-shaped, leaf-like structures.

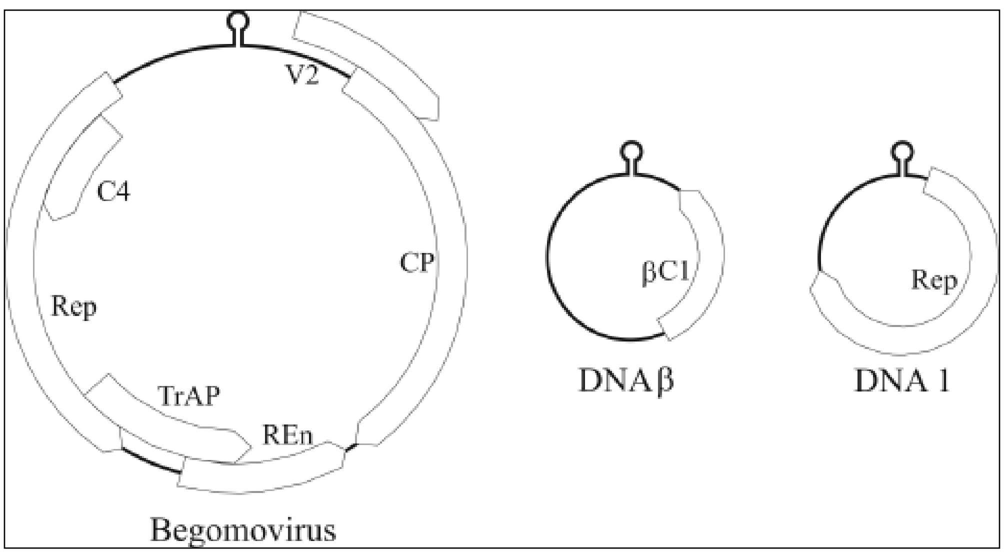


Figure 2. The components of the cotton leaf curl disease complex. Shown is the typical genome arrangement of a monopartite begomovirus, the DNA β and the associated DNA 1. The position and orientation of encoded genes are shown as arrows. These are the replication associated gene (Rep), the transcriptional activator (TrAP), the replication enhancer (REn), the coat protein (CP) and the βC1 gene. The functions of genes labelled as V2 and C4 remain unclear. The position of a stem loop structure, which marks the origin of virion-strand DNA replication for geminiviruses, conserved between these three components is shown at the top of each circle.

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 (Mansoor *et al.*, 2003). A further begomovirus species, Cotton leaf curl Bangalore virus, has been isolated from CLCuD-affected *G. barbadense* in southern India (Chowda Reddy *et al.*, 2005). It is unlikely that this virus is involved in causing disease in the epidemic areas of northern Indian, although the precise geographic distribution of this virus has not yet been determined. The Burewala strain has thus far been shown to be associated with one begomovirus, a recombinant derived from CLCuMV and CLCuKV (tentatively named Cotton leaf curl Burewala virus; L. Amrao, manuscript in preparation), although there is mounting evidence to suggest that further viruses are being drawn into the epidemic.

The DNA β molecules are a recently identified group of symptom modulating, single-stranded DNA satellites that are associated with monopartite begomoviruses and occur only in the Old World. Since their identification in 2000, over 200 full-length DNA β sequences have been deposited with the databases (Briddon and Stanley, 2006). They have a highly conserved structure, being approximately half the size of their helper begomoviruses (~1370 nucleotides), encoding a single gene (known as βC1; Figure 2). This gene encodes a protein which is the major pathogenicity determinant of the complex. Constitutive expression of CLCuD βC1 in *Nicotiana benthamiana* leads to grossly deformed plants exhibiting virus-like symptoms consisting of swollen veins and occasional enations (Saeed *et al.*, 2004). Expression of the gene from a Potato virus X vector, in either *N. benthamiana* or *N. tabacum*, induces symptoms indistinguishable from CLCuD in these hosts, including vein swelling, vein darkening, enations and the characteristic leaf-like outgrowths (Qazi *et al.*, 2007). This indicates that βC1 is capable of inducing the 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 (Cui *et al.*, 2005).

The Multan strain of CLCuD was associated with only a single type DNA β (the CLCuD DNA β), despite the disease being 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 tomato leaf curl disease associated DNA β (Amin *et al.*, 2006). The significance of this is unclear.

Natural host plant resistance to CLCuD in cotton was the major factor in overcoming the devastating losses to 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. A broad-spectrum resistance, which is effective against all the viruses present in the field, is required if the approach is to stand any chance of durability. 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 plants' own defences to target the invading virus. The one "target" present in all CLCuD-affected plants is CLCuD DNA β, and initial studies attempted to induce PTGS/TGS against this molecule, with little success. Efforts that have targeted 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 have shown more promise (Asad *et al.*, 2003; Mubin *et al.*, 2007; Sanjaya *et al.*, 2005). Both these strategies are presently being assessed for effectiveness and durability in cotton under field conditions to determine whether the sequences being used provide a sufficiently broad-spectrum resistance to all the CLCuD-associated begomoviruses.

References

Amin, I., Mansoor, S., Amrao, L., Hussain, M., Irum, S., Zafar, Y., Bull, S.E., and Briddon, R.W. (2006). Mobilisation into cotton and spread of a recombinant cotton leaf curl disease satellite. Archives of Virology 151, 2055-2065.

Asad, S., Haris, W.A.A., Bashir, A., Zafar, Y., Malik, K.A., Malik, M.N., and Lichtenstein, C. P. (2003). Transgenic tobacco expressing geminiviral RNAs are resistant to the serious viral pathogen causing cotton leaf curl disease. Archives of Virology 148, 2341-2352.

Briddon, R.W., Bull, S.E., Amin, I., Mansoor, S., Bedford, I.D., Rishi, N., Siwatch, S.S., Zafar, M. Y., Abdel-Salam, A. M., and Markham, P. G. (2004). Diversity of DNA 1; a satellite-like molecule associated with monopartite begomovirus-DNA β complexes. Virology 324, 462-474.

Briddon, R.W., and Stanley, J. (2006). Sub-viral agents associated with plant-infecting single-stranded DNA viruses. Virology 344, 198-210.

Chowda Reddy, R.V., Muniyappa, V., Colvin, J., and Seal, S. (2005). A new begomovirus isolated from *Gossypium barbadense* in Southern India. New Disease Reports [http://www.bspp.org.uk/ndr/] Volume 10.

Cui, X., Li, G., Wang, D., Hu, D., and Zhou, X. (2005). A begomovirus DNA β-encoded protein binds DNA, functions as a suppressor of RNA silencing, and targets the cell nucleus. Journal of Virology 79, 10764-10775.

Mansoor, S., Briddon, R. W., Bull, S.E., Bedford, I. D., Bashir, A., Hussain, M., Saeed, Zafar, M.Y., Malik, K. A., Fauquet, C., and Markham, P.G. (2003). Cotton leaf curl disease is associated with multiple monopartite begomoviruses supported by single DNA β. Archives of Virology 148, 1969-1986.

Mansoor, S., Khan, S. H., Bashir, A., Saeed, M., Zafar, Y., Malik, K. A., Briddon, R.W., Stanley, J., and Markham, P.G. (1999). Identification of a novel circular single-stranded DNA associated with cotton leaf curl disease in Pakistan. Virology 259, 190-199.

Mubin, M., Mansoor, S., Hussain, M., and Zafar, Y. (2007). Silencing of AV2 gene by antisense RNA protect transgenic plants against a bipartite begomovirus Virology Journal 4: 10.

Qazi, J., Amin, I., Mansoor, S., Iqbal, J., and Briddon, RW. (2007). Contribution of the satellite encoded gene βC1 to cotton leaf curl disease symptoms. Virus Research, in press.

Saeed, M., Behjatnia, S.A.A., Mansoor, S., Zafar, Y., Hasnain, S., and Rezaian, M.A. (2004). A single complementary-sense transcript of a geminiviral DNA β satellite is determinant of pathogenicity. Molecular Plant-Microbe Interactions 18, 7-14.

Sanjaya, Satyavathi, V. V., Prasad, V., Kirthi, N., Maiya, S. P., Savithri, H. S., and Lakshmi Sita, G. (2005). Development of cotton transgenics with antisense AV2 gene for resistance against cotton leaf curl virus (CLCuD) via *Agrobacterium tumefaciens*. Plant Cell, Tissue and Organ Culture 81, 55-63.

11. Science Communication and Technology Acceptance

Claudia Canales
International Service for the Acquisition of Agri-Biotech Applications- ISAAA

Modern Biotechnology: a New Tool in the Box

The improvement of the genetic make-up of crops to enhance their agronomic qualities and performance is as old as agriculture itself. Farmers have traditionally crossed their crops to related species harboring desired traits, and have selected among the progeny the plants which better suited their needs.

The development of modern biotechnology techniques, specifically of genetic engineering (GE), has lend breeders a new, powerful tool to accomplish this task, as it allows to precisely identify the genes responsible for a trait, and to transfer these into crops. Unlike conventional breeding, only the desired genes are incorporated into the target crop, and due to the universality of the genetic code, the source of genes for improvement is not limited to related species.

Although not a replacement of conventional breeding methods, GE may provide a better solution, in specific circumstances, to agricultural constraints such as pests, diseases and adverse environmental conditions. At the same, GE is also a highly controversial technology as it generates public concerns that fall both within and outside the scientific domain. Ultimately, the success of any new technology and its products depends on whether these are adopted by the intended users: farmers and consumers in the case of genetically modified (GM) crops.

Science Communication and Technology Acceptance

Effective science communication is an essential part of technology acceptance. However, communication does not, and should not, necessarily equate to the blanket acceptance of new technologies. The notion that public rejection of scientific advances is the result of ignorance and simple lack of information (known as the 'knowledge deficit model') has not only been proven to be erroneous, it has also often negatively influenced the adoption of innovation (Hornig Priest, 2001). Effective science communication is nevertheless indispensable to promote an open and transparent debate about the potential benefits, and also potential risks, of new technologies on a case-by-case basis. This debate is central to ensure the responsible adoption of novel technologies, and to guarantee that users have a genuine choice.

Learning the Hard Way: the EU GM Debate

What can we learn from the GM debate in the European Union (EU) regarding science communication? The debate provides a good example of an ineffective science communication effort. The controversies surrounding GM foods in Europe were preceded by a number of food scare incidents (the most infamous of which is perhaps mad cow disease-BSE), which had undermined public trust in the public institutions meant to protect consumers. In this climate of distrust, a scientist, Árpád Pusztai, claimed in the UK media in 1998 and in early 1999 that feeding GM potatoes to rats harmed their health. Importantly, the results had not at that stage, been peer-reviewed and accepted for publication in a scientific journal, a standard scientific procedure to ensure quality in research. Nonetheless, the reaction of the press was huge. A sample of titles of newspaper articles on that incident is presented below (from Burke, 2004).

"Lifting the lid on the horror of GM foods" - The Express
"The GM pollen that can mean a cloud of death for butterflies" - Daily Mail
"GM risk in daily food of millions" - Guardian
"GM food threatens the planet" - Observer
"Scientists warn of GM crops link to meningitis" - Daily Mail
"Meat may be tainted by Frankenstein food" - Daily Mail

A series of scientific initiatives were subsequently carried out in the UK to address public concerns regarding several aspects of GM foods. These included a Panel Review of toxicologists commissioned by the Royal Society which analyzed Pusztai's data and invalidated the claims of the research (1999); the Farm Scale evaluations of GM beet, oil seed and maize (Firbank, 2003); the Advisory Committee on Releases on the Environment Report (ACRE, 2004); the Report on the scientific, social and ethical implications of GM crops (UK Agricultural, Environmental and Biotechnology Commission); and the British Medical Association (BMA) Report on GM Food and Health (2004). The BMA concluded that there was "no robust evidence that GM food is unsafe, and GM foods have enormous potential to benefit developed and developing countries". However, these initiatives did little to significantly change the tone of media coverage on the GM food in the UK.

Interestingly, a survey of public opinion on GM foods in the UK revealed that 74 percent of consumers were not sufficiently concerned about GM foods to actively avoid buying these (Consumer Watch, 2003). The majority of the public was therefore unconvinced about the advantages of GM technology. The decisive influence in the GM debate was therefore of the media and of opinion groups. One should perhaps also not forget that the media reported on the information that was most accessible to them, and that the reaction of scientists was often late and defensive.

The implications of the GM debate are vast. In the EU, it led to a six years *de facto* moratorium on GM foods (1998-2004); it affected the level of 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 GMs in developing countries was also affected; it raised international trade issues and market acceptance issues for those countries which trade with the EU; and importantly, it has greatly increased the costs of research and regulatory approvals which, especially in developing countries, has a much greater impact on national public research institutions operating with very limited funds than on large multinational companies. The debate has had therefore a very significant, direct effect on the adoption of the technology world-wide.

Public Perception on Biotechnology

The GM debate brought up a series of existing public concerns, an indication of the fact that the public and scientists operate under different value systems, and perceive risk in a very different way. Key factors influencing public perception of risk include: the perceived level of personal control (voluntary risks are usually better accepted than involuntary risks, like smoking); the degree of participation in the decision process; the availability of adequate information; considerations of the benefits to be derived; concepts of fairness such as the distribution of benefits, food security and monopoly by industry; and catastrophic potential, especially with regard to children and future generations.

Issues falling outside the scientific domain, such as ethical values, like the notions of "meddling with God" and "interfering with Nature", play a very important part in technology acceptance, and should therefore be duly considered. A survey on the language used in news articles on biotechnology revealed that about one quarter of media articles also contain the words "nature" and "natural", and that in media reports against the technology these words are often associated with words such as "meddling", "tinkering", "interfering", "messing", and "playing God games" (Hansen, 2006). The word "Nature", defined by Williams (1983) as "perhaps the most complex word in the language", has been endowed with many contrasting meanings and values. Two of the most powerful ones are Nature as something pure and fragile that should be protected from contamination and from human interference; and Nature as a powerful and vengeful force that will strike back if the balance is upset. These values are deeply engrained in our culture, and they are not new.

On Biotechnology and Other Monsters

GM foods owe their descriptions as "Frankenstein Foods" or "Frankenfoods" to the famous work of fiction by Mary Shelley (1818). Frankenstein, the scientist that created a living being out of dead human body parts in an attempt to defeat death - with terrible consequences, and his monster, have held a tight grip on human imagination for almost two centuries. Shelley called her creation the "modern Prometheus", a titan from ancient Greek mythology who enraged the gods by stealing the fire from them to hand it to humans for their warmth and protection. As a punishment, Prometheus was chained to a rock, and an eagle came to feed on his liver for eternity. If Frankenstein is no spring chicken (with 189 years of age), Prometheus is over two millennia his senior.

Shelley was influenced in her work by the scientific advancements of her time. During the early 1800s, scientists learned about the electric basis of the nervous system (galvanization experiments), anatomy studies were improving our knowledge of the human body, and the first successful human blood transfusions were carried out. Although blood transfusions are now a standard medical procedure, and one that is responsible for saving countless lives, this was not an innovation devoid of controversies and concerns at first. Innovation and scientific progress change the way we live, and they also inevitably carry a degree of uncertainty and risk. Therefore, innovation always generates concerns, and scientists have a social and moral duty to address these.

Principles of Effective Science Communication

Effective science communication is not a linear flow of information from the scientists to the public. "Science's new social contract with society" involves the inclusion of experts in the social sciences, and the participation of all interested groups, both essential for the development of "socially robust knowledge" (Gibbons, 1999).

A number of principles for effective science communication have been identified (Borchelt, 2001). Instead of providing only what the public "needs" to know, science communicators should identify what the public "wants" to know, and make this information available in a clear and accessible format. Communication should also be a rigorous discipline that is incorporated in the scientific process from the start, rather than an optional after-thought of research funded by separate sources than the research itself, as often is the case now. As the general public is very heterogeneous in interests, level of knowledge and concerns, communication should also always have an intended audience, as the "one-size-fits-it-all" message usually does not address very well any of the different stakeholders. Finally, science communication messages should be pro-active and positive, rather than reactive and defensive, as once public perception has been modeled in a specific way, it is very difficult to modify it, as the EU GM debate illustrates very clearly. A useful strategy for science communication is to develop a "message map", a tool for organizing information in a transparent manner, thereby promoting the exchange of information and open dialogue.

Science Communication and the Media

For the majority of people, the main exposure to science developments after formal education occurs mainly, if not exclusively, through the media. The media plays, therefore, an essential role in science communication, as it represents the bridge between scientists and the public. The relationship between scientists and journalists is, however, not an easy one.

The main barrier to effective communication between scientists and journalists is language, as science has evolved during the last century in a way as to require a highly specialized, technical vocabulary. Messages for the media must however be presented in simple terms, avoiding jargon and unnecessary details. Other challenges include the fact that most science journalists have not had specific training in sciences, which can lead to mistakes, over-simplification, or to out of context references, especially in cases when the original message lacks clarity. Scientists also sometimes fear losing control over the outcome of their interaction with the media ("news stories with legs"), which may result in damaging publicity for the scientist. An additional difficulty in science reporting is that the media prefers to cover stories with "news" value, rather than to follow up on the developments of a research. Human value, drama and scandal are also very valuable for the media, and these are not always harmoniously paired with science reporting.

However, it is important to realize that the media responds to public demand, and that journalists have to work under a specific set of conditions. As scientists will not change the way the media functions, they must learn to understand it better, and to work with it more effectively and to their advantage. Ultimately, scientists must fully embrace their responsibility to communicate, and they must do so with the means that are available to them.

References

ACRE (2004). Advice on the implications of the farm-scale evaluations of genetically modified herbicide-tolerant crops. www.defra.gov.uk/environment/acre/fse

BMA (2004). Genetically modified foods and health: a second interim statement. www.bma.org.uk/GMFoods

Borchelt, R. E. (2001). Communicating the Future: Report of the Research Roadmap Panel for Public Communication of Science and Technology in the Twenty-First Century. Science Communication 23: 194-211.

Burke, D. (2004). GM food and crops: what went wrong in the UK? EMBO reports 5: 432-436.

Firbank, L.G. (2003). The Farm Scale Evaluations of spring-sown genetically modified crops. Phil Trans R Soc Lond B 358: 1777–1778.

Gibbons, M. (1999). Science's new social contract with society. Nature 402: C81.

Hansen, A. (2006). Tampering with nature: 'nature' and the 'natural' in media coverage of genetics and biotechnology. Media Culture Society 28: 811-834.

Hornig, Priest S. (2001). Misplaced Faith: Communication Variables as Predictors of Encouragement for Biotechnology Development. Science Communication 23: 97-110.

Royal Society. (1999). Review of data on possible toxicity of GM potatoes. www.royalsoc.ac.uk/gmplants.

Williams, R. (1983) Keywords: A Vocabulary of Culture and Society. London: Flamingo/Fontana.

12. Development of Transgenic Bt Cotton in China and its Implications for IPM

Jingyuan Xia
National Agro-Tech Extension & Service Center (NATESC),
Ministry of Agriculture (MOA), No 20 Mai Zi Dian Street,
100026 Beijing, China (Mainland)

China is the largest cotton producer in the world with about 4.5 million tons of lint produced annually, accounting for over 20 percent of the world's total production. Damage from pests is one of the major limiting factors for cotton production in the country, where over 100 pest species have been recorded to attack cotton. The key pests are seedling diseases, boll diseases, Fusarium wilt, Verticillium wilt, cotton aphid, red spider mites, cotton bollworm and pink bollworm. The yield losses due to damage from these pests are estimated to be 10-15 percent of the potential production, and even up to 30 percent upon their outbreaks.

Chemical control is one of the major measures for cotton pest management. The heavy dependence on the application of pesticides has resulted in the serious problem of "3R" (resistance, resurgence and residues). Breeding the host-plant resistance has therefore been considered the most effective and economic approach for control of cotton pests. However, the development of an ideal cultivar for production through conventional breeding is a slow process. Biotechnology has been thought the most efficient way to breed crop varieties highly resistant to target pests. In the 1980s, scientists from the United States successfully inserted the foreign Bt toxin gene into cotton and bred several cotton cultivars with that gene. The new cultivar showed a high resistance to lepidopterous pests in transgenic plants, especially to cotton bollworms. Soon after that, the Chinese scientists followed this new research trend and made a milestone progress in this field.

So far, several gene constructs have been constructed, such as the single gene (Bt), the double genes (Bt+CpTI), and the tribal genes (Bt+CpTI +Go, Bt+CpTI+GNA, Bt+CpTI+herbicide resistance, Bt+CpTI+male sterile). Three methods for genetic transformation have been applied, including Agrobacterium, pollen-tube path way and gene gun, with the transforming efficiency of 5, 2 and 8 percent, respectively. Over 20 Bt cotton cultivars have been released for production, and their acreage reached 3.2 million hectares in 2006 or 2/3 of the nation's total.

Bt cotton shows high resistance to lepidopterous pests (especially to bollworms), but not to sucking pests such as cotton aphid, red spider mites and others. Transgenic cotton increases the abundance of predator populations and decreases that of parasitoid ones. The Bt cotton-based IPM system has been established, with bio-ecological regulation at the early and the late seasons, and the chemical control at the mid season. The monitoring system for Bt toxin resistance has also been established, including the screening procedures in labs and field testing. Monitoring results show that there is a high potential for the cotton bollworm to develop resistance to Bt toxin in the lab, although so far, no resistance has been detected in the field.

The adoption of transgenic Bt cotton has brought about significant economic, social and ecological benefits. In terms of economic benefit, the value from savings from insecticide application amounts to US$120-150/ha, and the value from increased yields is US$150-200/ha. In terms of the social benefit, the labor-hand is decreased by 20-30 percent and the poisoning incidences due to spraying has decreased by over 90 percent. In terms of the ecological benefit, the abundance of beneficial species has increased by 20-40 percent. Thanks to adoption of the transgenic cotton, cotton production has been stabilized, the varietal structure has been optimized, and market competitiveness has been enhanced.

Improvements in Bt cotton in future research activities should focus on increasing resistance with time and tissue specification. The application should be more emphasized on the establishment of an efficient system for Bt toxin resistance management.

13. Bt Cotton Adoption in India

B. M. Khadi, Director
Central Institute for Cotton Research,
Indian Council of Agricultural Research, India

Introduction

Cotton is an important fibre crop of global significance, cultivated in tropical and sub-tropical regions of more than 70 countries the world over. The major producers of cotton are the United States, China, India, Pakistan, Uzbekistan, Argentina, Australia, Greece, Brazil, Mexico and Turkey. These countries contribute about 85 percent of the global cotton production. India has the largest area (9.1 m. ha) under cotton at the global level, produces 503 kg lint /ha and ranks second in production (4.59 mt) after China during 2006-07.

Cotton plays a key role in the Indian economy in terms of generation of direct and indirect employment in the agricultural and industrial sectors. Textiles and related exports, of which cotton constitutes nearly 65 percent, account for nearly 33 percent of the total foreign exchange earnings of India which at present is around US$ 17 billion with a potential for a significant increase in the coming year. The textile industry is the second largest employment generator after agriculture. At present, cotton provides nearly 65 percent of raw cotton material to the textile industry.

The textile policy of 2000 aims at achieving the target of textile and apparel exports of US$ 50 billion by 2010 of which the share of garments will be US$ 25 billion. Consequently, the demand for cotton is likely to increase in the coming decades in respect of internal consumption, as well as to meet the targeted export demand. This will require concerted research, development and extension efforts to make Indian cotton internationally competitive in terms of quantum and quality.

The elimination of quota restrictions has opened the way for the most competitive developing countries to develop stronger clusters of textile expertise, enabling them to handle all stages of the production chain from growing natural fibres to producing finished clothing.

A Vision 2010 for textiles formulated by the government after intensive interaction with the industry and export promotion councils aims to increase India's share in the world textile trade from the current 4-8 percent and to achieve export value of US$ 50 billion by 2010. Vision 2010 for textiles envisages growth in Indian textile economy from the current US$ 37 billion to US$ 85 billion by 2010, creation of 12 million new jobs in the textile sector, and modernization and consolidation for a globally competitive textile industry.

Cotton cultivation in India

Cotton is cultivated in three distinct agro-ecological regions (north, central and south) of the country. The northern zone is almost entirely irrigated, while the percentage of irrigated area is much lower in the central and southern zones. The central zone has the lowest percentage of land under irrigation and accounts for nearly 60 percent of the country's cotton area (Table 1).

Table 1. Cotton profile

Zones	Irrigated	Rainfed
North Zone	100 % *G. hirsutum, arboreum* *Intra hirsutum* hybrids & Diploid hybrids	-
Central Zone	23% *Intra hirsutum* hybrids *G. hirsutum*	77% *G. herbaceum, G. arboreum, G. hirsutum, Intra hirsutum* hybrids, Diploid hybrids
South Zone	40% *Intra hirsutum* hybrids Inter specific hybrids (H x B) *G. hirsutum* *G.barbedense*	60% *G. herbaceum* *G. arboreum* *Intra hirsutum* hybrids *Inter specific* hybrids (H x B) Diploid hybrids

Under the rainfed growing conditions, rainfall ranges from <400 to > 900 mm. Coupled with aberrant precipitation patterns over the years, this leads to large-scale fluctuations in production. In the irrigated systems, tract canal, well irrigation and micro-irrigation systems are employed.

The **northern zone** comprises Punjab, Haryana and parts of Rajasthan and UP. The region is known for growing *hirsutum-arboreum* type of cottons under irrigated conditions on alluvial and sandy soils. After the introduction of Bt cotton, farmers have extensively cultivated intra-hirsutum Bt cottons. This zone has the highest productivity (583 kg lint/ha). Presently, short to long staple cotton is grown in mechanized farms in the area where cotton-wheat is the predominant cropping system. Frequently encountered problems are salinity, alkalinity and the rise in the water table. The northern zone (Punjab, Haryana and Rajastan) occupies only 16 percent of the total cultivated area but contributes more than 18.5 percent of the production.

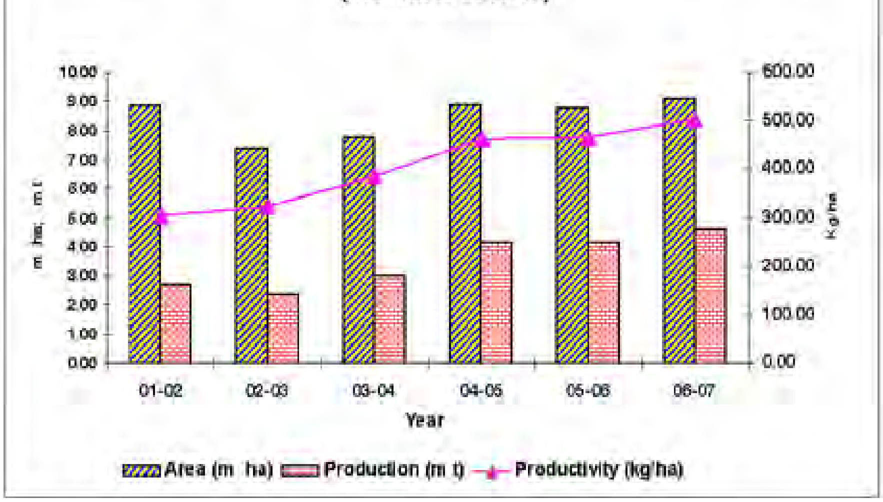
The **central zone** is composed of a rainfed tract of MP, Maharashtra and Gujarat. This area which grows cotton as a mono-crop or as an intercrop, is known as the central *hirsutum-arboreum-herbaceum* and hybrid zone, and is more suitable for diploid cottons. Cotton productivity in the area is the lowest (448 kg lint per hectare) among the three due to the vagaries of the monsoon and the predominantly black soil that is infertile and susceptible to runoff, erosion and nutrient losses. The unpredictable rain and infertile soil cause more weeds, pests and disease problems. Farmers in this area are resource poor and are therefore, not in a position to invest more. Cultivation is done traditionally with bullock-drawn implements and by manual labour. The central zone occupies more than 68 percent of the total area but contributes less than 60 percent to the total production, and is characterized by the proliferation of hybrids.

The **southern zone**, comprising Andhra Pradesh, Karnataka and Tamil Nadu, a zone for growing *hirsutum-arboreum-herbaceum-barbadense* and hybrid cottons, produces 535 kg lint/ha. Soils are both black and red, and of poor to average fertility. Due to the prevailing climate, cotton can be grown throughout the year, both under irrigated and rainfed conditions. The zone is well known for growing long and extra long staple HxB hybrid and *barbadense* cottons. Cotton is grown in the south as the sole crop or in intercropping system with onion, chili, cowpea, maize and others or in rotation with rice. Pest and disease problems are more severe here than in the two other zones. The southern zone occupies 15.3 percent of total cotton area, and contributes nearly 16.3 percent to the national production.

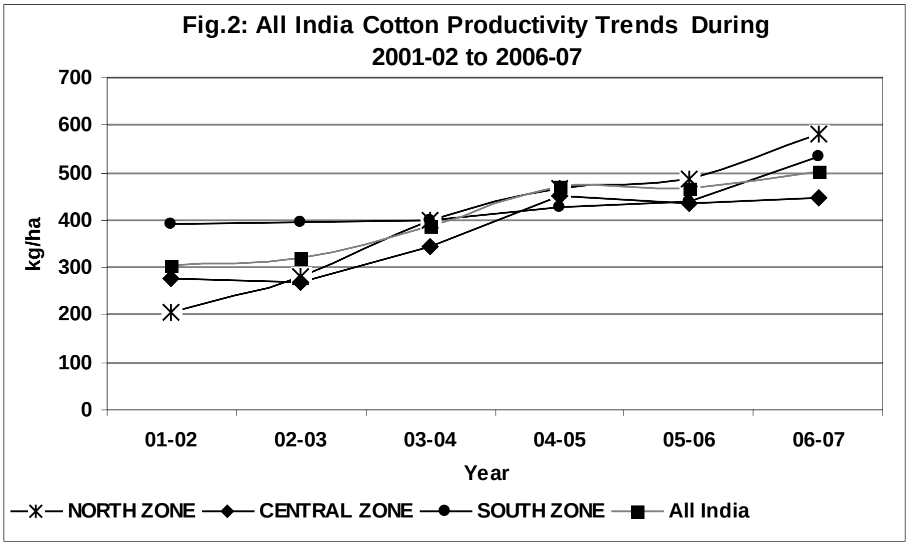
Details of the area, production and productivity profile of the country (over the years) as well as in the three zones is presented in Figs. 1 and 2.

The production trends as depicted in Fig.1 clearly indicate that there has been a significant enhancement in production from 2004/05 onwards as compared to the earlier years (from 3.01 mt in 2003/04 to nearly 4.59 mt in 2006/07). Adoption of improved technologies IPM, IRM, new chemistry (including Bt cotton), coupled with favorable weather and low insect pest pressure in major cotton growing tracts, have enabled this transformation in productivity. During 2006/07, Punjab and Gujarat States recorded much higher productivity than the national average, and contributed to a large measure to enhanced production at the national level.

Fig.1: Trends in Cotton Area, Production and Productivity in India (2001-02 to 2006-07)



The average national productivity showed a remarkable spurt from nearly 303 kg lint/ha (2001/02) to 503 kg lint/ha in 2006/07. Among the three zones, the northern and the southern areas recorded relatively higher productivity compared to the central zone, and the enhancement was quite conspicuous in 2006/07 as compared to 2005/06. A trend of continuous improvement is quite clear from 2002/03 onwards (Fig.2).



Silver lining in cotton production

India was the third largest importer of cotton in the world in 2002/03. By contrast, a couple of years later (in 2005/06), the country became the third largest exporter of cotton worldwide. The cotton growers in Gujarat achieved cotton yields of 728 kgs./ha in 2005/06, which was higher than the world average of 715 kgs/ha. To harvest record crops in succession for three consecutive years is a record in itself in as much as never before has the country ever harvested successive good crops. Currently, India is the second largest producer of cotton in the world after China.

Bollworms, the major cotton pests

Bollworms cause significant yield losses in cotton. Three types of bollworms, American bollworm (*Helicoverpa armigera*), pink bollworm (*Pectinophora gossypiella*) and spotted bollworms (*Earias vitella*), attack cotton which has no known sources of resistance to the pest in its germplasm anywhere in the world. Consequently, about 10 percent of the insecticides worldwide are used for the control of insects in cotton alone. Insecticides have adverse effects on (i) natural predators and parasites of bollworms, (ii) beneficial insects, (iii) human health, and (iv) microorganisms such as nitrogen fixing bacteria. Use of insecticides also leads to environmental pollution (soil and water), increase in cost of cultivation and sometimes, development of resistance in insects against insecticides. Hence, the need to develop bollworm-resistant cotton to control yield losses was considered urgent.

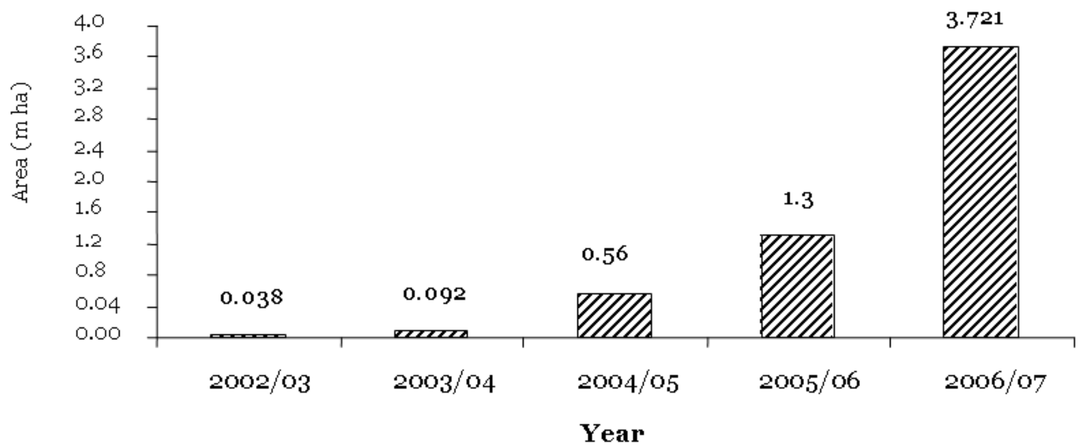
Around 45 percent of crop pesticide is used on cotton, creating a potential for social, economical and environmental problems in the country. Indiscriminate use of pyrethroids, introduced in India during the 1980s, has resulted in the development of resistance in bollworms and in the resurgence of white flies. Since we are in need of safe and sustainable agriculture, it is imperative to deploy effective and eco-friendly strategies to manage insects. Genetic engineering provides us with valuable tools to develop transgenic crops carrying resistance to insect pests.

Bt cotton adoption in India

In India, after extensive testing of Bt cotton hybrids (with cry1 Ac gene) in All India Coordinated

Cotton Improvement Project (AICCIP), the government approved commercial cultivation of Bt cotton hybrid in 2002. In the first year of its release, Bt cotton hybrids occupied 0.038 m ha (2002). The area under Bt cotton hybrids gradually increased to 0.56 m ha in 2004/05 and showed a steep increase to 1.3 m ha. in 2005/06 followed by a phenomenal enhancement to 3.721 m ha in 2006/07 (Fig.3).

Fig. 3: Spread of Bt Cotton in India



Thus, within a span of five years, nearly 42 percent of the cotton area in India was under Bt hybrid cultivation. It is predicted that with availability of more Bt hybrids, coupled with reduction in seed cost from 2006 onwards, the area under Bt cotton is likely to show a perceptible increase in 2007/08 as well. Among the cotton growing states, Maharashtra leads with 0.2 m ha under Bt cotton, followed by Andhara Pradesh and Gujarat with 0.67 and 0.33 m ha, respectively. Among the northern states, the area was greatest in Punjab, with 0.28 m ha, followed by Harayana, with 0.042 m ha. Thus, the cultivation of Bt cotton hybrids has picked up momentum in the last two years. Bt cotton is being cultivated in all the three cotton growing zones of the country (Table 2).

Table 2. Adoption of Bt cotton by state

State	2004 (ha)	2005 (ha)	2006 (ha)
Maharashtra	200,000	590,000	200,0000
Gujarat	130,000	150,000	330,000
Madhya Pradesh	85,000	145,000	310,000
Andhra Pradesh	80,000	280,000	676,000
Karnataka	18,000	30,000	80,000
Tamil Nadu	10,000	25,000	-
Northern Zone	n/a	60,000	
Punjab			281,000
Haryana			42,000
Rajasthan			2,000
Total	**500,000**	**13,000,000**	**372,1000**

Three hybrids, MECH 12, MECH 162 and MECH 184, from Mahyco Monsanto were recommended in 2002 for cultivation in the central and south cotton growing zones. In 2004, one more Bt hybrid (RCH-2) was recommended for commercial cultivation, while in 2005, 16 hybrids were approved for commercial cultivation. During 2006, 42 hybrids were recommended for commercial cultivation (Table 3). All these hybrids were developed by private seed companies utilizing different genes (Table 4).

Table 3. Bt cotton hybrids approved for commercial cultivation in India

Zone	Company	Hybrid
North	Mahyco, Mumbai	MRC-6304, MRC-6025, MRC-6029
	Rasi Seeds, Attur, Tamil Nadu	RCH-134 RCH-317, RCH-308, RCH-314
	Ankur Seeds, Nagpur	Ankur-2534
	Nuziveedu Seeds, Hyderabad	NCS-913, NCS-138
	J.K.Agri Seeds, Hyderabad	JKCH-1947
	Nath Seeds, Aurangabad	NCEH-6 R
North and Central	Mahyco, Mumbai	MRC-6301
	Ankur Seeds, Nagpur	Ankur-651
Central	Rasi Seeds, Attur, Tamil Nadu	RCH-144, RCH-138, RCH-118, RCH-377
	Ankur Seeds, Nagpur	Ankur-09
	Mahyco, Mumbai	MECH-12, MRC-7301 BG II, MRC7326 BG II, MRC-7347 BG II
	Ajeet Seeds, Aurangabad	ACH-11-2 BGII, ACH-155-I
	Krishidhan Seeds, Jalna	KDCHH-441 BGII
	Nath Seeds, Aurangabad	NCEH-2R
	Ganga Kaveri, Hyderabad	GK-205
	Tulasi Seeds, Guntur	Tulasi-4 Bt
	Vikki Agrotech, Hyderabad	VICH-III
	Vikram Seeds, Ahmedabad	VICH-5 Bt, VICH-9 Bt
	Pravardhan Seeds Ltd., Hyderabad	PRCH-102
	J.K. Seeds, Hyderabad	JK Varun Bt (Event I)
Central and South	Mahyco, Mumbai	MECH-162*, MECH-184*
	Rasi Seeds, Attur, Tamil Nadu	RCH-2
	Nuziveedu Seeds, Hyderabad	NCS-145 Bunny, NCS-207Mallika
	Ajeet Seeds, Aurangabad	ACH-33-1 Bt
	Emergent Seeds Ltd., Hyderabad	Brahma Bt

Zone	Company	Hybrid
South	Mahyco, Mumbai	MRC-6322, MRC-6918, MRC-7351 BG II, MRC-7201 BG II
	Rasi Seeds, Attur, Tamil Nadu	RCH-20, RCH-368, RCH-111, BG I, RCH-371 BG I, RCHB-708 BG I
	Ganga Kaveri, Hyderabad	GK-209, GK-207
	Nuziveedu Seeds, Hyderabad	NCS-913
	Nath Seeds, Aurangabad	NCEH-3R
	J.K. Agri Seeds, Hyderabad	JK Durga, JKCH-99
	Prabhat Seeds Ltd., Hyder-abad	PCH-2270
	Krishidhan Seeds, Jalna	KDCHH-9632
	Vikram Seeds, Ahmedabad	VICH 5

*Mech 162 & Mech 184 are not approved for AP

Table 4. Genes utilized for the development of transgenic cotton hybrids in India

Company's Name	Gene utilised
Mahyco	cry1Ac
Monsanto	cry1Ac+2Ab
Nath Seeds	cry1Ab+Ac fusion (China)
JK Seeds	cry1Ac modified (IIT Khargpur, India)
Syngenta	Vip3A+cry1Ab
Dow Agri. Science	cry1Ac+ cry1 F
Metahelix	cry1C
ICAR	cry1Aa3
	cry1F
	cry1Ia5
	cry1Ab
	cry1Ac
NBRI	cry1Ec

The transgenic hybrids released in the country can be categorized in different ways on the basis of the transgene used: (1) Bollgard (single gene) (2) Bollgard II (double gene), and based on the species involved (1) Intra-*hirsutum* (2) Inter-specific hybrids (*hirsutum* x *barbadence*)

1. **Bollgard:** The majority of transgenic hybrids belong to this group. It includes 55 hybrids
2. **Bollgard II:** This group includes seven hybrids viz., MRC 7201, MRC 7301, MRC 7326, MRC 7347, MRC 7351from Mahyco;ACH 11-2 from Ajit Seeds; KDCHH 441 from Krishidhan Seeds.

3. **Intra-hirsutum Hybrids:** This group again includes the majority of transgenic hybrids. Out of 62 transgenic hybrids released so far, 60 hybrids come under this group.
4. **Hirsutum x Barbadens Hybrids:** This group includes only two transgenic hybrids, viz., MECH 6918 from Mahyco and RCHB 708 from Rasi Seeds

The largest number of transgenic cotton hybrids have been released by Mahyco and Rasi Seeds (14 each), followed by Nuziveedu (4), JK Seeds (4), Gangakaveri Seeds (4), Krishidhan Seeds (4), Nath Seeds (3), Ankur Seeds (3), Vikram, Prabhat seeds, and Tulsi Seeds (two each). Emergent, Vikki's and Pravardhan seeds released one hybrid each.

Development of Bt cotton varieties

The Indian Council of Agriculture Research and Department of Biotechnology have entrusted the development of transgenic cotton varieties to CICR, Nagpur, NRCPB, New Delhi, NBRI, Lucknow, ICGEB, New Delhi and UAS, Dharwad. The available genes, cry1Ac, cry1Aa3 and cry IF, were transferred in *G. hirsutum* and *G. arboreum* cultivars. The Review Committee on Genetic Modification (RCGM) of India carried out a contained open field trial with T2 generation transgenic plants in 2005, and the RCGM-replicated multi-location trials are under way in the current season 2006.

Development of Bt kits

The Central Institute for Cotton Research in Nagpur has developed diagnostic kits (Bt Express, Bt Detect, Bt-Zygosity, Bt Quant) for the detection of Bt toxin, and these kits have been effectively deployed all over the country to verify the purity of Bt seeds and to ensure the supply of quality Bt hybrid seeds to the farming community.

Quantitative expression of cry1Ac in Bt-cotton

Quantification of cry1Ac expression in various plant parts of eight Bt-cotton hybrids was done using ELISA and bioassays throughout the cropping season 2001/03. cry1 Ac expression ranged at 0.01 to 19 µg/g in various parts of the plant. The highest expression was in leaves at 75 days after sowing (DAS). A decline in expression of toxin levels was observed in all the eight hybrids. The earliest decrease was in MECH-162, with toxin levels falling to 1-2 µg/g by 85 DAS. Expression in some hybrids such as RCH-144 and MECH-184 declined only after the 120th DAS. The expression levels were highly variable in different plant parts. On an average, the cry1Ac expression in the eight Bt-cotton hybrids was found to be adequate for bollworm protection at least until the first 100-120 days after sowing. The current study showed that increasing levels of *H. armigera* survival were correlated with decreasing toxin levels. An overall analysis revealed that the Bt cotton technology has a capability of reducing insect pest infestations by 60-90 percent under field conditions.

Resistance Monitoring

Ninety-four field populations of *H. armigera* from 44 sites from the north, central and south of India were bioassayed with cry1Ac during 1998-2006. The log dose probit response indicated that cry1Ac was highly toxic to the bollworm larvae collected from all the sites in India. Strains from south India were found to be more tolerant to cry 1Ac compared to all other strains from the rest of the country. The range of LC50 was 0.01 to 0.88 µg/mL of diet (88-fold tolerance) in field populations of *H. armigera* collected from various parts of the country over the five-year bioassay period. Strains from south India periodically showed tolerance levels that were higher (>0.16 µg/mL) than the composite average (0.10 µg/mL) published baseline value. However, the tolerance observed throughout the assay period was found to be within the acceptable limits of the baseline, and did not indicate any shift in tolerance of *H. armigera* to cry1Ac. The LC_{50} and IC_{50} values of cry1Ac in our studies are similar to those reported previously for *H. armigera* strains from India, Australia and China. However, the baseline LC50 susceptibility values of H. armigera to cry1Ac in China were found to be very variable, with a range from 0.091 to 9.073 µg/ml diet. The baseline LC50 values of 0.01-0.67 µg/ml reported by CICR previously, and 0.11-0.71 µg/ml reported recently for Indian strains indicate that the Chinese *H. armigera* strains are inherently more tolerant to cry1Ac than the Indian strains. The baseline range of EC50 values at 0.003-0.008 and EC90 0.009-0.076 µg/ml diet, published by Jalali *et al.* (2004), our previous EC50 data of 0.014-EC90, 0.084 µg/ml diet, and the current values of the Bt seed-based bioassays at IC50, 0.012-0.013 and IC90, 0.091-0.109 µg/ml diet, showed that the results of the bioassays on Indian *H. armigera* population were comparable even when performed independently in laboratories across the country.

Resistance management strategies—new insights for the Indian conditions

Large-scale cultivation of Bt cotton hybrids may lead to the development of resistance to Bt toxins. To avoid this, the planting of five border rows of non-Bt cotton surrounding each acre of Bt cotton has been recommended. The area accounts for 20 percent refugia. However, modeling studies showed that maintenance of a 20 percent refugia may not confer significant advantages in delaying resistance development. This is mainly due to the natural availability of non-structured refugia in the form of alternate host crops in the cotton eco-system in India.

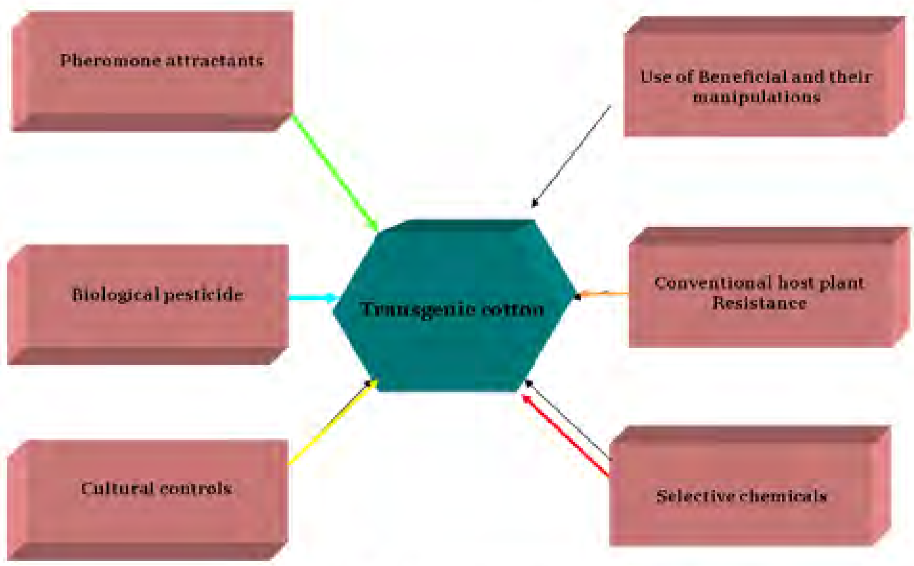
The stochastic model 'Bt-Adapt' developed at CICR in Nagpur to understand and predict the rate of resistance development of *H. armigera* to cry1Ac based Bt cotton showed that with 40 percent Bt cotton area in India, it would take at least 11 years for a cry1Ac resistant allele frequency in H. armigera to reach 0.5, which would cause difficulties in pest control with Bt cotton. One of the most important strategies in Bt resistance management is to reduce the Bt cotton surviving population of *H. armigera*, which represents resistant genotypes, through integrated pest management practices.

The strategies that would extend the usefulness of Bt technology include:

1. The use of alternate genes that do not share common resistance mechanisms to cry1Ac, either in transgenic plants or in rotation, alternation or combination;
2. The use of eco-friendly methods such as cultural control or handpicking of surviving bollworms in Bt cotton fields. Biopesticides that are neem-based or HaNPV would be useful to manage younger larvae on 60- to 90-day-old crops. Alternatively, conventional insecticides such as endosulfan, thiodicarb, quinalphos and chlorpyriphos, or new molecules such as spinosad, emamectin benzoate, novaluron or Indoxacarb can be used on 90- and 120-day-old crops to reduce populations of resistant genotypes;
3. The identification and use of attractive synchronous alternate host crops for *H. armigera* which could be used as intercrop or trap crop refuges; and
4. The avoidance of Bt-based biopesticides that may contribute to the selection of a broad spectrum resistance to several useful Bt genes of interest.

Integrated Pest Management in Bt Cotton

With its intrinsic resistance to bollworm damage, Bt cotton can become an ideal component for implementing integrated pest management (IPM). The expression of cry1 Ac is not uniform throughout the growing period, and usually by 110-120 days of crop age, the expression level comes down, considerably rendering the crop relatively susceptible to bollworms. The problem of sucking pest has increased considerably in most of the Bt hybrids. The adoption of the IPM system with all its biological, cultural and other components will be immensely beneficial for economical, effective and eco-friendly management of insect pests in Bt cotton.



Sustainable IPM based on transgenic cotton

Impact of Bt cotton in India

The consistent and perceptible increase in cotton production and productivity during the last three years is partially attributed to higher rate of adoption of Bt cotton in the country.

After the introduction of Bt cotton in 2002, the insecticide use pattern in cotton in India has undergone a complete change. The conventional groups of insecticides were replaced by the new chemistries for their enhanced efficacy. Over the last four years, more than 40 percent of India's cotton area was covered by Bt cotton, which resulted in low insecticide use against bollworms. The recommended insecticides for bollworm control were spinosad, indoxacarb and emamectin benzoate among other ecologically acceptable groups of insecticides. The recently recommended cotton pest management strategies in India are based on the use of a rational and sensible sequence of insecticides that are effective on the target species. These cause reduced disturbance to beneficial fauna and minimize selection pressure and rotation of insecticide groups based on unrelated resistance mechanisms. Thus, cotton pest management in India is now almost free of the conventional chemistries. It now ranks among the few countries that use mostly eco-friendly pesticides and fewer pesticides for bollworm control.

14. Experience with Bt cotton in Colombia

Jorge Cadena Torres
Research Coordinator
CORPOICA, Colombia

Summary

Colombia is located at the northwest part of South America. It is very close to the equator and therefore is considered a tropical country having constant temperature and day-length throughout the year. This makes it possible to grow cotton all year long. Even though there is historic data documenting cotton fiber production in the 1920s, modern cotton production in the country is considered to have started in the1970s. Colombia registered the largest area (377,246 ha) planted to cotton in 1977. This has since decreased, reaching 65,396 ha in 2005, with a lint production of 51,610 tons and lint yield of 789 kg/ha.

About 7,584 farmers plant cotton each year and the average farm size in the country is 8.6 ha. There are two rainy seasons: one in February/March and a second in July/August. This, along with some sanitary regulations, has contributed to the definition of two production zones: one at the interior of the country (the internal valleys), which grows cotton from February to July; and a second production zone, located at the North Coast and Llanos high plains, which grows cotton from July to December. Most farmers in Colombia are small farmers (72%), cultivating farms of less than five hectares, which contribute about 28 percent of the planted area.

After adopting the UN Biodiversity Act and the Cartagena Protocol on Biosecurity, Colombia first introduced transgenic cotton for evaluation in 2001. Biotech cotton was subsequently released for commercial use after three years of testing. Varieties offered in the market are BtI, which provides protection against *Heliothis virescens, Alabama argillacea, Trichoplusia ni,* and *Sacadodes pyralis*. Pests that require insecticide applications in Colombia are boll weevil, Spodoptera, sting bugs, white fly, Heliothis, and Colombian pink bollworm. However, insect pests vary in the two cotton production zones: boll weevil, Spodoptera, sting bugs and white fly are more important in the North Coast; and Colombian pink bollworm and boll weevil in the interior zone.

These differences in pest distribution and importance, especially the occurrence of Colombian pink bollworm at the interior, have led to greater adoption of transgenic cotton in the interior zone than at the North Coast. After commercial release in 2004, adoption in the interior zone increased from 19 to 24 and to 63 percent of planted area in 2004, 2005 and 2006, respectively, while at the North Coast, adoption has progressed slower, from 15 to 24 and to 29 percent for the same years. There has also been a difference in the adoption with regard to farm size. While at the North Coast, adoption by small farmers declined from 15 to 8 and to 5 percent for years 2004, 2005, and 2006, respectively, it increased in the interior zone from 33 percent in 2004

to 44 percent in both 2005 and 2006. Economic evaluation indicates that technology costs are well worth for farmers at the interior, who have to protect their crop against *Sacadodes pyralis*, while for farmers at the North Coast it is not worth it, since Bt cotton does not provide protection against the prevailing pests. Bt II has not yet been approved for commercial use in Colombia, and since it provides a broader spectrum of protection against pests, especially Spodoptera, this may change the current picture of adoption in the country. RR has also only recently been approved.

Index words: cotton Colombia, transgenic, Bt Cotton

Experience with Bt Cotton in Colombia

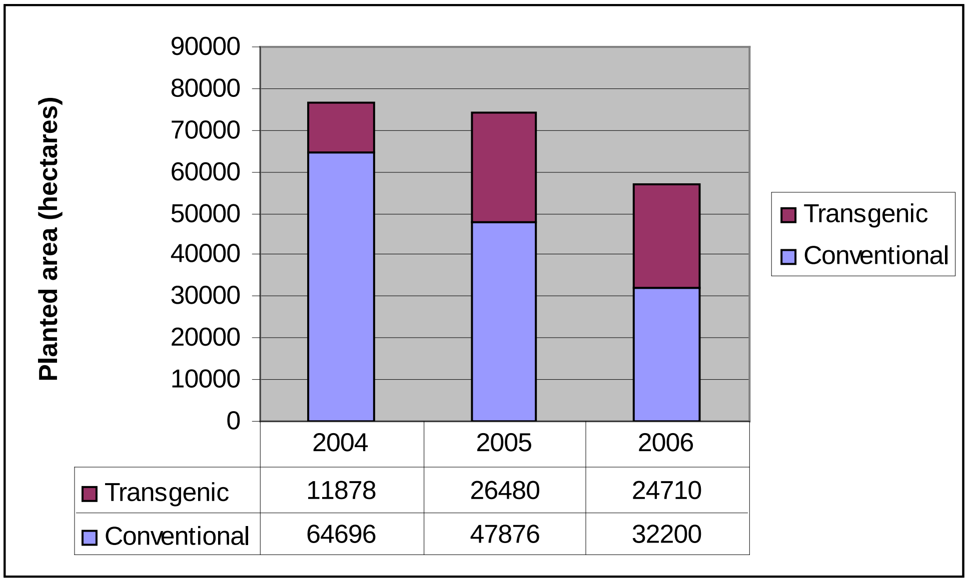
Most cotton seed planted in Colombia is imported from the Delta & Pine Seed Company of the United States. The most popular variety is DP Opal, which is planted on 71 percent of the land. Local varieties account only for 14 percent of the planted area.

Colombia has adopted the UN Biodiversity Act and the Cartagena Protocol on Biosafety. The Ministry of Agriculture is in charge of regulations, and the Colombian Agricultural Institute (ICA) was designated in 1998 to regulate the incorporation of transgenic crops in the country. The ICA created the Biosecurity National Committee (CTN) in 1998 to establish GMO protocols and regulations. The first application to introduce a transgenic crop was placed by Monsanto in 2001 for Bt I cotton. After three years of field evaluation, including its effects on the fauna, pollen flow, wild cotton and on inter crossing, the CTN released in 2004, the first transgenic crop for commercial use in Colombia: Bt cotton. Additional crops currently under evaluation include flowers, coffee and maize. Bt II cotton and the stack variety of cotton are also now being studied, and are expected to be released in 2008. RR cotton received authorization in 2006

DP NuOpal, the Bt I transgenic variety that is available in the market, provides protection against *Heliothis virescens, Alabama argillacea, Trichoplusia* and *Sacadodes pyralis*. The main pests requiring insecticide applications in Colombia are boll weevil, Spodoptera, sting bugs, white fly, Heliothis and Colombian pink bollworm. A recent survey on cotton production costs carried out by Conalgodon (2005) indicated that insecticide use accounts for 12 percent of total cotton production costs. Of this, 56 percent is for boll weevil control, 23 percent for Spodoptera, 8 percent for sting bugs, 4.5 percent for white fly, 6.5 percent for Heliothis, and 2 percent for Colombian pink bollworm control.

However, there are differences in pest distribution in the two cotton production zones. Boll weevil, Spodoptera, sting bugs and white fly are more important in the North Coast, while the Colombian pink bollworm, boll weevil and white fly are more important in the interior zone. The differences in pest distribution, especially the occurrence of high populations of Colombian pink bollworm in the interior, have affected the adoption of transgenic cotton (Figure 1).

The total area planted to transgenic cotton in Colombia has doubled in three years, from 11,878 ha the year it was first introduced (2004), to 24,710 ha in 2006 (Figure 1). However, the adoption of this technology, as expressed by planted area, is affected by the type of pests present in each production zone. While adoption has been increasing dramatically in the interior zone, in the North Coast, the planted area is increasing slowly (Figure 2). After commercial release in 2004, adoption at the interior zone increased from 19 to 24 and to 63 percent of planted area in the years 2004, 2005 and 2006, respectively. At the North Coast, adoption increased from 15 to 24



	2004	2005	2006
Transgenic	11878	26480	24710
Conventional	64696	47876	32200

Figure 1.

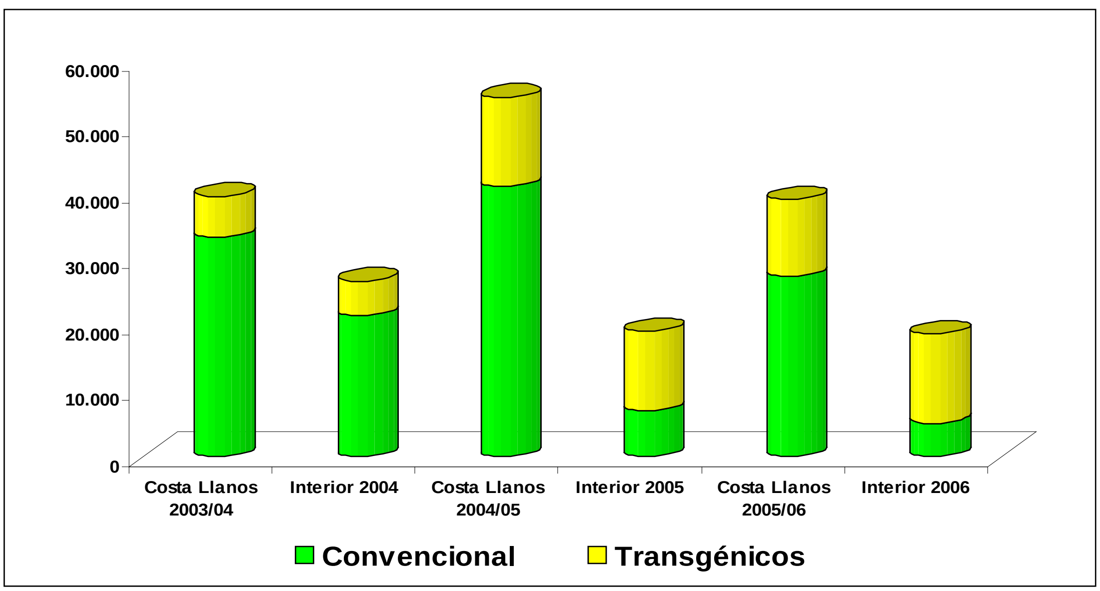


Figure 2. Area planted to Bt cotton in Colombia by production zone since 2004.

and to 29 percent of planted area in these same years. These adoption rates represent the effect of the protection provided by transgenic cotton and the distribution of the main pests affecting cotton crops in each production zone. While the Colombian pink bollworm (*Sacadodes pyralis*) has been in the last three seasons the main pest in the interior, boll weevil, *Spodoptera*, sting bugs and white fly have been more important in the North Coast zone. Adoption of transgenic cotton has been slow in the North Coast where the pests present are not controlled by the toxin produced by the Bt gene.

In Colombia, small farmers have had access to transgenic cotton. However, there have been differences in its adoption depending on farm size and production zone. While at the North Coast, adoption by small farmers (less than 5 ha) has been decreasing from 15 to 8 and to 5 percent during the years 2004, 2005 and 2006, respectively, in the interior zone, adoption has increased from 33 to 44 and to 44 percent during the same years (Figure 3). The production area of the interior zone is mostly irrigated land, and in general, farmers have found this technology

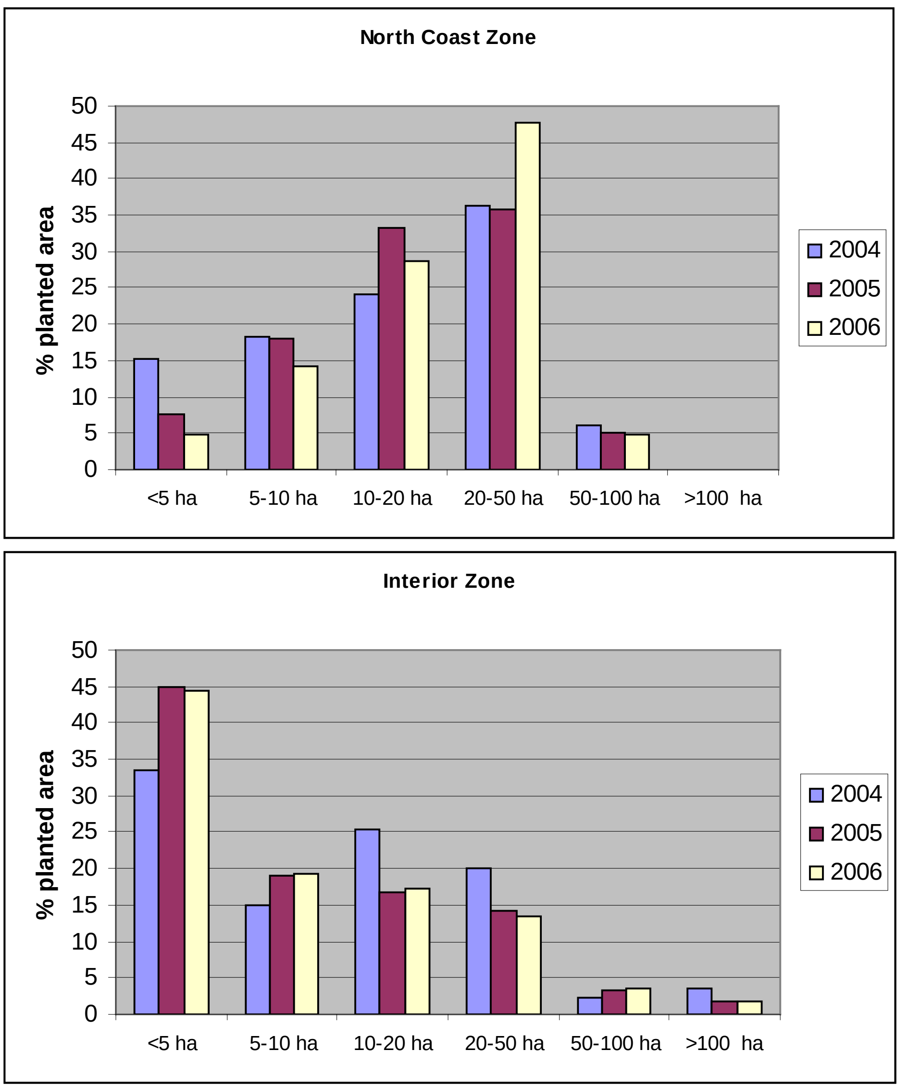


Figure 3. Area planted with Bt cotton in Colombia by farm size at the North Coast and the interior production zones.

very useful, as it gave them high yields, high returns on their investments and protection against their main pests. In some cases, the Cotton Growers Associations have forced farmers to adopt this technology, providing credit only to those farmers who plant transgenic varieties.

On the other hand, the production area of the North Coast Zone is mainly dry land, and in general, farmers do not obtain very good returns by planting transgenic cotton since the main pests present in the zone are not controlled by Bt cotton.

In fact, an economic evaluation of transgenic cotton in the North Coast during 2005 indicated that the increase in lint yields was not enough to cover the increases in production costs due to the technology fee and the seed cost. Table 1 shows that the cost of production increased per ton of seed cotton produced. For farmers at the interior zone, the story is different since their crops are protected against *Sacadodes pyralis*, and the use of irrigated land maximizes the returns from the use of transgenic varieties. Bt II has not yet been approved for commercial use in Colombia, and RR has only recently been approved. Since Bt II provides a broader spectrum of protection, especially against Spodoptera, its use may change the current picture of adoption in the country.

Table 1. Production cost of planting one hectare of Bt cotton in the North Coast production zone in Colombia, 2005.

Variety	Seed-Cotton Yield kg/ha	Seed Cost US$/ha	Total Cost US$/ha	Cost/Ton
Bt Cotton	2,993	169.90	1,748.53	584.20
Non Bt Cotton	2.776	109.87	1,552.91	559.47

200 KG INCREASE IN YIELD
US$60.00 INCREASE IN SEED COST
US$195.00 INCREASE IN TOTAL COST
US$24.73 INCREASE IN COST PER TON

Farmers in the North Coast have found the following disadvantages of growing Bt cotton:
- There is higher monetary risk.
- The risk is higher in dry land than in irrigated land.
- The cost of seed is higher:
- US$12.55/kg seed + technology fee versus US$ 6.00 for conventional seed
- US$169.90/ha (13 kg/ha of seed used)
- Some farmers report increases in non target pests, sting bugs and white fly, although this has not been documented.
- The insecticides used for controlling sting bugs are also effective against Colombian pink bollworm and cheaper than the technology fee, therefore farmers prefer to use insecticides.
- There is still no protection against important pests, like Spodoptera and sting bugs, which are considered more important than Colombian pink bollworm.
- The technology is not available in local varieties.
- Imported seed is more expensive than local seed.
- Transgenic seed imported from South Africa has low gin yields (37 vs 39 percent in conventional varieties).
- Bt II, which may provide a better protection for farmers, is not yet available.

On the other hand, farmers at the Interior Zone have found the following advantages of Bt cotton:

- Bt cotton provides protection against the main pests causing damage to cotton crops: *Sacadodes pyralis*, Heliothis and Alabama.
- Bt cotton represents an insurance during seasons when pest attacks are high.
- Farmers planting Bt cotton have the chance to obtain higher yields than those growing conventional varieties. The difference has been at least 200 kg/ha of seed cotton.
- The yield potentials are more expressed and capitalized in irrigated land.

Conclusions

Bt Cotton was the first transgenic cotton released for commercial use in Colombia in 2004. However, Bt cotton has not been 100 percent adopted by farmers; only 43 percent of the production area was planted with this variety. Meanwhile, the transgenic DP NuOpal from the Delta&Pine Seed Company of the United States has been planted on almost 71 percent of the cotton area in Colombia.

The lack of transgenes available for incorporation into local varieties is likely to affect the level of adoption, since small farmers use these local varieties. The variety offered in the market provides protection against *Heliothis virescens, Alabama argillacea, Trichoplusia ni,* and *Sacadodes pyralis*. However, pests requiring insecticide applications in Colombia are mostly boll weevil, Spodoptera, sting bugs, white fly, Heliothis and Colombian pink bollworm. The differences in pest distribution between two cotton production zones in Colombia affect the level of adoption. While boll weevil, Spodoptera, sting bugs and white fly are more important in the North Coast, the Colombian pink bollworm, boll weevil and white fly are more important in the interior zone. These differences in pest distribution, especially the occurrence of high populations of Colombian pink bollworm at the interior, have affected the adoption of transgenic cotton.

15. Agricultural Biotechnology Research in Turkey

İsa Özkan
Cotton Research Institute, Nazilli-Turkey

Introduction

In Turkey, agricultural biotechnology research started in the 1970s, and was mainly on tissue culture, particularly on *in vitro* micropropagation of fruit trees and ornamental plants. After 1990, biotechnological research initiatives progressed on to include modern molecular techniques: plant regeneration via organogenesis or embryogenesis; *in vitro* micropropagation of valuable plant materials; anther and ovule culture; transformation of crop plants by *Agrobacterium tumefaciens* or particle bombardment; gene expression studies; the use of molecular marker techniques for polymorphism between different genotypes; and genetic mapping and gene isolation.

Plant biotechnology research is now carried out in many universities and research institutes, including the TÜBİTAK Marmara Research Center; the Agriculture Faculties of Ankara; Çukurova University; Akdeniz University; Gaziosmanpaşa University; Selçuk University; Sutcu Imam University; Ege University; Atatürk University; the Biology Department of Izmir High Technology Institute; the Biology and Chemistry Departments of the Middle East Technical University; the Biology Departments of Istanbul and Boğaziçi Universities; and the agricultural research institutes of the Ministry of Agriculture and Rural Affairs.

This paper presents an overview of agricultural research activities in Turkey. Currently, there are no initiatives to develop new genetically modified (GM) cotton varieties, as transgenic crops have not been approved for use in the country.

A. General Agricultural Biotechnology Research

Agricultural Faculty of Ankara University

Biotechnology research projects at Ankara University include *in vitro* production in flower bulbs, micropropagation of fruit trees, anther culture of fruit trees, and the adventitious shoot regeneration via organogenesis and embryogenesis in wheat, maize, lentil, pea alfalfa, sainfoin, cicer milkvetch, rapeseed and sunflower. Also ongoing are the establishment of transformation protocols by particle bombardment of pea, wheat and maize; and *Agrobacterium tumefaciens*-mediated transformation of lentil, rapeseed and sainfoin. Additional projects include the production of insect resistant sainfoin, the use of pathogen related gene promoters to eliminate the expression of marker genes in transgenic plants and the use of molecular DNA makers (RAPD, AFLP and ITS) to identify genetic variation in wild wheat species, lentil, grapevine and rose populations of Turkey.

Middle East Technical University

Department of Biology

The Research Group of Plant Biotechnology is currently involved in the genetic manipulation of crop plants with resistance against osmotic stress (salt/drought) and nematodes. Target plants of the studies comprise wheat, lentil, chickpea, potato, tomato, eggplant and tobacco (as a model plant). *Agrobacterium*, particle bombardment and electroporation protocols are used as transformation systems.

Department of Chemistry

The Chemistry Department has a project named "Assessment of genetic relationship of Turkish wheat genotypes using microsatellite and AFLP markers".

TÜBİTAK Marmara Research Center, Gene Engineering and Biotechnology Research Institute

Plant Biotechnology Group

The general subjects of the projects are tissue culture systems and gene transfer techniques for barley, wheat, tobacco, potato, chickpea, poplar, *Paulownia*, sunflower and cotton. Some projects are:

- Development of genetically developed poplar clones for paper raw material. The aim of this study is to reduce lignin in poplar wood through the introduction of antisense copies of the genes coding for O-metiltransferase and peroxidase enzymes into poplar by *Agrobacterium tumefaciens*.
- Identification of novel genes associated with water stress tolerance in barley. This project aims to isolate and functionally characterize barley genes that are differentially expressed (induced or repressed) during water stress. Filter-based cDNA arrays will be produced, and large numbers of barley cDNA clones will be hybridized with labeled mRNAs isolated from plants either exposed to drought or growing normally. The differentially expressed cDNAs will then be sequenced and grouped according to their putative functions.
- Production of cotton resistant to fungal (Verticillium) diseases
- Application of *in situ* hybridization techniques to identify nucleotides related to drought resistance in barley

Plant Molecular Genetics Group

- Determination and development of plants with tolerance to heavy metals in the southeast region of Turkey
- Determination and isolation of the genes responsible for drought tolerance and abscisic acid production in wheat using mRNA differential display technique
- Development of cotton plants tolerant to heavy metals

Agricultural Faculty of Çukurova University

At Çukurova University a number of biotechnology projects are underway:

- Micropropagation of apple, cherry, pistachio, vine, fig, strawberry and banana
- Adventitious shoot regeneration studies by organogenesis and embryogenesis in cotton, forage crops, vine, citrus and tomato

- Haploid plant production in wheat, barley, melon, water melon, gourd and pepper

Gene transfer projects comprise:
- Transformation of wheat, citrus sp., melon and watermelon
- Production of herbicide resistant melon and wheat
- Production of bacterial disease resistant tomato and lemon
- Production of virus-resistant citrus and potato

Genetic diversity studies using DNA markers:
- Genetic characterization of cherry, sour cherry, fig, pistachio, almond, pepper and citrus sp. using RAPD and SSR markers

Izmir High Technology Institute

The following studies use biotechnological methods:
- AB QTL (Advanced Backcross Quantitative Trait Loci) analysis in processing tomatoes for the identification of agronomically, biologically, nutritionally and technologically important genes from wild tomato species and their simultaneous introgression into cultivated tomatoes using DNA markers
- Determination of the molecular and genetic control of the biochemical and physiological responses to biotic and abiotic stresses in tomato
- Physiological and genetic characterization of salt tolerance in tomato (*Lycopersicon esculentum*)
- Determination of genetic variation in antioxidant activity and dietary fiber content in cultivated and wild species of tomato, pepper and eggplant and molecular mapping of the genes associated with these traits
- Comparative genome analysis in Solanaceae with eggplant (*Solanum melongena*) as a model system

Agricultural Faculty of Akdeniz University
- *In vitro* culture and gene transfer in crop plants
- Determination of apomixes biology using genetic transformation
- *In vitro* micropropagation of ornamental plants

Agricultural Research Institutes of the Ministry of Agricultural and Rural Affairs
- Molecular marker studies in wheat, barley, cotton sp. and citrus sp.
- Production of virus-free plants in citrus sp.

B. Biotechnology Research in Cotton

In Turkey, biotech research activities in cotton have been carried out approximately for 5-6 years. Some projects are listed below:

Production of cotton resistant to fungal (Verticillium) diseases. This study is carried out in TÜBİTAK Marmara Research Center, Gene Engineering and Biotechnology Research Institute.

In this project, adventitious shoot regeneration system suitable for gene transfer has been established in cotton. Selectable and reporter marker genes have been introduced into cotton by *A. tumefaciens* or particle bombardment. In the future, genes that are resistant to *Verticillium* will be introduced into cotton.

Agricultural Faculty of Kahramanmaras Sutcu Imam University (KSU)

A great number of agricultural biotechnology researches on cotton is carried out at this faculty. Some of the projects are:

- Genetic diversity of diploid and tetraploid cottons determined by SSR markers, and its relationship with fiber quality traits. This study aims to determine the genetic diversity for diploid and tetraploid cotton genotypes, and to use its relationship with fiber quality parameters to identify molecular markers that might be used in plant breeding.
- Mapping genes that control lint quality and their transfer in cotton through marker assisted selection (MAS breeding). In this project, molecular markers for lint quality parameters (length, strength, and micronaire) will be identified and used in ongoing breeding program.
- Screening cotton germplasm and wild accessions for gossypol content and its molecular analysis.
- Genetic improvement of cotton with tolerance to biotic and abiotic stresses.
- Development of molecular mapping populations for economically important traits in cotton.

Cotton Research Institute

At the Cotton Research Institute, an ongoing biotechnology project is the “Genetic Mapping and Molecular Breeding for Fiber Related Traits and Verticillium Resistance in Cotton (Gossypium)”.

The main objective of the project is to use molecular methods to incorporate verticillium resistance into superior fiber quality lines. In order to achieve this goal, a molecular genetic linkage map of cotton is being developed using AFLP, CAPs and SSR markers, for the identification of quantitative trait loci (QTL) associated with verticillium resistance and with fiber traits to transfer the target genomic regions into an elite genetic background using MAS.

CONCLUSION

At present, agricultural biotechnology research in Turkey has focused on plant regeneration via organogenesis or embryogenesis, in vitro micropropagation of valuable plant material, anther and ovule culture, transformation of crop plants by *Agrobacterium tumefaciens* or particle bombardment, gene expression and use of molecular marker techniques for polymorphism between different genotypes.

In the future, research work will be concentrated on the development of insect, herbicide and disease-resistant plants; the isolation of drought- and disease-resistant genes; and the mapping of agronomically important genes.

There are currently no projects to develop GM cotton in Turkey. As a matter of fact, there is no need to develop insect-resistant GM cotton varieties because Turkey does not have a serious insect problem while only the Çukurova region has a tolerable insect problem. Essentially, except for the Çukurova region, insecticide treatment is done two or three times per growing season, and spraying is usually done against insects which do not include the American bollworm (Helicoverpa armigera) and pink bollworm (Pectinophora gossypiella). Weed problem is encountered in every region, but because labour is cheap, there is no need for GM varieties with tolerance to herbicides. Consequently, Turkey will continue to use and develop biotechnology systems, but presently GM cotton is not required in Turkey, although nobody knows what the future holds.

16. Current Status and Prospects of Biotech Cotton in Pakistan

Yusuf Zafar, S. Mansoor, S.Asad, M. Rahman Z.Mukhtar, M. Asif, A. Bashir and K.A. Malik
National Institute for Biotechnology and Genetic Engineering, (NIBGE)
Faisalabad, Pakistan

1. Abstract

Approval for the cultivation of indigenously developed genetically modified cotton (GM cotton) is still pending in Pakistan, the fourth largest cotton producing country in the world. The National Institute for Biotechnology and Genetic Engineering (NIBGE) in Faisalabad developed GM cotton for various traits, i.e., virus resistance, insect resistance, salinity tolerance in indigenous and well-adapted varieties. Recently, fiber improvement in cotton through genetic engineering has also been initiated with the transformed plants still at various stages of evaluation.

Meanwhile, the legislative and regulatory mechanisms for the safe release of GM crops have been delayed, and Pakistan's biosafety rules have been issued in April 2005. The capacity of the national biosafety directorate to evaluate and monitor the GM material is limited and needs to be strengthened. Several other regulations like the Plant Breeders Rights (PBRs) and the amendment in the Seed Act of 1976 are yet to be promulgated. This environment of weak regulation has resulted in the unapproved spread of Bt cotton in the country. Rough estimates (2005/06) of area under unauthorized Bt cotton was around 0.15 million hectares, and is expected to substantially increase to a large area in the next cotton season (2007/08).

There is a strong need to counter the unapproved spread of Bt cotton, which could ruin the cotton production system due to the potential spread of new diseases and the production of lint of untested quality. The simplest approach to address this issue is to activate the approval process, thus allowing the public and private sectors to enter into a national evaluation system for the commercial release of GM cotton.

2. Introduction

Cotton biotechnology was initiated in the country by the onset of an epidemic of cotton leaf curl virus disease (CLCuD) in 1992/93. The loss in primary production has been estimated at US$ 5 billion (1993/98). The Pakistan Ministry of Food, Agriculture & Livestock (MinFAL), with financial assistance from the Asian Development Bank, initiated a national mega project (US$ 5 million), with the second largest component related to cotton biotechnology. This included molecular virology, cotton transformation, genetic engineering and cotton genomics.

Meanwhile, the Common Funds for Commodities (CFC) in co-operation with the International Cotton Advisory Committee (ICAC) funded a tripartite project (US$ 1.2 million) consisting of

NIBGE, Faisalabad, Pakistan, John Innes Centre, Norwich, UK and the University of Arizona, Tuscan in the United States (Zafar *et al.*, 2003). The cotton biotechnology programme at NIBGE, was further consolidated by a research grant of US$ 0.1 million by the Agriculture Department of the Government of the Punjab (1998/2001). Researchers were trained abroad and strong international linkages were established that resulted in the exchange of experts and materials for research among the collaborative laboratories. All these efforts paved the way for laying a strong foundation of cotton biotechnology in the country.

Other agencies which have capabilities in developing GM cotton include the Center of Excellence in Molecular Biology (CEMB), Punjab University, Lahore. The group is mainly focused on developing insect resistant Bt cotton. Recently there was an effort to expand the cotton biotech programme by entering into public-private partnership with national/international seed companies for multiplication and commercialization of GM cotton (Bt) seed.

3. Cotton leaf curl virus resistant cotton

An epidemic of cotton leaf curl disease (CLCuD) in Pakistan in 1992/93 significantly affected cotton production, which decreased from 12.7 million bales in 1991/2 to 8.0 million bales in 1996. The molecular virology team of NIBGE contributed significantly in the isolation, characterization and management of cotton leaf curl virus.

National efforts were successful and scientists developed CLCuD resistant varieties and a management strategy which enabled Pakistan to regain the production level and to achieve record production of about 14.7 million bales in 2004/05. However, in 2001, a new mutant virus strain attacked the commercial resistant varieties (Zafar, 2002) and their primary resistant source (LRA, CP15/2 and Cedix) thus posing new threats to cotton production in the country (Arshad *et al.*, 2006).

CLCuD is caused by a complex consisting at least of the seven begomoviruses (DNA-A) and a satellite (DNA ß). The latter plays a determinative role in symptom induction (Mansoor *et al.*, 2003). A complete characterization of geminivirus components associated with resistance breakdown was carried out and a recombinant geminivirus species named cotton leaf curl Burewala Virus (CLCuBv) was found to be associated with the disease. This new species is a recombinant of cotton leaf curl Multan virus (CLCuMV) and cotton leaf curl Khokran virus (CLCuKV). A recombinant DNA beta that was previously found in tomato has now been detected in cotton (Mansoor *et al.*, 2006).

Genetically engineered cotton for virus resistance based on pathogen-derived resistance has been developed. Several vectors with varying components (open reading frames-ORFs) of virus (new & old, DNA-A or beta) have been constructed and many lines of GM cotton (Coker 312) were developed through *Agrobacterium*-mediated transformation (Asad *et al.*, 2003). GM cotton for virus resistance has been tested for Burewala virus in glass house and contained field experiments, and has shown variable resistance against Burewala as well as the old strains. These transgenic lines (Coker 312) have now been introgressed into local elite cultivars and will be tested in the field after obtaining approval from the National Biosafety Committee.

4. Insect Resistant Cotton

Over 96 insects and mite pests have been reported to attack cotton among which cotton boll worms and sucking pests (such as whitefly, cotton jassid, thrips and aphids) have caused the most damage. In Pakistan, bollworms are a serious threat, and consist mainly of three types: American bollworm (*Helicoverpa armigena*), spotted bollworm (*Erias vitella*) and pink bollworm (*Pectinophora gosspiella*). Recently, army worms (*Spodoptera* sps) also emerged as a serious pest. The constant rise in import/application of pesticides has resulted in increased production cost, environmental and public health problems, and the development of resistance in the insect pest.

To counter these problems, NIBGE initiated in 1999/2000 the development of genetically engineered insect resistant cotton. Various gene constructs with *Cry1Ac*, *Cry2Ab*, *CryI5a* and ViP were developed in various combinations. In addition to these reported genes, a new atrocotoxin hvt gene derived from Australian funnel web spider was employed as a new source of resistance to insects, especially army worm (Khan *et al.*, 2006). This gene produces a neurotoxin affecting K/Ca channels (like pyrethroids do), and creates broad spectrum resistance against all forms of prevailing boll worms. The plants are at various stages of development/evaluation, and one case of insect resistant GM cotton (IR-FH-901) has been submitted (April 2006) for “exempt status” to the National Biosafety Committee of the Ministry of Environment of Pakistan for its formal release. Another institute, the CEMB, first developed GM rice with synthetic *Cry1Ac* (Bashir *et al.*, 2004), and later extended the construct to cotton.

5. GM Cotton for Abiotic Stress

There are two main determinants of salt tolerance: H^+-pump and Na^+/H^+ exchangers. *AVP1* encodes the protein which is ubiquitous in vacuolar membranes for H+ pumping into the vacuole to establish a transmembrane proton electrochemical gradient (PEG). To develop drought- and salt-tolerance in cotton plants, 80 hypocotyls of Coker-312 were transformed with the *AVP1* gene under *2×35S* promoter (pRG-560), and 70 independent calli were placed on embryogenic medium. Plants from 20 independent events have been transferred to containment. Preliminary molecular analysis confirmed the presence of the transgene as determined by PCR. Seeds were harvested from three T_0 *AVP1* transgenic cotton plants, and seed germination analysis was performed under different salt regimes. Moreover, their rooting pattern in comparison with non-transgenic control Coker-312 was studied. Transgenic *AVP1* cotton plants exhibited a more vigorous root system and higher growth rate compared to controls. Biochemical and physiological studies on these developments are currently under way.

Another important salt determinant is a Na^+/H^+ exchanger, encoded by *AtNHX1*. This gene is also tonoplast abundant and specific, and utilizes the PEG for Na+ sequestration into the vacuole. The gene (AtNHX1) conferring salt tolerance was cloned to engineer salt tolerance in cotton,. The gene obtained from *Arabidopsis* was cloned in the plant expression vector pJit60 under the *2X35S* promoter. The cloning of the AtNHX1 expression cassette in plant transformation vector pBS 389 has been completed. The transformation of the construct into cotton is in progress. The transgenic cotton plants will be intercrossed for the pyramiding of both genes (*AVP1 & AtNHX1*) in a single genome.

6. Initiatives for the Improvement of Cotton Fiber Quality

The improvement of cotton fiber properties is important to enhance the quality of cotton and its subsequent use in the cotton industry, thus, the initiation of a program to improve cotton fiber quality through genetic engineering. The program looked into each of the four established cotton fiber development stages, fiber initiation, elongation, secondary cell wall deposition and maturation.

To capture the genes involved in fiber development, cDNA libraries from the first three fiber development stages were prepared. Key genes, such as those encoding expansins, lipid transfer proteins (LTPs), tubulins and actins, were screened in the cDNA libraries. Fibers isolated at 10 days after pollination (DAP) were found to represent a stage where almost all the fiber development genes could be detected. The 10 DPA cDNA library was therefore selected for the isolation of expressed sequence tags (ESTs) aimed at developing DNA chips for fiber development specific genes. About 10, 000 clones from the library were catalogued and further cataloging is in progress.

Key genes reported to be involved in fiber elongation (expansins) in cotton were utilized to modify the expression of expansins from 0-20 DPA using the *LTP3* promoter. Expansins are known to play an important role in improving the fruit size in different plants. The constructs are now under transformation process to *G. hirsutum* var. Coker. Diverse sources of expansins from other natural fibers having long staple length may be utilized to improve cotton fiber. The *Calotropis procera* fiber cDNA library was constructed from fast growing fibers. The four expansins identified in this plant were used to make plant expression cassettes to transform them into cotton. The transformation of these genes in *G. hirsutum* var. Coker using *Agrobacterium* is in progress.

The transformation of genes in elite cotton cultivars is currently achieved by *Agrobacterium*-mediated transformation initially in *G. hirsutum* var. Coker. The transgenic Coker is subsequently crossed with the elite cultivars to transfer the transgene. Pollen-mediated transformation has been selected to transfer the genes of interest directly into the elite cotton cultivars. Initial experiments have been successful in obtaining fertile seeds with transformed marker genes. It is expected that this technology will prove its worth in the transformation of elite cotton cultivars.

7. Cotton Genomics

Cotton genomic studies were initiated in 1997 using random amplified polymorphic DNA (RAPD) analysis to estimate genetic diversity among different cotton cultivars released in pre-CLCuD. The study concluded that low genetic diversity is the major cause of the CLCuD epidemic. Similarly, high genetic similarity (89.55 percent) was reported among the cotton cultivars released in the post-CLCD era (Rahman *et al.*, 2002), which may invite new disaster. The ploidy level of the cultivated cotton species, together with the selection pressure applied by the search for improvements in lint quality, has resulted in a very narrow genetic base. Thus, there is a need to introgress novel traits from diploid progenitor(s) species, especially *Gossypium arboreum* L., which requires suitable markers for use in MAS.

Our research efforts have focused on the identification of DNA markers associated with different traits, such as resistance to CLCuD. Three genes identified to be involved in disease resistance, including a suppressor (Rahman *et al.*, 2005) and linked DNA markers were used to develop two cotton cultivars: NIBGE-2 (Reg. no. Pak 022845, PI 647088), and NIBGE-115 (Reg. No. GP-880, PI 643972). Similarly, preliminary linkage maps for different defense umbrella traits were also developed. We have also identified QTLs for drought tolerance and for high quality fiber traits by tagging with DNA markers. The linkage maps developed using an intraspecific population are more practical, however, coupled with a concern of low genome coverage. Despite the spectacular advances made with conventional DNA markers (RAPD, microsatellite and AFLP), a need for novel genomic tools remains, such as single nucleotide polymorphisms (SNPs), to identify further polymorphisms in cotton that will be useful in developing high resolution maps. In the future, more attention will be devoted to producing consensus genome maps, which will be important to achieve the aim of 'breeding by design' in cotton improvement programs.

8. Biosafety Rules in Pakistan

Pakistan signed the Convention on Biological Diversity (CBD) at the UNCED in Rio de Janerio, Brazil on June 5, 1992, and ratified it on July 26, 1994. Although Pakistan has yet to ratify the Cartagena Protocol on Biosafety (CPB), it signed the treaty on June 4, 2001, when it was opened for signature by the UN.

In exercise of the powers conferred by section 31 of the Pakistan Environment Protection Act, 1997 (XXXIV of 1997), the Ministry of Environment of Pakistan came up with the Pakistan Biosafety Rules 2005 and promulgated this in April 2005 (www.environment.gov.pk). The National Biosafety Guidelines (NBG) were prepared through a national forum of all the stakeholders and experts, including the academic institutions, R&D organizations, industry, NGOs, human rights societies and international experts, such as the UNEP/GEF consultant Dr. Julian Kinderland of the UK. These guidelines have been prepared keeping in view the guidelines prepared by UNIDO, FAO, WHO, UNEP and all the developed and developing countries. Modifications to suit Pakistan's unique and specific socio-economic and geographic conditions were also integrated.

After passing through several developmental stages, this document was presented to the Ministry of the Environment in January 2000. The biosafety guidelines were enacted with the promulgation of the Pakistan Biosafety Rules in 2005. The mechanisms of monitoring and implementing of the NBG is built on a three tier system as specified in the Biosafety Rules 2005, namely, 1) National Biosafety Committee (NBC); 2) Technical Advisory Committee (TAC); and 3) Institutional Biosafety Committees (IBCs) at the institutional levels.

Most of the crop improvement activities using modern biotechnology are focused on cotton and rice, which are among the top five crops of Pakistan. Brassica, chickpea, chilies, cucurbits, potato, sugarcane, tobacco and tomato have recently been included in the list. Transgenic plants of these crops have been obtained, however, field evaluation has been hampered by the delays in the approval of the biosafety guidelines. With the recent enforcement of the Pakistan Biosafety Rules, locally developed or imported GM crops can now be tested in the field. No GM crop has so far been approved for commercial cultivation in Pakistan.

At present, various government offices in Pakistan are responsible for different issues related to the biosafety of GMOs. Issues related to the CBD, the Cartagena Protocol on Biosafety, Pakistan Biosafety Rules 2005, and the National Biosafety Guidelines are handled by the Ministry of Environment, while the WTO and Geographical Indications issues are under the jurisdiction of the Ministry of Commerce. Intellectual property rights (IPRs) are the responsibility of the Pakistan Patent Office of the Ministry of Industries; copyrights issues are the responsibility of the Ministry of Education; and Plant Breeder Rights are handled by the Ministry of Food, Agriculture

& Livestock. Many NGOs (Action Aid, Oxfam SDIP, SUNGI, World Web etc) are also actively involved in raising several issues related to biotechnology and biosafety of GMOs.

Recently, Pakistan has addressed IPR issues by forming an independent body, the Intellectual Property Organization Pakistan (IPOP, http://www.ipo.gov.pk). This agency has streamlined access by establishing one point of entry, unlike in the past when "trademarks" were the responsibility of the Ministry of Commerce, "copyrights" were processed at the Ministry of Education and "patents" at the Ministry of Industries.

Pakistan has been a participatory country in the Food and Agriculture Organization (FAO) project for Capacity Building in Biosafety of GM crops in Asia, and through this project, a number of scientists have been trained in risk assessment and risk management of GM crops, and in GMO testing. Pakistan has developed the facility for GMO testing at NIBGE. This institute is ISO-9001-2000 certified and provides GMO test facilities using ELISA/ Immunostrip Test and qualitative detection through PCR for 35S promoter, Nos terminator, *Npt11*, Hygromycin, GFP, BAR, *Cry 1Ab*, *Cry 1Ac* and *Cry 2Ab* (Zafar *et al.*, 2004).

With a National Biosafety Regulatory Framework in place, the National Biosafety Centre (a directorate of NBC) has recently been established in the Ministry of Environment, Islamabad, to monitor and evaluate incoming proposals. So far, NIBGE and CEMB have submitted applications to the NBC for field trials and commercialization of their versions of Bt cotton. NIBGE has applied for commercialization of its Bt cotton variety "IR-FH-901". It is worth to mention that NIBGE sought special permission in 1997 from the Ministry of Environment under the "Voluntary Code of Conduct for release of GMO into the environment" to conduct field trials for risk assessment of GMOs. CEMB has also submitted an application to NBC for the approval of the GM cotton varieties "MNH-93" and "CIM 482" with Bt genes (*Cry1Ab, Cry1Ac & Cry2A*) and to conduct field trials with the collaboration of a local and a multinational company.

9. Conclusion

Public sector institutions are exclusively involved in R&D of cotton biotechnology in Pakistan. GM cotton lines with many vital traits (virus resistance, insect resistance, salinity/drought tolerance and improved fiber quality) are at various stages of development/evaluation. Regulatory and legislative systems, though partly in place, are weak and need strengthening. A strong and vibrant regulatory system based on scientific principle is the only solution for the safe, effective and legal release of GM cotton in the country. Above all, the availability of legally approved cotton varieties is the only solution to check the illegal spread of Bt cotton that could have long term negative consequences.

References

Arshad, M., Y. Zafar and N. Islam (2006). New virus threaten cotton production in Pakistan. ICAC Recorder USA: Vol.XXIV(4) December 2006: 13-18

Asad, S., W.A.A. Haris, A. Bashir, Y. Zafar, K. A. Malik, N.N. Malik and C.P. Lichtenstein (2003). Transgenic tobacco expressing geminiviral RNAs are resistant to the serious viral pathogen causing cotton leaf curl disease. Archives of Virology: 148 (12): 2341-52.

Bashir, K., T. Husnain, T. Fatima, Z. Latif, S. A. Mehdi and S. Riazuddin. (2004). Field evaluation and risk assessment of transgenic indica basmati rice. Molecular Breeding 13: 301-312.

Khan S. A., Y. Zafar, R.W. Briddon, K.A. Malik and Z. Mukhtar (2006). Spider venom toxin protects plants from insect attack. Transgenic Research 15: 49-357.

Mansoor, S., R.W. Briddon, S.E. Bull, I.D. Bedford, A. Bashir, M. Hussain, M. Saeed, Y. Zafar, K.A. Malik, C. Fauquet and P.G. Markham (2003). Cotton leaf curl disease is associated with multiple monopartite begomoviruses supported by single DNA ☐. Archives of Virology (2003): 000:1-18.

Mansoor, S., R. W. Briddon and Y. Zafar.(2006). Geminivirus disease complexes; the threat is spreading. Trends in Plant Sciences, Vol.11(5): 209-212.

Rahman M., D. Hussain and Y. Zafar. (2002). Estimation of genetic divergence among elite cotton (*Gossypium hirsutum* L) cultivars/genotypes by DNA fingerprinting technology. Crop Science, 42: 2137-2144.

Rahman, M., T.A. Malik, D. Hussain and Y. Zafar.(2005). Genetics of resistance to cotton leaf curl virus disease in Gossypium hirsutum. Plant Pathology 54: 764-772.

Zafar, Y. (2002). Emergence of a new cotton leaf curl virus strain in Pakistan. ICAC Recorder USA: June 2002: 19.

Zafar Y., S. Mansoor, S. Asad, R. Briddon, M. Idrees, W. Sultan Khan, P. Markham, J. K. Brown and K. A. Malik. (2003) Genome Characterization of whitefly-transmitted geminivirus of cotton and Development of Virus-resistant Plants through Genetic Engineering and conventional Breeding. ICAC Recorder USA, June: 2003: 12-16.

Zafar, Y., M. Asif and A. M. Khalid. 2004. Capacity building in biosafety of genetically modified crops: GMO detection. NIBGE-FAO National Training Workshop on GMO detection.14-17 June, 2004. Pakistan. ISBN: 969-8189-10-8.

17. Biotech Cotton in South Africa: a Farmers' Perspective

Phenias Gumede
South Africa

Introduction

South Africa is one of the first countries, and the only one in Africa so far that has adopted genetically modified cotton for commercial production. Insect-resistant cotton has been produced since the 1997/98 growing season, followed by herbicide-tolerant cotton in the 2001/02 season, and by stacked-gene cotton in the 2005/06 season. In the 1998/99 production season, biotech cotton made up 10 percent of all cotton planted, and this increased to 84 percent in 2002/03. It is estimated that 90 percent of all cotton currently planted in South Africa are biotech varieties.

Commercial Cotton Growers

According to research undertaken by the University of Pretoria in 2002 involving large-scale cotton farmers, 39 percent indicated that the most important benefit of Bt cotton is that it saved on pesticide and application costs. The second most important reason for adoption of Bt cotton was that it gave them peace of mind about bollworms. When asked on the benefits of insect-resistant cotton, 77 percent of farmers indicated peace of mind and the freedom to go on with other farming activities as the most important. Most commercial cotton farmers are also involved in other farming activities during the cotton season. Using hired labour, scouting and spraying is especially difficult over the Christmas to the New Year period, as this is the crucial time in the production cycle of cotton in South Africa.

The cotton farmers also indicated other indirect benefits of biotech cotton like the reduction or elimination of pesticide spraying that has allowed predator insects to flourish. The major disadvantage of biotech cotton is the relative high cost of the seed and the technology fee. Also both large- and small-scale farmers still have to use chemicals to control insects like jassids and aphids, as these pests are not controlled by biotech cotton. These pests are now increasingly becoming the main cotton pests and therefore a major concern. Not only are costs of controlling them escalating, resulting in rising production costs, predator populations are also under threat due to the increase in spraying.

The personal experience with biotech cotton of a commercial cotton farmer planting wheat and cotton on 1600 ha under irrigation in the Limpopo Valley area of Weipe, on SA's Northern border, can be summarised as follows:

In 1993, bollworms, aphids and red spidermite affected cotton profits to such an extent that the farmer was considering to altogether discontinue cotton production. During this period, and before the introduction of biotech cotton, cotton yields were not only declining, but up to 15 sprays were required during a normal growing season. Since adopting biotech cotton, the number of insecticide sprays required are now down to about 3/season, mainly for secondary insects such as jassids. The farmer also reports that for the past eight years, it has not been necessary to spray even once for aphids and red spidermites, as these insects are controlled by beneficial natural predators which have increased in numbers due to the reduced spraying of insecticides. According to the farmer, biotech cotton has also had a very positive effect on the environment. He says that he now sees predator birds such as falcons and owls on the farm that were not present in the area for some time.

This farmer is of the opinion that cotton farming would not have been sustainable if normal conventional cotton farming practices were followed. In his experience, farming with biotech varieties is the most profitable and sustainable way of cotton farming.

Small-Scale Cotton Farmers

The major small-scale cotton production areas presently in South Africa are in Tonga in Mpumalanga, and Makhathini in northern KwaZulu-Natal. The area under cotton production and the number of cotton producers vary from year to year, and depend on the availability of production credit and on the price of cotton.

Small-scale cotton farmers have reacted positively to the introduction of genetically modified cotton seed with Makhathini showing an increase in the adoption of biotech cotton from 7 percent in 1997/98 to 75 percent in 1999/00 to over 90 percent currently.

This impressive increase in adoption of biotech cotton by small-scale farmers can mainly be attributed to the success of the farmers who first adopted the new technology compared to those farmers who did not. For small-scale farmers adopting the new technology, the most important benefit of biotech cotton was the savings on pesticide costs. In rural areas where infrastructure, transport and services are almost non-existent, managing pest infestation in crops is a major problem. Pesticide application implies huge difficulties for small-scale cotton farmers: with a low level of education the mixing of pesticides and calibration of knapsack sprayers are problematic. Applying pesticides is also very much a labour intensive activity for small-scale farmers. Walking with a knapsack sprayer on his back, a farmer has to cover a distance of between 10-20 km/hectare, taking almost a day to complete the task. Water is often a scarce commodity and has to be fetched from communal water points. By the time a farmer has noticed the bollworms, bought his pesticides and started to spray, severe damage to the crop has already been done.

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

References

Cotton South Africa

Willemse, J. Commercial cotton grower, Weipe, Limpopo Province, SA.

Gouse, M, Kirsten J.F. and Jenkins L. (2003) "Bt Cotton in South Africa: Adoption and the impact on farm incomes amongst small-scale and large- scale farmers." Agrekon Paper, Vol 42, No 1

Ismael, Y., Beyers L.,Thirtle, C. (2001) "Smallholder adoption and economic impacts of Bt cotton in the Makhathini Flats, Republic of South Africa." DFID Natural Resources Policy Research

18. Current Status of Biotech Cotton in Thailand

Banpot Napompeth
Founder & Adviser
National Biological Control Research Center (NBCRC)
Kasetsart University, Bangkok 10900, Thailand

Introduction to cotton cultivation in Thailand

Thailand has a land area of about 517,000 sq. km. and is located in the monsoon area of the continental Southeast Asia. Its major crops are rice, corn, rubber, cassava, kenaf, coconut, sugarcane, mungbean, soybean, sorghum, peanut and cotton.

Cotton cultivation under the humid tropics as it is in Thailand is characterized by "rain growth" that supports more insect pests. Subsistence cultivation of the native short-staple cotton, *Gossypium arboreum*, has been traditionally practiced for centuries. Cotton improvement and development began as late as the 1960s when the American upland cotton was obtained from Cambodia. In the yield trial of the long-staple "Cambodian" cotton in 1960, it was found that plant number 13 showed the best performance. Thus, Sukhothai (SK) 13 was the very first cotton variety recommended for commercial cultivation in Thailand (DOA, 1973).

Other cotton varieties from the United States introduced into Thailand included Stoneville 213 in 1961, Reba B-50 in 1963, Deltapine Smooth Leaf in 1972, and Reba BTK 12 in 1973. Breeding and improvement programs using these varieties have resulted in Tak Fah variety (Reba BTK 12 x Stoneville 213) in 1978. Further improvement of cotton varieties has also resulted in other cotton varieties such as Nakhon Sawan and Si Samrong 60, both widely cultivated in Thailand until today. Other early-maturing cotton varieties introduced into Thailand are Camd 1-2, Coker 201 Okra Leaf, and Delcot 277. G 115-7 was also introduced from the Ivory Coast (DOA, 1973; CDC, 1978).

The average holding size for cotton cultivation is 2-3 acres. In 1968, the area under cultivation was about 133,120 ha but decreased to about 60,800 ha in 1978, mainly because of heavy infestation of insect pests, particularly the cotton bollworm complex dominated by the cotton bollworm (*Helicoverpa armigera*) and other sucking insect pests such as the cotton leafhopper (*Amrasca biguttula*), cotton aphid (*Aphis gossypii*), cotton whitefly (*Bemisia tabaci*), thrips (*Scirtothrips dorsalis*), and mites. Intensive chemical sprays (10-15 or 20 sprays per season) made cotton cultivation unprofitable, and thus the area planted to cotton was greatly reduced. The market price of cotton also determines the annual acreage. Larger cotton acreage normally follows the year with higher price, and when cotton price drops, the total cotton acreage in the following season also drops. In order to meet domestic demand of the textile industry, cotton was imported from the United States, Turkey, Sudan, the former USSR, Brazil and Nicaragua during the 1970s and 1980s.

The aim of the then 4th Five-Year National Economic and Social Development Plan (1977-1981) was to increase the area under cotton to 164,000 ha in 1981. However, such a target has not been attained until now. During the 1980s, it was recommended that the annual acreage under cotton should be more or less around 50,000 ha to support a socio-economic condition of ca 40,000 families of cotton growers.

International Cotton Advisory Committee statistics show that cotton yield in Thailand in 2000 was only 140 kg/ha or a total of only 12,000 tons of which 2,000 tons were exported. At the same time, Thailand had to import 302,000 tons of cotton to meet the demand of the textile industry. In order to be self-sufficient in cotton production at the current yield, Thailand has to expand cotton area from ca 50,000 ha to at least 1.25 million ha!

Cotton pest management evolution in Thailand

In the 1960s, the key insect pests of cotton were the cotton leaffolder (*Sylepta derogata*) and the sucking pest complex consisting of the cotton leafhopper, cotton aphid and cotton whitefly. Among the bollworms were the pink bollworm (*Pectinophora gossypiella*), and the spiny bollworm (*Earias vittella*), while the so-called American bollworm or the cotton bollworm (*Helicoverpa armigera*) was then considered as a minor insect pest. The cotton bollworm (*H. armigera*) has been, since the 1970s, the dominating key insect pest of cotton that justified using all classes of synthetic insecticides, chlorinated hydrocarbons, organophosphates and carbamates.

Cotton pest control in Thailand has also gone through the patterns of classical phases of the evolution of pest control measures theorized by Smith (1969), namely, the *Subsistence Phase* characterized by small-scale subsistence and home-use cultivation; *Exploitation Phase* when modern agricultural practices, including irrigated large-scale plantation type cultivation and chemical pest control, were adopted and intensively applied, with profitable returns; *Crisis Phase* characterized by pests building up resistance to pesticides and consequently, more intensive, frequent, and higher doses of chemicals needed to control insect pests resulting in greatly reduced profits; *Disaster Phase* characterized by the inability to make cotton cultivation profitable because of insect pest problems; and finally the *Integrated Control and the Recovery Phase* when the concepts of pest management or integrated pest management (IPM) were adopted to make cotton production profitable again.

Typical insecticides recommended and employed for the control of cotton bollworms during the Exploitation, Crisis and Disaster Phases of Smith (1969) in Thailand were: toxaphene/DDT mixture; toxaphene/DDT/methyl parathion mixture; Sumithion/Thuricide mixture; Nuvacron/DDT mixture; Azodrin/endrin mixture; Sumicidin; Ripcord; Gusathion; Sevin, etc. These insecticides for cotton bollworms were also recommended for other lepidopterous pests of cotton, such as the cotton leafworm (*Spodoptera litura*), and the cotton semilooper (*Cosmophila flava*) (Napompeth, 1981).

Attempts on biological control were also carried out using the native predatory pentatomid, *Eocanthecona furcellata*, and the introduction of the chrysopid, *Chrysoperla carnea*, from California in the 1970s. Nuclear polyhedrosis virus (NPV) concoction and its crude preparations were also employed with variable success.

Regulation of GMOs/LMOs in Thailand

After the establishment of the National Center for Genetic Engineering and Biotechnology (BIOTEC) in 1983, an *Ad Hoc* Biosafety Subcommittee was appointed in 1990 to draft the Biosafety Guidelines in Genetic Engineering and Biotechnology for Laboratory Work and for Field Work and Planned Release. These were completed and approved by the National Science and Technology Development Agency (NSTDA) in June 1992, with the establishment of the National Biosafety Committee (NBC) in January 1993. These guidelines were revised, merged and simplified in November 2004 to become the Biosafety Guidelines for Work Related to Modern Biotechnology or Genetic Engineering (NBC, 2004). These guidelines are not legal-binding but are mandatory to all researchers and funding agencies providing research grants in modern biotechnology.

The existing laws applicable for the regulation of genetically modified (GM) or biotech crops are the Plant Quarantine Act B.E. 2507 (1964), and the Plant Variety Protection Act B.E. 2542 (1999). The Plant Quarantine Act 1965 was amended in 1999. Under this Act, the Ministerial Notification issued in 1994, 2000 and 2003, has prohibited the import into the country of a total of 89 plant species known to have undergone genetic modification, except for research purpose. A permit to import any of these plant species is to be granted in accordance with the Guidelines for Application for Permit to Import or to be in Transit of Prohibited Articles into the country for study and research purpose issued by Department of Agriculture (DOA), Ministry of Agriculture and Cooperatives (MOAC) in 2001.

Following the notification prohibiting the import of 40 GM plant species into the country in 1994, an additional 49 species were included in 2003, totaling 89 species. All the regulations on genetically modified organisms (GMOs) were under the *Ad Hoc* Biosafety Subcommittee until late 1992, the National Biosafety Committee (NBC), and under BIOTEC until 1993. From 1994, onwards, all regulations related to GM crops fall under the authority of DOA, MOAC. The regulations related to GMOs or living modified organisms (LMOs) for food, feed or processing (GMOs/LMOs-FFP) are under the authority of the Food and Drug Administration (FDA), Ministry of Public Health (MOPH). FDA has issued a notification on mandatory labeling of GM corn and GM soybean products in 2003.

The overall policy on production of biotech crops in Thailand is yet to be comprehensively formulated. The policy will not set to develop genetically modified plants, animals and microorganisms, or attempt to use genetically modified organisms in production and processing for trade, unless scientifically sound assessment and evaluation has been conducted to warrant their safety.

However, in April 2001, the Cabinet yielded to pressure from anti-GMO NGOs to "ban" all the field trials of GM or biotech crops in the country until the enactment of a biosafety law. The NGO representative in the National Biosafety Committee (NBC) advocated that the draft biosafety law should be completed within six months, but there has been no progress since then. Finally, the draft Biosafety Law under the Ministry of Natural Resources and Environment (MONRE), the Convention on Biological Diversity (CBD) and the Cartagena Protocol National Focal Point is still being subjected to the process of public hearings as of today.

Field trials of biotech cotton in Thailand

Applications to carry out field study and research on a new hybrid system of GM corn, seed production of virus resistant seed of GM cantaloupe and squash, seed production of GM tomato with altered ripening characteristics, and seed production of FLAVR SAVR tomato during 1992-1993 were endorsed and "approved" by the *Ad Hoc* Biosafety Subcommittee and the National Biosafety Committee. Only the field trials for seed production of FLAVR SAVR tomato were carried out and completed in 1993.

After the Ministerial Notification of June 1994 prohibiting the import of known 40 biotech plant species, except for study and research purposes, the DOA approved imports of biotech cotton by Monsanto in 1995 (Cry1Ac Btk), 1996 (Bt cotton), 1997 (NUCOTN 32B, NUCOTN 33B,Bt), and 1999 (R&R cotton).

Although the trials conducted in confinement as well as the small-scale isolated and large-scale field trials under DOA experiment stations and farmers' fields have been completed, deregulation was not granted due to accusations by the anti-GMO NGOs in 1999 that the biotech cotton escaped from the farmers' field trials and "contaminated" the non-GM cotton fields. The Bt Cotton Fact-finding Mission appointed by the then Deputy Minister of MOAC, and led by the DOA Director-General, carried out field sampling in the cotton-growing areas of Loei, Phetchabun, Lop Buri and Nakhon Ratchasima provinces during October-November 1999. Bt cotton was detected in some of the samples collected from Loei and Lop Buri provinces but was not detected in samples collected from Phetchabun and Nakhon Ratchasima provinces. It was then concluded that to a very small extent, Bt cotton had "contaminated" non-GM cotton fields.

This event led to the "ban" on biotech crop field trials that was imposed by the Cabinet on April 2001 until a biosafety law is adopted, no doubt yielding to pressure mounted by the anti-GMO NGOs and their allies. This unjustifiable moratorium has since caused an impasse on biotech crop research and development in Thailand, with no resolutions or any provisional alternative legal measures put in place. What is there is a "wait-and-see" situation on the current status of the biosafety law as its final version awaits approval and enactment.

In a worsening of the situation, the Cabinet yielded to additional demand from anti-GMO NGOs in August 2005 that all research work on GM crops confined to the laboratory in government research agencies and universities be discontinued, and that all GM crops being investigated be destroyed. With no questions asked, the Cabinet passed an order for the concerned ministries, research agencies and universities to comply with the demand from the anti-GMO NGOs. No actual inquiries were made on the likely threats, dangers or hazards posed by the GMOs or LMOs to the environment or human health.

The reality of biotech cotton in the fields

No matter how persistent the anti-GMO NGOs' campaign against biotech crops is, it is well known that cotton growers are eager to adopt biotech cotton to lessen the damage caused by cotton bollworm infestation and to reduce the number of chemical sprays. Bt cotton seed was made available by the agricultural supply and seed retailers and was freely traded among the growers. Some growers saved their Bt cotton seed for further sales and for their own cultivation. As a result, both recommended non-GM cotton and GM cotton have been cultivated extensively in the country since 2000. The growers in the former cotton-growing areas who had abandoned its cultivation because of insect pest problems have begun to grow "Bt cotton" once again as their cash crop.

On 25 February to 2 March 2003, ISAAA (Thailand) organized a GM cotton study tour for Thai cotton grower representatives, an NBC representative and a press correspondent, to observe the cultivation and research related to Bt cotton in Maharashtra, Madhya Pradesh and Andhra Pradesh, India. Although it was late in the season and long after the cotton harvest, the Thai cotton growers were very impressed with the farmers' remnant cotton fields and experimental plots and with the research facilities for GMO detection at the Central Institute for Cotton Research in Nagpur. They also observed the Bt cotton cultivation promotion campaign carried out by the farmers' association in Hyderabad.

Field surveys conducted by ISAAA (Thailand) in some selected cotton-growing areas in Nan province in the northern highland area and in Phetchaburi province southwest of Bangkok in May 2003 revealed that the cotton growers preferred to grow Bt cotton over the locally recommended cotton varieties. In Nan province, local ginning factories assisted the farmers in growing Bt cotton by networking farmers' cooperatives with sources of Bt cotton seed. In the Kaeng Krachan district of Phetchaburi, where cotton cultivation was earlier abandoned, the farmers had began to grow cotton again using only Bt cotton.

It is ironical that no government authority is interested in finding out the facts on the extent of Bt cotton cultivation in the country in order to obtain data, analyze the situation and arrive at appropriate management strategies. DOA, MOAC seems to ignore the situation so that the department would not be blamed for not exercising its authority properly. By law, all the "illegal" Bt cotton plants found in the fields must be confiscated and destroyed. But it is anticipated and foreseeable that exercising such an action might cause a sociological impact among the poor growers. Thus, *"taking no action is the best action"* has been adopted.

Bt cotton cultivation in Sa Kaeo and Kanchanaburi

Nevertheless, the Advisory and Steering Working Group on the Development of Thailand National Biosafety Framework has decided to carry out field surveys to gather facts and compile current data and information on the extent of GM crop cultivation in Thailand, with emphasis on cotton and soybean. For biotech cotton, the surveys were carried out from July to November 2005 in selected key cotton-growing districts of Sa Kaeo and Kanchanaburi provinces.

Sa Kaeo, an eastern province of Thailand adjacent to Cambodia; Phayao, a province in the northern highland area north of Chiang Mai and south of Chiang Rai; and Kanchanaburi, a western province adjacent to Myanmar, are at present the country's largest cotton-growing provinces. In 2004, the area under cotton in Sa Kaeo, Phayao and Kanchanaburi provinces were ca 2,430 ha, 2,054 ha, and 1,053 ha respectively, totaling 5,537 ha, accounting for about half of the country's total cotton acreage in 2004 of 10,560 ha. Bt cotton cultivated in these provinces and other provinces is uniformly called by the nickname *"Fai Sa Mo Lek"* which means *"Iron boll cotton."* Local cotton varieties, Si Samrong 60 and Nakhon Sawan are also being cultivated in these provinces.

In the field surveys conducted from 25-27 September 2006 at Khlong Hat district of Sa Kaeo province, 33 out of 39 cotton samples collected from eight separate plots, or 84.62 percent, were biotech cotton. However, at Sai Yok district, Kanchanaburi province, the field survey conducted during 6-9 November 2006 revealed that 98 out of 144 cotton samples collected from 24 separate plots, or 68.06 percent, were biotech cotton. An interview also revealed that 82.3 and 77.8 percent of the cotton growers at Sa Kaeo and Kanchanaburi, respectively, grew *"Fai Sa Mo Lek"* or Bt cotton.

Conclusions

Although the cultivation of biotech cotton in Thailand is considered "illegal" by the government, in reality it is being widely cultivated in almost all cotton-growing provinces of the country. The question thus arises on how to cope with the current situation, and what could be compromised. Most certainly for the government authorities concerned, this means that they can no longer ignore the issue and that they should seek, with no further delay, the most appropriate and immediate measures that will be acceptable to all stakeholders concerned.

References

Cotton Development Committee (CDC). 1978. Proceedings of Seminar on Cotton. Kasetsart University Auditorium. 13-17 November 1978. Bangkok.301 pp. (in Thai).

Department of Agriculture (DOA). 1973. Handbook of Agriculture 1973. Department of Agriculture. Bangkok. 419 pp. (in Thai).

International Cotton Advisory Committee (ICAC). 2000. World Cotton Map. Rabobank and ICAC. The Netherlands.

Napompeth, B.1981. Thailand national profile on pest management and related problems. Special Publication 4. National Biological Control Research Council, Kasetsart University. Bangkok, Thailand. 105 pp.

National Biosafety Committee (NBC). 2004. Biosafety guidelines for work relate to modern biotechnology and genetic engineering. BIOTEC. National Science and Technology Development Agency, NSTDA), Ministry of Science and Technology. Bangkok. 167 pp.

Smith, R.F. The new and the old in pest control. Proceedings Accademia Nazionale dei Lincei, Rome (1968). 366(138): 21-30.

18. Overview on the Achievements, Challenges and Future Prospects of Cotton Research and Production in the Sudan

Elfadil. A. Babiker
National Coordinator for Cotton Research
Gezira Research Station, Cotton Research, Sudan

Abstract

As the Cotton Research Program (CRP) marked its 100th year (Massey Jubilee) in 2004, it had already released more than 50 varieties and improved lines, and formed various recommendations on cultural practices, pest management and fibre quality improvement. However, adoption at the farm level was disappointing, with yield averaging 400-450 kg lint/ha, as compared to ideal yield (as per research results) of 1200-1500 kg lint/ha and a world average of 700 kg lint/ha. Declining yields have been a normal course for the last 80 years, despite the variations in financial policies adopted throughout the years. To reverse this trend and to bridge the gap between research and the farm, future research and technology transfer should embark upon precision agriculture, where site-specific approach rather than general blanket recommendations should be promoted.

Cotton is a very inefficient crop in terms of input utilization, due to its perennial and indeterminate growth habit and a tendency to divert assimilates to vegetative growth. Therefore, under conditions of poor input management such as improper timing of fertilizers and insecticide application, excessive growth (rank growth) is eminent. Accordingly, the recent release of new early maturing varieties that are resistant to diseases and insects may improve yields and lower the cost of production. However, farmers should have a better understanding of the physiology of cotton and how it relates to input use. Combined with technical follow-up, and financial, social and policy measures that enhance attended farming, farmers will be able to optimize the benefits from adopting these new early maturing varieties.

Introduction

Cotton farming is a livelihood issue and a way of life for more than 300,000 Sudanese farmers. The intensive labor demand in cotton farming and cotton-based industries provides employment, reduces poverty, improves lives and encourages settlement in rural areas. The year 2004 marked the 100th anniversary of the Cotton Research Program. However, cotton has been grown commercially in the Eastern Sudan (Tokar Delta), where traditional organic farming is still in practice, since 1867. Cotton has a strong presence in Sudanese agriculture, both as a leading cash crop and as the mainstay economy. In the 1920s, the Cotton Research Program (CRP) started recruiting scientists of the highest eminence in agriculture like Massey, Gregory, Growther, Lambert, Bailey, Knight and Innes. Experiments of the pioneer expatriate scientist contributed to the scientific base for cotton research and were not only of great importance to the Gezira Cotton Crop, but have been recognized as seminal outside the Sudan.

It is worth noting that during the period prior to the mid-'70s, cotton production research was entrusted to the Empire Cotton Growing Corporation (ECGC). With headquarters in the Sudan, the ECGC conducted research in several countries (including the Sudan, Uganda, Tanzania, Nigeria, South Africa and Rhodesia) and derived numerous research findings that benefited not only the African member countries but the cotton producing countries at large. Genetic control of the devastating bacterial blight disease is a world-renowned research achievement where the pioneer work was centered in the Sudan with the regional variety testing including most of the countries in the region. Worthy of special mention is the marking of the 50th anniversary (Golden Jubilee) of the establishment of the Gezira Research Station with an international symposium on "Cotton Growth in the Gezira Environment" (Sidig and Huges, 1969). Twenty six papers on various aspects of cotton research were presented and published as symposium proceedings. These proceedings have been incorporated into a Sudanese Cotton Handbook, which has contributed significantly to the scientific knowledge on cotton research prior to the 1970s.

The broader objectives of the CRP are:

1. Varietal improvement for higher yields, earliness, disease and insect resistance, ensuring that the basic fibre quality characteristics of the traditional types (i-e Sakel and Lambert) remain essentially unchanged;
2. Diversification of intrinsic quality by breeding new styles and varieties to meet the wider requirement range to meet demands of the textile and spinning industry;
3. Productivity improvement through multidisciplinary technological packages that fit into the integrated crop management (ICM) strategy;
4. Providing different stakeholders with innovations and decision-making assistance, corresponding to the needs of specific production environments; and
5. Reducing stickiness caused by whitefly honeydew secretions, which is a puzzling bottleneck for the Sudan cotton market.

Framework and Achievements of the CRP

To date, the framework for cotton research is pillared on the following specialties: variety improvement, cotton stickiness and testing technology, and agronomy and crop physiology.

1. Variety improvement

1.1 Breeding

The contribution of conventional breeding in variety development was summarized by Knight (1954), Low (1962), Rose (1959), Siddig (1965) and Kheiralla (1969). The initiative started with the introduction of the variety Domains Sakel (D.S.) in the beginning of the last century. With the outbreak of the leaf curl and bacterial blight diseases, the program was geared towards developing resistant varieties using the available gene pool. The gene combination B2B6 gave adequate and durable protection against the prevailing bacterial blight race.

The appearance of a new race in the late sixties prompted the search for a new gene combination. Sources of resistance were identified and different gene combinations ($B_2B_3B_6B_7B_9$) conferring satisfactory resistance were availed (Mustafa and Babiker, 2006). The leafcurl, on the other hand, was controlled in the barbadense material through the incorporation of a single partially dominant gene. The number of released varieties and registered lines to date exceed 50 but only 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). Encouraging results from crossing and selection programs have, however, produced hundreds of lines that could replace current varieties that have long been grown in the region.

Biotechnological research is focused on the production of double haploid (DH) cotton and molecular tagging of useful traits for DNA marker-assisted selection. We are especially interested in incorporating the DH technology in our hybrid breeding project. Through DH, we can fix the hybrid vigour and overcome the problem of hybrid seed production. The program also contains very promising advanced lines resistant to the new race (post-Barakat) of the bacterial blight, in addition to resistance to Fusarium wilt. Morphological characters such as okra leaf, hairiness, and frego-bracts that reduce the insect-pest damage has also been a focused research area.

1. 1. 1. Past released varieties and registered lines

Categorized on spinning quality as follows:

Extra Fine count (EFC)	X1530 X1730A Bar XL1 Barakat Barakat 82 Barakat 90 DS	Bar 14/25 VS1 VSA VS82 Tyiba EX (73) BK Barakat S
Fine count (FC)	Huda Huda 82 ASH A34 High Count Acala (HCA) Barac (69) 2	Shambat x Acala (93) H Maryoud Maryoud 82 Shambat B
Medium Count (MC)	Barac (67)B Shambat C Reba W296 Acala 83 Sudac-K Acala (93)M Bar Wilds40	XA1129 Acala4-42 Wild Sus 1/16 Almac (80) 15 Almac (69) 29 Barhop 11 Barhop 7
Coarse Count (CC)	Albar (57) 12 Acrain Acrain 83 Nuba 95 BA-1303 BA-1308 N.T. 205/41 P 32/81	BarSP84 Bar 7/8.1 Bar 11/7 N.T. 58/39 511/D P77/81 N.T. 96/40 Deltapine

1.1.2. Newly released varieties

More recently (2004/05 and 2005/06), nine varieties were released (Mustafa *et al.*, 2004 and 2006; Elsiddig and Mursal, 2004 and Ahmed *et al.*, 2006) as listed below:

A. Siddig (Sudan Pima):
This variety is a selection from a cross between Barakat-90 and Pima and is resistant to Fusarium wilt. It is an extra-fine count cultivar excelling Barakat-90 in length, strength and fineness.

B. Hadi (Okra-leaf Barakat):
A selection from a cross between Barakat-90 and Pima Okra, this is a fine count cultivar, is early-maturing, high-yielding and with better GOT than Barakat 90.

C. Kheiralla (CRP-12):
A high count Acala (HCA), has jassid and bacterial blight resistance and harbors less whiteflies (with lower stickiness). It excels Nour(93) in yield and in fineness.

D. Hamid (BB-82):
This medium-count, high-yielding, early-maturing genotype is resistant to bacterial blight and jassids, has low preference to whiteflies and harbors less population of ABW and has emerged as a suitable choice for short duration low management system. Hence, it can be recommended for Integrated Crop Management (ICM) due to its open canopy, low leaf area, medium hairiness and earliness. It can also be fitted into short-season production systems in rain-fed areas, where problems of late drought are encountered.

E. Knight (BB-90):
Due to its improved yield, resistance to bacterial blight, and yarn strength, BB90 is a medium count cultivar recommended for irrigated areas with high bacterial blight disease incidence (B2B3B6B7B9). It can be used to enhance the deteriorating fiber bundle strength of medium staple cotton.

F. Abdin (BB-80):
The fine count cotton variety Abdin, derived from the cross (Barac(67)B× BLCABPD8S-1-90) F1 × (Shambat collection 19-95-1 × CAHUGARPIH-1-88) F_1, was evaluated across ten environments in the Sudan in 2003/05. Abdin gave average lint yield advantage of 61 percent over Shambat-B. It has a ginning out turn percentage of 36 compared to 29 for Shambat-B and a growth period of 150-160 days, 15-25 days earlier than Shambat-B. Abdin also possesses the ($B_2B_3B_6B_7$) gene combination that confers resistance to the bacterial blight disease races prevalent in the Sudan. In addition, it has a higher degree of tolerance to jassids. The fibre testing data revealed that Abdin has a sizeable increase in fibre strength and count spinning product as compared to Shambat-B, and is therefore of value in the spinning and textile industry. Abdin emerged as a suitable cultivar for bridging the fine-count cotton quality gap that had been created by the commercial withdrawal of Shambat-B owing to its ginning problems.

G. Burhan (BB-65):
Burhan gave average lint yield advantage over Albar A (57) 12, Almac (80) 15 and Acrain of 37, 29 and 21 percent, respectively. Stability measures found Burhan to be the most stable and widely adaptable to rain-fed cotton growing areas of the Sudan. Burhan has high resistance to bacterial blight disease and a higher degree of tolerance to jassids. It has a growth period of 135-140 days, 10-15 days earlier than Albar A (57) 12. Since Burhan has a shorter growth period, it can best be suited for rain-fed areas more prone to late drought problems.

H. Khalifa (Damazin):
Khalifa excelled Albar (57) 12, Almac (80) 15 and Acrain by 32, 30 and 30 percent in seed cotton,

and by 50, 41 and 32 percent in lint yield, respectively. Khalifa is suitable for cotton growing areas in the tested environments, and has stable seed cotton and lint yield. It matures earlier than the other genotypes tested, as demonstrated by the reduced number of days to first flowering. Khalifa is resistant to both old and new races of *Xanthomonas compestris* pv *malvacearum*. Thus, the high stable seed cotton and lint yield, adaptability to the testing environments, earliness of maturity and blight resistance of Khalifa makes it a suitable cultivar for commercial production in rain-fed areas of Southern Kordofan and Blue Nile regions of the Sudan.

I. Wagar:
Wagar gave an average seed cotton (36, 25 and 15%) and lint yield advantage (73, 21 and 16%) over Shambat-B, Barac (67) B and Nour, respectively, and produced seed cotton and lint yield comparable to that of Hamid. Moreover, Wagar exhibited higher ginning out turn surpassing that of Hamid. Wagar is suitable to a wide range of environments, and has stable seed cotton and lint yield. It has longer fiber length, and higher spinning and better micronare values than Hamid. It requires fewer days to the onset of flowering and boll opening, matures earlier than the commercial varieties. Wagar requires 145 mean days to last picking, fewer compared to Nour, Barac (67) B and Shambat B which require 180, 165 and 165 days, respectively. Wagar excelled all tested genotypes in the Gadarief rain-fed area, producing 68 percent seed cotton and lint yield advantage over the traditional cotton variety Acrain.

1.2 Enrichment, characterization and maintenance of cotton genetic resources

1.2.1. Evaluation of Shambat collection

During the last century, the ECGC had transferred all its germplasm from the West Indies (Trinidad) to the Sudan to enrich the Shambat Type collection. The collection, including the different forms of the diploid species and the tetraploid land races, is maintained by growing the seeds every three years at two sites (Shambat and Medani) and by keeping samples of the seeds in the gene bank. The cotton germplasm in the Sudan contains very diverse materials ranging from 40 members of the diploid wild species ($2n = 2x = 26$) of the 8 genomes (A,B,C,D,E,F,G,K) to over 800 accessions of the land races of the tetraploids ($2n = 4x = 52$).

It is noteworthy that the Sudan is home to *Gossypium anomalum* (member of the B genome) and to the land race *G. hirsutum var. punctatum*. Despite the difficulty of transferring desirable characters from the diploid species to the commercial *hirsutum* and *barbadense* cotton, successful transfers have been achieved, including the incorporation of the bacterial blight resistance genes from *G.arboreum*, *G.herbaceum*, hairiness from *G. anomalum*, and increased oil content from *G. sturtü*. Gene transfers are relatively easier from the tetraploid accessions. About 50-80 accessions are characterized each season. Morphological, phenological and yield-related characteristics have been documented for about 200-250 of wild and cultivated specimens, and the process is continuing. From these studies several lines have been introduced in crosses with commercial cultivars.

1.2.2. Variety maintenance

Maintaining an existing cultivar is more important than the development of a new one, and is one of the major concerns of the program. Nevertheless, seed mixtures have been reported, despite presence of morphological differences and colour markers. Accordingly, plants that are true to type were strictly selected from the commercially grown varieties in the propagation plots at GRS as a nucleus for the foundation seeds. This is in addition to the routinely rigorous purification program of the breeder seeds.

1.2.3 Seed production

Cottonseed multiplication and certification is a top priority of the CRP. The program continues to conduct intensive training courses on seed production for the personnel of various cotton growing corporations. The program provides seed to breeders and supervises the production of foundation seeds in cooperation with the production schemes throughout the country.

2. Cotton Stickiness and Fibre Testing Technology

All the material, from single plant selections through lines and varieties, are tested for stickiness, lint out turn and quality characteristics. The laboratory also performs studies on spinability (classical and open-end micro-spinning) and determines yarn strength and defects (neps and irregularities).Outstanding achievement has been made in the investigation into the causes and control of stickiness in cotton, a problem which could threaten the market prospects of Sudan's cotton. Thus, integrated crop management packages to control insect-induced stickiness in the field were made available as early as the 1980s. Recent research (Gourlot and Frydrych, 2001) indicated a variety of progress in the understanding and management of stickiness to improve the marketability of cotton produced in zones affected by stickiness.

3. Agronomy and crop physiology

The development of agronomic practices that improve crop productivity and quality while also reducing production costs has been the focus of several research activities. Short- and long-term field studies were performed to determine optimum agronomic inputs for cotton (Burhan, 1971; Burhan, 1968; Burhan and Mansi, 1970; Babiker *et al.*, 2005; Ali *et al.*, 2002; Elhassan and Abdelatif, 2005). Factors studied included planting date (Elsiddig *et al.*, 2005) plant density, irrigation, fertilizer, soil preparation, growth regulators, plant physiology and crop modeling (Babiker, 2004). These studies generated technical packages that fit both ecologically different zones and variability in crop duration. Despite the success of the technical packages recommended, the implementation at the farm level is disappointing due to the lack of commitment by farmers and lack of follow-up by experts.

Challenges to cotton production and future prospects

Cotton production faces crucial challenges such as: stagnating low yields, escalating costs of production, low cotton prices, inefficient pest management, stickiness, yield variability within the same location, late cotton picking, subsidies in the developed countries, diminishing production capital and competition from other crops. These obstacles diminish the benefits from continuing cotton cultivation. Yet, all the parties involved in cotton production are optimistic that Sudanese cotton will regain and even surpass its former position through the enhancement and implementation of site-specific and low-input technologies. Significant improvements in institutional, policy and financial aspects must be made if the cotton industry is to prosper and achieve competitiveness in the global economy. These challenges have to be taken up by the whole spectrum involved in the cotton sector, i.e., researchers, extension workers, production agronomists, economists and policy makers.

1. Stagnating low yields

Sudan average lint yield is about 400-450 kg/ha, estimated to be 1/3 of research plots, and 2/3 of the world average (700 kg/ha), and by far lower than that of Egypt (800 kg/ha) and Syria (1300kg/ha) .

2. Pest management

The major insect pests are: bollworms, jassids, thrips, flea beatles, whiteflies and aphids (Bindra, 1985). Chemical pesticides have been the main method of control but they present the following problems:

1. High cost (30-40% of total cost)
2. Non-selectivity of the insecticides used, being toxic to both insects and natural enemies
3. Flare up of secondary pests: i.e. bollworm used to be secondary pests in cotton and now, it is a major pest
4. Development of resistance to pesticides by insects like bollworms and whiteflies

Pest management has been a challenging problem to researchers, hence, the FAO-sponsored IPM project conducted in the 1980s and 1990s (Abdelrahman *et al.*, 2002). The project recommended the following:

1. Increase of the Economic Threshold Level (ETL)
2. Gradual adoption of non-spraying cotton strategy
3. Adoption of cost effective pesticide management practices
4. Implementation of an IPM strategy that includes insecticides as a component, but not as the only method of control

3. Yield variability within the same location

Farmers in the same location usually obtain varying yields, despite using the same inputs. The variability is very high, in the range of 300-1200 kg/ha of lint. Decisive factors to enhance productivity include: efficient agronomic management of basic cultural practices, better understanding of the inputs (water, fertilizers, insecticides) and interactions (i.e. avoiding rank growth and unnecessary use of insecticides).

4. High cost of production

Costs continue to increase, even though yields are stagnating. To sustain cotton production, we have to increase yield by optimizing inputs, thus decreasing production cost. Accordingly, characterization of farmers according to their efficiency in crop management is very important. Input use should be tailored to farmers' management practices and the expected yield levels. Some farmers use high rates of nitrogen (3N) and neglect proper management of the other inputs (e.g., poor timing of insect control). For instance, excessive nitrogen use causes problems such as rank growth, delayed maturity, difficult defoliation and poor insect control. Combining soil tests with petiole nitrate monitoring during the season will enable the farmer to use optimal nitrogen levels. This technique consistently leads to good yields and maintains vegetative/reproductive balance of the crop.

5. Machine planting and picking

Both cotton planting and picking were abandoned during the 1970s and 1980s due to socio-economic reasons. Today, however, labour shortage is a chronic problem, hence, the need to introduce planting and picking machinery.

6. Instrument-based fiber quality testing

The price of cotton is determined by its quality. Spinners prefer an instrument-based classing system rather than the traditional manual classing that has been used to determine quality. Accordingly, the Sudan had started adopting the HVI classing system but sees the necessity for more instruments and personnel training.

7. Physiology of cotton plant as related to input use

Cotton has a complex growth habit (perennial and indeterminate), making proper management a crucial factor, especially with regard to the timing of and the rates of input application as related to the environment. As such, cotton favours vegetative growth at the expense of floral and fruit production. Source-sink relationship changes in favour of excessive vegetative growth (rank growth) under high levels of nitrogen, frequent irrigation, poor plant thinning and bollworm attack. Hence, future research should emphasize the judicious application of inputs as related to the physiology and biology of the crop. Extension experts and field agronomists have to be trained in this area.

8. Precision agriculture

This should be a future focus area for research, since for the last 80 years, all recommendations have been of a general nature. The release of new early maturing varieties, intra-field variability, variations in farm management and finance ability, targeted yield levels and reluctance by some farmers to use costly high inputs, emphasize the need for precision agriculture to target site specific problems.

Conclusions

It is a reality and a challenge that both stagnating low yield and escalating production costs threaten cotton production in the Sudan. Adding to the challenge of growing cotton is its very complex growth habit (perennial and indeterminate) where poor management of inputs leads to excessive vegetative growth at the expense of floral and fruit production.

Efforts to maximize yields for the past 80 years using the old late-maturing varieties have proved to be uneconomically feasible. Measuring up to the challenge, the Cotton Research Program has bred under zero-insecticide conditions, early-maturing and short-stature varieties (e.g., Hamid, Abdin, Burhan and Damazin). Commercial adoption of these new varieties will ultimately reduce the cost of production. Furthermore, the early-maturing varieties, being of short duration, are more adopted to precision agriculture where site-specific constraints such as water and labour shortage and pest infestation at the end of the season are anticipated.

Accordingly, timing and proper rates of fertilizer and insecticide application, scheduled irrigation, recommended plant population and their interactions with the phenology of the crop, as well as the farmers' daily attendance to their cotton plants, are all critical in maximizing source to sink balance and in improving yield. Future research should therefore be embarked on in search of new techniques that will enable a better understanding of cotton response as related to input use, and raise production efficiency as well. If such understanding materializes and is supported by attended farming, the stagnation in cotton productivity will definitely be reversed.

REFERENCES

Ahmed, S.B., A.M. Mustafa and E.A. Babiker. (2006) Proposal for the release of K5 (Wagar) as a medium count cotton for irrigated and rainfed areas In: Proc. of the Variety Release Committee, Khartoum, June 23, 2006

Abdelrahman, A..A., R.M.Ahmed, A.H. Mohmed and A.A. Malik (2002). Cotton production without the use of insecticides. In: Proceedings of the workshop on the effect of pesticides, fertilisers and other chemicals residues on agricultural products, Khartoum, October 12, 2002.

Babiker, E.A.(2004) "Effect of plant density and spatial arrangement on growth, quality and yield of morphologically varying cotton varieties." *Gezira J. Agric.Sci.*, 2(1) 16-25

Babiker, E.A, A.A. Hamada and S.B. Ahmed.(2005) Response of cotton to NP fertilizers and cropping sequences on irrigated vertisols of the Rahad Scheme. In: Proc. of the 38th Meeting of the Crop Husbandry Committee, 38:117-124.

Bindra, O.S. (1985) "Relation of cotton cultivars to the cotton pest problem in the Sudan Gezira." *Euphytica*, 34:856-894.

Burhan, H.O. and M.A..Taha. (1974) Effect on new cotton varieties of sowing date, plant population and time of fertilizer application. In: Cotton Growing Review, 51:177-186.

Burhan, H.O. (1968) "Factors involved in the fluctuation of cotton yields in the Sudan Gezira." *Sudan Agric. J.* 4:37-49.

Burhan, H.O. and M.G. Mansi. (1970) "Effect of N, P and K on yields of cotton in the Sudan Gezira." *Exp. Agric.*, 6: 279-286.

Burhan, H.O. (1971) "Response of cotton to levels of fertilzer nitrogen in the Gezira." *Cotton Growing Review* 48: 116- 124.

Elhassan, O.M.A and A.H. Abdelatif, (2005). Effect of intra-row and inter-row spacing on growth, yield and fibre quality of rainfed cotton in the Blue Nile State. In: Proc. of 38th Meeting of the Crop Husbandry Committee. Medani, 38, 107-111.

Elsiddig, A.A.and I.E. Mursal. Proposal for the release of CRP12 (kheiralla) as a High Count Acala (HCA) for Irrigated Schemes. 2004

Elsiddig, K., Elhassn, O.M.A. and Babiker,E.A. (2005) Optimum sowing date of cotton in the Gezira: A research review of past experiment work. Bulletin No.1.

Gourlot, J-P and R. Frydrych. (2001) Improvement of the marketability of cotton produced in zones affected by stickiness. Technical paper on the project CFC/ACAC/11.

Hamada, A.A.and M. Knapp. (1998) Effect of weeds on Barac(67)B and Sudac-K cotton varieties at Rahad Scheme. Pilts, 16(2):69-76.

Kheiralla, A. I. Varieties in the Gezira environment. (1969) Medium Staple Cotton. In: Cotton Growth Environment. M.A.Siddig and L.C.Hughes(eds) ARC.

Knight, R. L. (1954) "Cotton breeding in the Sudan." *Emp. J.Expt.Agric.*, 22: 68--92 and 176-84.

Low, A. (1962) New cotton varieties for the Sdan. Emp. Cott.Gr. Rev. 39,95-105.

Mustafa, A..M.and E.A. Babiker. (2006) "Knight: A new cotton cultivar with a broad resistance to bacterial blight." *U of K.J. Agric. Sci.* 14(1) 64-77.

Mustafa, A..M., E.A. Babiker and O.M.A. Elhassn. (2006) Proposal for the release of new high yielding and early maturing cultivars, Damazin and BB65(Khalifa and Burhan) for rain-grown sector in the Sudan. Variety Release Committee, June 7, 2006, Khartoum.

Mustasfa, A..M., E.A. Babiker, H.O. Kanan, A.H. Abdellatif and G.E. Abdelmagid. (2004) Proposed for the release of the new cotton cultivars (BB82 and BB90) resistant to bacterial blight. In: Proc.of the Variety Release Committee, Medani, December 11, 2004.

Mustasfa, A..M., Babiker, E.A., H.O. Kanan, A.H. Abdellatif and G.E. Abdelmagid. (2006) Proposed for the release of the new cotton cultivars BB80 (Abdin) a new fine count long staple cotton variety. Variety Release Committee, June 23, 2006. Khartoum.

Naiem A.Ali, Abdelaziz A., El Fadil H.,.Babiker, E. A, Mirghani, S., Kamal Hamid, Mostaf A.M. Idris, Momer M., and Abdall M.A. (2002), Response of irrigated cotton to fertilizer form and rate. Crop Husbandry Committee. Medani.

Rose, M. F. (1959) Cotton research and the development of the commercial crop in the Sudan. Emp. Cott. Gr. Rev. 36, 252-62.

Siddig, M. A..and L.C. Hughes. (1965) New and prospective cotton varieties for the Sudan.Emp. Cott. Gr. Rev., 42.

Siddig, M.A. (1969), Cotton Growth in the Gezira Environment.Symposium to mark the fifth Anniversary of the Gezira Research Station, 6-9, January 1969.

Appendix 1.

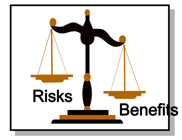
Regulatory procedures for Genetically modified crops in India

Dr C. D. Mayee

Chairman, Agricultural Scientists Recruitment Board, New Delhi

Regulating GMOs

- Food Safety
- Environmental Safety
- Agronomic Benefits
- Transparency



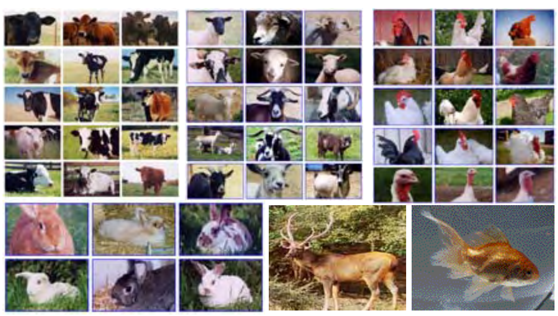
** No technology is 100% risk free*

REGULATIONS AND RISK ASSESSMENT

Why regulate?

Case by case study to gain experience and familiarity with particular crop- transgene combination

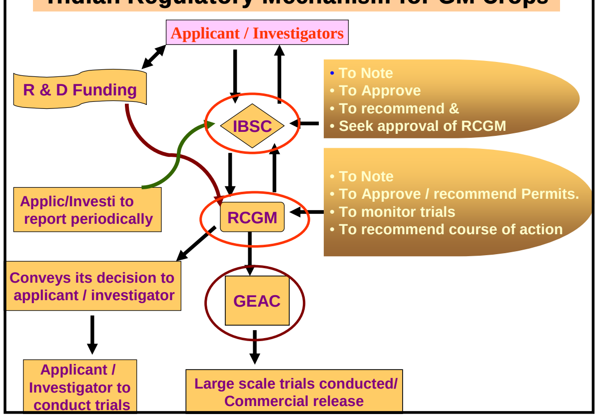
Environmental biosafety and human safety issues..

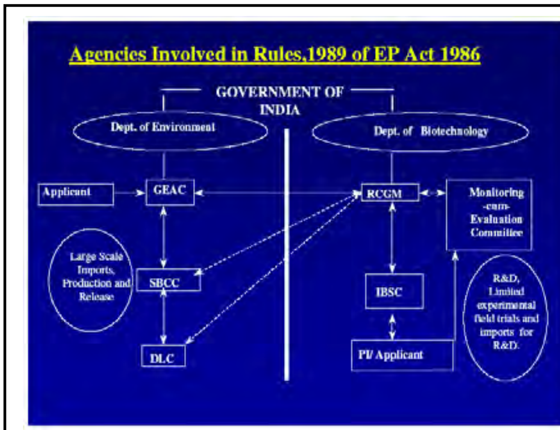


Current Regulatory Mechanism for GMOs: Statutory Bodies

1. Recombinant DNA Advisory Committee (RDAC)
2. Institutional Biosafety Committee (IBSC)
3. Review Committee on Genetic Manipulation (RCGM)
4. Genetic Engineering Approval Committee (GEAC)
5. State Biotechnology Coordination Committee (SBCC)
6. District Level Committee (DLC)

Indian Regulatory Mechanism for GM Crops





General Biosafety, Risk Assessment and Agronomic Parameters for Transgenic Development

- Genetic and Molecular parameters include copy of inserted gene, stability of gene expression level, efficacy
- Environmental Parameters include have transfer, implication of out crossing, effect
- Toxicity parameter include effect on small laboratory (rats & rabbit) animals effect on livestock animals (goat) effect on birds and effect on fish
- Allergenicity parameters primary skin irritation in rabbits/ pigs, Irritation of mucus membrane test in rabbit / guinea and immunological response in suitable animal systems
- Agronomic parameters efficacy of genetic phenotype, yield, growth and development, response to major disease and insect pests, quality parameters economic cost and benefits ratio

Applicant – New gene/event: Submits data on copy number, stability & locus

BIOSAFETY EVALUATION

First stage (1-2 years): RCGM permission for lab, greenhouse & restricted open field cultivation within notified premises: Gene-flow evaluation, biosafety/disposal monitoring by IBSC & report to RCGM

Second stage (1-2 years): GEAC permission for multilocation large scale trials (1 acre) @ two per state to evaluate environmental biosafety, safety to livestock, birds, fish, non target insects and soil health. Food/feed safety testing by notified institutions. Monitored by MEC

Gene / event biosafety clearance by GEAC

Approved event

AGRONOMIC EVALUATION

Notified genotype: One year agronomic evaluation

Non-notified genotype: 2-3 year agronomic evaluation

Co-ordinated project, SAU & state variety release committee

Commercial notification/release by GEAC

Traceability/monitoring by SBCC/DLC

ICAR (AICCIP) evaluation

North Zone: 8	Central Zone: 12	South Zone: 10
Irrigated: 8 Punjab Faridkot, Ludhiana, Abohar, Muktsar Haryana Hisar, Sirsa (CICR) Rajasthan Sriganganagar, Hanumangarh	Irrigated: 6 Gujarat Surat, Junagadh, Anand M. P. Indore Maharashtra Rahuri (Summer) Rainfed: 6 Gujarat Bharuch Rajasthan Banswara M. P Khandwa Maharashtra Akola, Nanded, Nagpur	Irrigated: 5 Tamilnadu Coimbatore, Srivilliputur Karnataka Raichur, Sriguppa A. P Lam, Guntur Rainfed: 5 Karnataka Dharwad, Mysore, Shimonga A. P Nandyal, Adilabad

Bollgard Development Process in India

Mahyco Institutional Biosafety Committee established in 1995

Review Committee on Genetic Manipulation

Import of Seeds 1996

Backcrossing

Studies conducted

Environmental Safety		Bioefficacy & Agronomic benefit		Biosafety studies	
Pollen Flow	1997	Field trials		Allergenicity Study	1998
Aggressiveness Studies	1997-98	Year	No. of trials	Goat Study	1998
Pollen flow	2001	1998-99	40	Cow Study	2001
Soil Studies	2001-02	1999-02	19	Buffalo Study	2001
Gene stability	2001	2000-01	25	Chicken Study	2001
		2001-02	376	Fish Study	2001
				Protein detection in oil	2001

GEAC Data Evaluation 2001

Seed Bulk-up Approval 2001

Commercialization 5th April, 2002

Bt-cotton genes

1. *cry1Ac*
2. *npt-II* (neomycin phosphotransferase II conferring Kanamycin resistance)
3. *aad* gene (3"(9)-O-aminoglycoside adenylyltransferase (AAD), which allowed for the selection of the *Agrobacteria* on media containing spectinomycin or streptomycin.
4. *cry2Ab2*
5. *uidA* genes (β-D-glucuronidase (GUS) marker protein
6. nopaline synthase gene (NOS 3') from *Agrobacterium tumifaciens,* which provides the signal for mRNA polyadenylation.
7. petunia heat shock protein 70 (HSP70)
8. chloroplast transit peptide from the *Arabidopsis thaliana* 5-enolpyruvyl shikimate-3-phosphate synthase gene (CPT2), which is used to direct the protein to the chloroplasts.

Introduction of Bt cotton in March 2002

Beyond doubt, Bt-cotton represents the best of state-of-art technologies

NGO noise

Bt Cotton and Quality Pesticides Ensured Prosperity of Malwa Farmers

In 2002, Cotton production was 13.07 lakh bales only

In 2006 Cotton production doubled & touched 23.95 Lakh Bales due to farsightedness of Captain Govt. and its commitment to farmers

The Tribune 7 Dec 2006

Adoption of Bt Cotton in India (2002-06)

Year	Area under Bt Cotton (ha)	No. of Farmers
2002-03	44,500	-
2003-04	100,000	-
2004-05	500,000	300,000
2005-06	13,00,000	10,00,000
2006-07	38,00,000	23,00,000

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

Event	North	Central	South	Total Hybrids
Bollgard-I (Mahyco)	12	29	26	48
Bollgard-II (Mahyco)	0	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

GM Crops in Public Sector (ICAR) India: Various Stages of Development

Stage I: Large scales Field trials in Progress (Close to Commercial Approval)

Crop	Trait (Character)	Gene	Variety
Cotton	Resistance to bollworm	Cry 1 Ac	Bikaneri Narma, Sahana, LRA 5166, RG-8
Rice	Resistance to Yellow Stem Borer	Cry 1 Ac	IR 64
Potato	Quality Improvement	Ama 1	Kufri Chipsona 1, Kufri Badshah, Kufri Chipsona 2
Brinjal	Resistant to shoot and fruit borer	Cry 1 abc	Pusa Purple Long
Tomato	Resistant to Leaf Curl Virus	Rep antisense	Pusa Early Dwarf
Tomato	Salinity and Drought Tolerance	Osmotin	Pusa Ruby
Mustard	Salinity and Drought Tolerance	Osmotin	Pusa Jaikisan

Source: ICAR, DBT, GEAC

Stage II: Greenhouse Stage

Crop	Trait (Character)	Gene (s)
Cotton	Resistance to Bollworm	Cry 1 F, Cry 1 Aa3
Rice	Resistance to Yellow Stem Borer	Cry 1 Aa3
Wheat	Drought Tolerance	DREB 1a
Sorghum	Resistance to Stem Borer	Cry 1 Ab
Brinjal	Resistance to Shoot & fruit borer	Cry 1 Ac
Potato	Resistance to PVY	Rep sense, Rep antisense
Potato	Resistance to Late Blight	RB gene
Tomato	Delayed Ripening	Antisense ACC Synthase
Tomato	Improved Texture	Expansin

Source: ICAR, DBT, GEAC

Stage III: Laboratory Stage

Crop	Trait (Character)	Gene (s)
Cotton	Resistance to Leaf Curl Virus	Antisense Cp
Rice	Sheath Blight Resistance Salinity & Drought Resistance Submerge Tolerance	Chitinase DREB 1a TPSP PDC
Maize	Resistant to Stem Borer	Cry 1 Ab
Chickpea	Resistant to Pod borer	Cry 1 Aa 3
Pigeon pea	Resistant to Pod borer	Cry 1 Aa 3
Soybean	Resistant to Mungbean Yellow Mosaic Virus	Rep sense Rep Antisense
Mustard	Salinity and Drought tolerance Resistant to aphids	DREB1 a . Z a 112 Lecilin gene
Tomato	Salinity and Drought tolerance Resistance to Leaf Curl Virus Resistance to Fruit borer	DREB 1a Truncated Rep gene. Antisense Rep Cry 1Aa 3
Banana	Resistance to Banan Streak Virus Ressistance to Bunchy top Virus Resistance to Fusarium wilt	Rep Anitsense Cp gene Anti microbial Peptide gene
Papaya	Resistance to Leaf Curl Virus Resistance to Ring Spot Virus	Rep Antisense, Cp sense Cp Antisense
Cassava	Resistance to Mosaic Virus	Rep Antisense
Potato	Resistance to Mosaic & Leaf Curl Virus	Cp Sense, Rep Antisense
Groundnut	Resistance to Tobacco Streak Virus	Cp Sense, Cp Antisense

Source: ICAR, DBT, GEAC

GM Crops in Private Sector & other Institutes in India

Crop	Company	Transgene
Brinjal	Mahyco Mumbai	Cry1 Ac
Cotton	62 Bt Cotton Hybrids released, 106 in large scale trials, Four events commercially approved. Many under consideration 1) Bollgard I (Cry 1Ac gene) 2) Bollgard II (Cry 1Ac & Cry 2 Ab genes 3) GFM Event (Cry 1 Ab & Cry 1 c genes 4) Event 1 (Cry 1 Ac gene)	
Cauliflower	Mahyco, Mumbai Sungrow, New Delhi	Cry 1 Ac Cry 1 Ac
Cabbage	Sungrow New Delhi	Cry 1 Ac
Chickpea	ICRISAT Hyderabad	Cry 1 Ac & Cry 1 Ab
Groundnut	ICRISAT Hyderabad	IPCVcp:IPC Vreplicase gene

Contd..

Crop	Company	Transgene
Maize	Monsanto, Mumbai	CP4 EPSPS
Okra	Mahyco, Mumbai	Cry 1 Ac
Pigeonpea	ICRISAT Hyderabad Mahyco, Mumbai	Cry 1 Ab + SBTI Cry 1 Ac
Rice	Mahyco, Mumbai	Cry 1 Ac
Sorghum	Mahyco, Mumbai	Cry 1 Ac
Tomato	Mahyco, Mumbai	Cry 1 Ac

Source: DBT, GEAC, ICRISAT, Mahyco

Post release assessment

State Level Committee

1. Additional Director of Agriculture - Chairman
2. Joint Director of Agrl. - Member
3. Assistant Director of Agriculture (Cotton) - Member
4. Representative from Agrl. University - Member
5. Representative from NGO - Member
6. Representative from Dept. of Seed Certification - Member

District Level Committee

1. District Joint Director of Agriculture - Chairman
2. Deputy Director (Plant Protection) - Member
3. Representative from Agrl. University - Member
4. Representative from farmer association - Member
5. Representative from Dept. of Seed Certification - Member

Bt Transgenic Cotton – Environmental Issues

- In case of Bt transgenic cotton, the environmental issues needed to be addressed are :
- Gene flow through pollen or soil residue to
  a. Closely related cutligens
  b. Wide and weedy relatives
  c. Soil bacteria-concern being not much of Bt gene but the selectable marker *npt* II
  d. Resistance to Bt in insects

REGULATORY FRAMEWORK IN INDIA

1. GOVERNMENT RULES FOR GMOs
2. RECOMBINANT DNA GUIDELINES, 1990
3. GUIDELINES FOR RESEARCH IN TRANSGENIC PLANTS, 1998
4. SEED POLICY, 2002
5. PREVENTION OF FOOD ADULTERATION ACT
6. THE FOOD SAFETY AND STANDARDS BILL, 2005
7. PLANT QUARANTINE ORDER 2003
8. TASK FORCE ON APPLICATION OF AGRICULTURAL BIOTECHNOLOGY
9. DRAFT NATIONAL ENVIRONMENT POLICY, 2004
10. DRAFT NATIONAL BIOTECHNOLOGY STRATEGY 2005

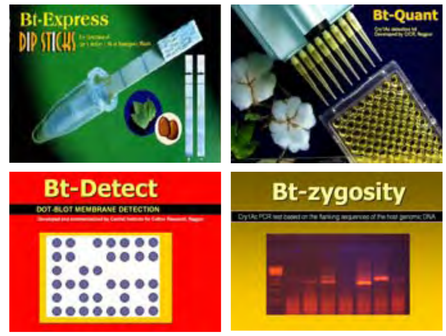
Government Commitment for Biosafety

- Notified Rules in 1989 for activities relating to research, development and use of Genetically Modified Organisms (GMOs) and their products.
- MoEF is the focal point for all biodiversity related matters including biosafety; and
- Ratified the Cartagena Protocol in January, 2003.

Legal and illegal GMOs

Detection kits and quality control

Bt-detection kits developed by CICR



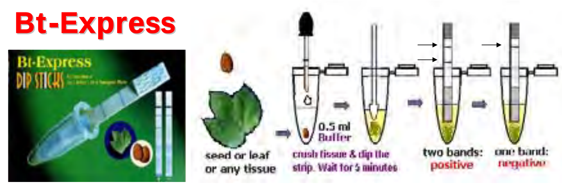
Bt Detection Kits

Application

1. Confirm genetic transformation & evaluate expression levels
2. Facilitate marker assisted selection in back-cross programs
3. Quality Control

Users:
Farmers, Seed Industry, Researchers, Enforcement agencies, Government Officials, NGOs and Extension workers.

Bt-Express



Bt-Express: A pack of 50 strips. Cost Rs. 20 per test, but free for farmers

A simple immunological test that can be used directly in the field by even illiterate farmers. The kit is provided with complete material adequate for 50 tests. It can be used for seeds, leaves, squares, flowers or any tissue. The test takes 10 minutes to complete and gives a clear result in detecting the presence/absence of the Bt-toxin in the tissue tested. Highly popular with farmers. Thus far 5 lakh strips have been sold from CICR.

Development of Transgenic Bt Cotton in China and Its Implication for IPM

Dr. Jingyuan Xia
NATESC, MOA, China
March 2007, Pakistan

Main Topics

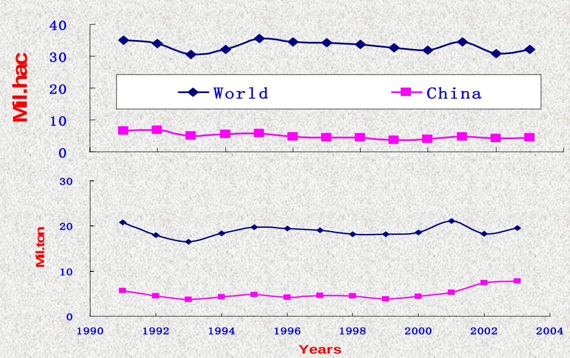
1 General Information
2 Development of Bt Cot.
3 Performance of Bt Cot.
4 Implication for IPM
5 Profitability Analysis
6 Aspects in Future

1 General Information

1.1 Cotton region
1.2 Cotton production
1.3 Cropping system
1.4 Major pest species
1.5 Damage & yield loss

1.1 Cotton region

1.2 Cotton production



1.3 Cropping system

GM Crops in Private Sector & other Institutes in India

Crop	Company	Transgene
Brinjal	Mahyco Mumbai	Cry1 Ac
Cotton	62 Bt Cotton Hybrids released, 106 in large scale trials, Four events commercially approved. Many under consideration 1) Bollgard I (Cry 1Ac gene) 2) Bollgard II (Cry 1Ac & Cry 2 Ab genes 3) GFM Event (Cry 1 Ab & Cry 1 c genes 4) Event 1 (Cry 1 Ac gene)	
Cauliflower	Mahyco, Mumbai Sungrow, New Delhi	Cry 1 Ac Cry 1 Ac
Cabbage	Sungrow New Delhi	Cry 1 Ac
Chickpea	ICRISAT Hyderabad	Cry 1 Ac & Cry 1 Ab
Groundnut	ICRISAT Hyderabad	IPCVcp:IPC Vreplicase gene

Contd..

Crop	Company	Transgene
Maize	Monsanto, Mumbai	CP4 EPSPS
Okra	Mahyco, Mumbai	Cry 1 Ac
Pigeonpea	ICRISAT Hyderabad Mahyco, Mumbai	Cry 1 Ab + SBTI Cry 1 Ac
Rice	Mahyco, Mumbai	Cry 1 Ac
Sorghum	Mahyco, Mumbai	Cry 1 Ac
Tomato	Mahyco, Mumbai	Cry 1 Ac

Source: DBT, GEAC, ICRISAT, Mahyco

Post release assessment

State Level Committee

1. Additional Director of Agriculture - Chairman
2. Joint Director of Agrl. - Member
3. Assistant Director of Agriculture (Cotton) - Member
4. Representative from Agrl. University - Member
5. Representative from NGO - Member
6. Representative from Dept. of Seed Certification - Member

District Level Committee

1. District Joint Director of Agriculture - Chairman
2. Deputy Director (Plant Protection) - Member
3. Representative from Agrl. University - Member
4. Representative from farmer association - Member
5. Representative from Dept. of Seed Certification - Member

Bt Transgenic Cotton – Environmental Issues

- In case of Bt transgenic cotton, the environmental issues needed to be addressed are :
- Gene flow through pollen or soil residue to
  a. Closely related cutligens
  b. Wide and weedy relatives
  c. Soil bacteria-concern being not much of Bt gene but the selectable marker *npt* II
  d. Resistance to Bt in insects

REGULATORY FRAMEWORK IN INDIA

1. GOVERNMENT RULES FOR GMOs
2. RECOMBINANT DNA GUIDELINES, 1990
3. GUIDELINES FOR RESEARCH IN TRANSGENIC PLANTS, 1998
4. SEED POLICY, 2002
5. PREVENTION OF FOOD ADULTERATION ACT
6. THE FOOD SAFETY AND STANDARDS BILL, 2005
7. PLANT QUARANTINE ORDER 2003
8. TASK FORCE ON APPLICATION OF AGRICULTURAL BIOTECHNOLOGY
9. DRAFT NATIONAL ENVIRONMENT POLICY, 2004
10. DRAFT NATIONAL BIOTECHNOLOGY STRATEGY 2005

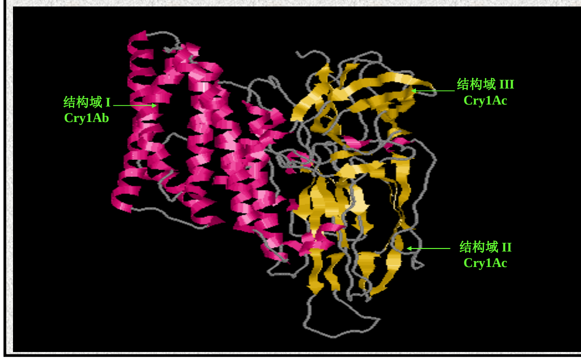
Government Commitment for Biosafety

- Notified Rules in 1989 for activities relating to research, development and use of Genetically Modified Organisms (GMOs) and their products.
- MoEF is the focal point for all biodiversity related matters including biosafety; and
- Ratified the Cartagena Protocol in January, 2003.

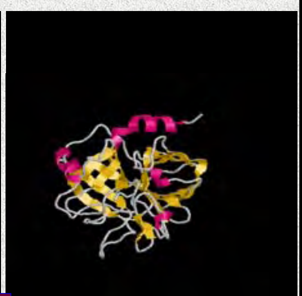
2.1 Gene construction

- Single gene: Bt
- Double genes: Bt+CpTI
- Multi-genes:
  - Bt+CpTI+Go
  - Bt+CpTI+GNA
  - Bt+CpTI+herb-resist.
  - Bt+CpTI+male-sterile

♦ Single (Bt)



♦ Double (Bt+CpTI)



GFM Cry1A CpTI

♦ Triple (Bt+CpTI+Go)

♦ Triple (Bt+CpTI+GNA)

♦ Triple (Bt+CpTI+herb-resit.)

♦ Triple (Bt+CpTI+male-sterile)

2.2 Transformation

- Agro-bacterium: >5% with 5-7 months
- Pollen-tube: 2%
- Gene-gun: >8%
- Scale: 8000 plants/yr

♦ Three methods

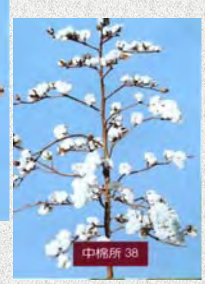
2.3 Biosafety asses.

- Methods: Molecular, biological & ecological
- Results:
  439 cases submitted
  349 approved
  145 var.(line) certified

2.4 Released varieties

- No. var. released: 99
- Straits: Single & double genes; early, med.-early & med.; convent. & hybrid
- Quality: Length (27-32mm), strength (28-34 cN/tex) & micron (3.9-5.1)

↖Bt cotton



↖Bt hybrid

↖Bt+CpTI

♦Char. of major varieties

Var.	Length (mm)	Stregth (cN/t)	Macron
CCRI41	31.0	34.0	4.0
CCRI45	30.1	33.8	4.8
CCRI46	31.0	34.0	4.0
LMY22	31.3	34.6	5.0

2.5 Cultivation tech

- **Tech systems: Single & double cropping**
- **Key strategies: Regulation with water & fertilizer, balance of promotion & control**

2.6 Commercialization

- **Institutions: Research-led, industry-led, prod. base-led & association-led**
- **Approaches: Field test, demonstration, extension**
- **Acreage: 2.5 m. h in 2005 (>50% of nation's total)**

3 Performance of Bt Cot.

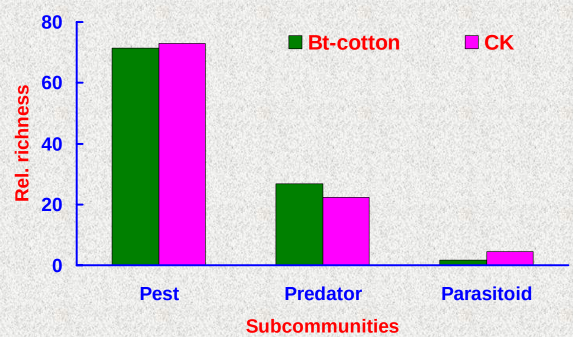
3.1 Effects on herbivores

3.2 Effects on predators

3.3 Effects on parasites

3.4 Effects on communities

On communities



4 Implication for IPM

4.1 Bt cot.-based IPM system

4.2 Resist. mgt. system

4.1 IPM system (1/2)

— Soft-techniques

- Field-monitoring at regular
- Apply the control threshold

Generation	Medium var.	Short var.
2^{nd}	25-30 SL	20-25 SL
3^{rd} & 4^{th}	20-25 SL	15-20 SL

4.1 IPM system (2/2)

— Hard-techniques

- **Pre-season:** Cultivating cotton fields
- **Early:** Seed treatment
- **Mid:** Chemical control
- **Late:** Spray with OPs

4.2 Resist. mgmt. (1/2)

— Resist. monitoring

- **Lab screening:** Base line & resistance strains
- **Field monitoring:** Locations with Bt application & Bt cotton

♦Resist. monitored in fields (1998-2006)

No resist. found so far

4.2 Resist. mgmt. (2/2)

— Mgt. strategies

- **“High doses”:** Needed due to dynamics of spatiotemporal resistance
- **“Refuges ”:** Not necessary due to diversified cropping systems *except for* the areas with Bt corn/soybean

5 Profitability Analysis

5.1 Economic benefits

5.2 Social benefits

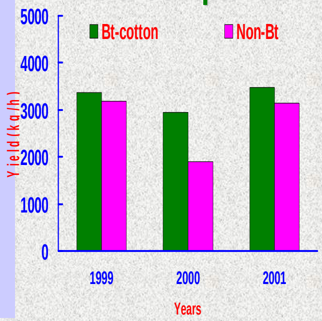
5.3 Ecological benefits

5.4 Integrated benefits

5.1 Economic benefits

- Incect.dec.: 120-150$/h
- Yield inc.: 150-200$/h
- Intercrop: 350-400$/h

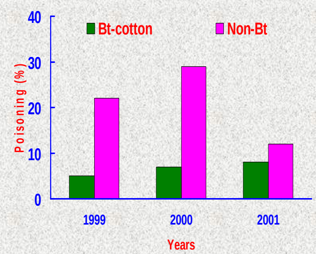
Yield comparison



5.2 Social benefits

- Labor-hand decreased: 20-30%
- Poisoning-incidence decreased: >90%

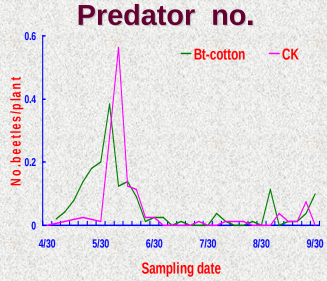
Comparison of Poison-incidence



5.3 Ecological benefits

- Insecticide decreased: 60-80%
- beneficial increased: 20-40%

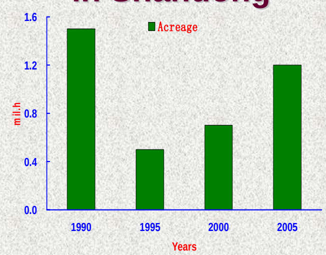
Comparison of Predator no.



5.4 Integrated benefits

- Production stabilized
- Structure optimized
- Net-income Increased
- Marking enhanced

Cotton-acreage in Shandong



6 Aspects in Future

6.1 Innovation-oriented

6.2 Improvement-oriented

6.3 Application-oriented

6.4 Resist. mgt-oriented

6.1 Innovation-oriented

- Genes: Stress-tolerant, fiber quality, male-sterile
- Promoters: Time & tissue specified
- Transformation: Increased efficiency & scale
- Breeding: High yield with Good fiber-quality

6.2 Improvement-oriented

- **Variety:** Increase resistance of current varieties with patio-temporal resistance
- **Industrialization:** Promoting agro-enterprises
- **Regulation:** Patent-protection & simplified approval

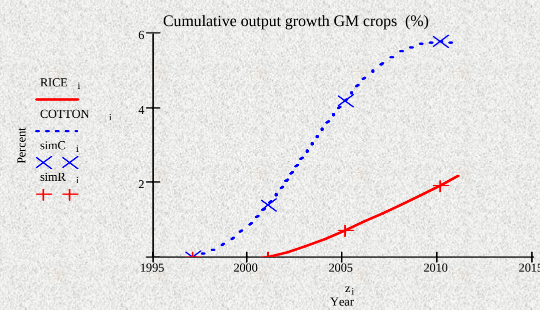
6.3 Application-oriented

- **Cultivation aspects:**
  Developing Bt cotton-based production systems
- **IPM aspects:**
  Developing Bt cotton-based IPM systems

6.4 Resist. mgt-oriented

- **Genetic strategy:** Multi-gene transformation & foreign gene plus physical or biochemical characters
- **Bio-ecological strategy:** Management of cropping systems

♦Simulated GMC growth rate in China



Welcome to NATESC

Appendix 3.

- Biotechnology status in Africa
- Status in South Africa
- Status in Egypt
- Constraints
- Way forward

GM COTTON IN AFRICA

Osama A. Momtaz

Deputy Director, AGERI, ARC, EGYPT.

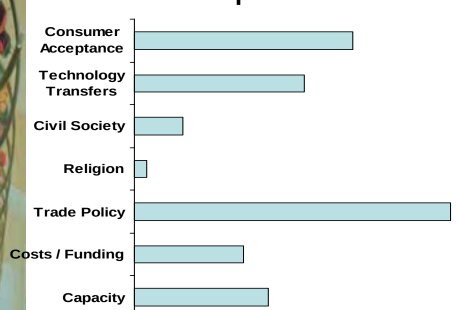
Agricultural Biotechnology in Africa

- 1 country (South Africa) has commercial plantings of GM crops
- 6 countries (Burkina Faso; Egypt; Kenya; South Africa; Zimbabwe, Mauritius) have reported field trials of GM crops
- 20 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 GMO research and development
- 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; Zimbabwe) have the capacity and institutions to conduct research and development in agricultural biotechnology
- Many African countries have ratified the Cartagena Protocol on Biosafety to date

STATUS OF BIOTECHNOLOGY IN AFRICA

- **Genetic modification technology is being employed in: South Africa, Zimbabwe, Egypt, Kenya, Nigeria, Uganda, Malawi, and Mauritius.**
- **Only South Africa has reached the commercialization stage.**
- **Most countries do not yet have the regulatory or scientific capacity to needed to conduct trials on biotech crops.**

Barriers for Adoption of GM Crops in Africa



Agricultural Biosafety in Africa

Jan 06

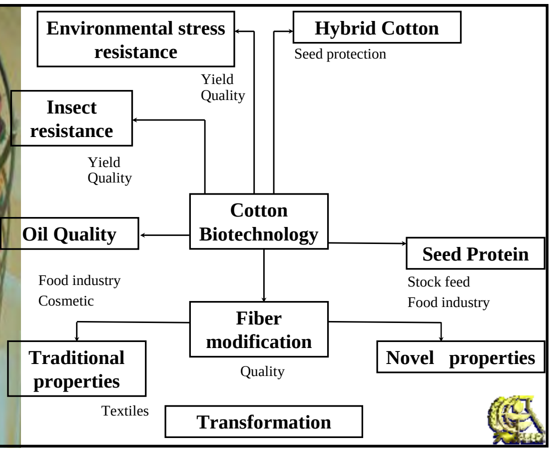
Biosafety development	Countries
Signed onto UNEP development project (will accede to the Cartagena Protocol on Biosafety)	Algeria, Benin, Botswana, Burkina Faso, Cameroon, Cape Verde, Democratic Republic of the Congo, Djibouti, Egypt, Eritrea, Ethiopia, Gambia, Ghana, Kenya, Lesotho, Liberia, Libyan 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	Tunisia, Morocco, Mauritania, Burkina Faso
Have draft legislation	Kenya, Mauritius, Namibia, Nigeria, Uganda, Zambia
Have legislation, but frameworks not yet functioning	Cameroon, Malawi
Have functioning GM legislation	Egypt, South Africa, Zimbabwe

GM in South Africa

- Insect tolerant cotton
- Herbicide tolerant cotton
- Insect and herbicide tolerant cotton
- Herbicide tolerant soya
- Herbicide tolerant maize
- Insect tolerant maize

GM CROPS IN AFRICA

- Insect resistance
- Virus resistance
- Drought tolerance
- Fungal resistance



GM COTTON IN EGYPT

Cotton Fiber Development

1- Initiation, (-3~2 DPA)

2- Elongation, (3~14DPA)

3- Secondary wall deposition, (15~27 DPA), and

4- Maturation (45~60 DPA).

Construction of PAC library

Nuclei, Mega-base DNA and HMW DNA Preparation

Nuclei, Mega-base DNA and HMW DNA Preparation

PAC Vector Preparation

PAC Transformation

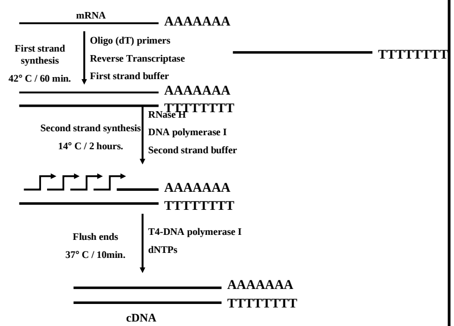
Identification of Fiber Genes (Actin, Expasin, Tubulin)

PAC Library Screening

Restriction Fingerprinting

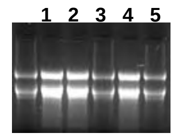
PCR-based Positional Cloning

C- cDNA Synthesis



A- Total RNA-isolation

(1) A
(2) D
(3) TM-1 "American"
(4) Giza 45 } "Egyptian"
(5) Giza 83



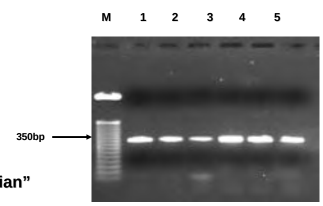
Formaldehide-agarose gel

B- mRNA isolation

E- BLAST ® Analysis

F- Verify expression patters using RT-PCR and real-time PCR

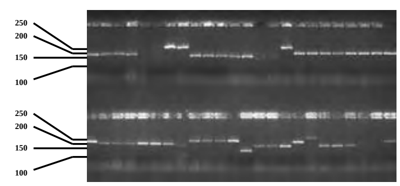
(M) 50bp ladder
(1) A
(2) D
(3) TM-1 "American"
(4) Giza 45 } "Egyptian"
(5) Giza 83



2 % agarose gel

D- AFLP- cDNA Analysis

- Cutting the interested bands and eluting the DNA fragments
- Re-amplification and cloning of these bands

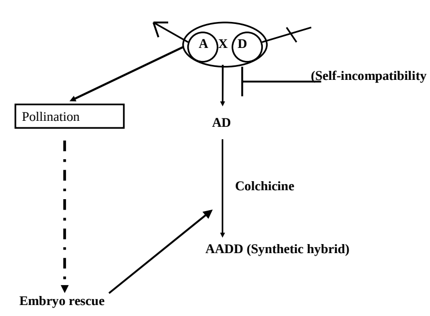


Abiotic Stress Tolerant Cotton

Genes affecting compatible solutes:

- Mannitol-1-phosphate dehydrogenase
- Inositol methyl transferase
- Aldose reductase
- P5C reductase
- P5C synthetase
- Betaine aldehyde dehydrogenase
- Choline mono-oxygenase

Establishment of a Synthetic Cotton Hybrid



What Do African Countries Need to Develop Biotechnology ?

- Political will to use the technology
- Resources and capacity
- Regulatory frameworks that work
- Public and private sector commitment
- Stakeholder involvement
- No trade barriers
- Public understanding and acceptance

- Construction of a plant expression vector

- Transformation of Egyptian cotton, Giza 86 & Giza 87 varieties

- Regeneration of mature plants through tissue culture

- Screening of putatively transformed plants:
  a) Herbicide painting
  b) Molecular testing

Way Forward

We need to aim for more coordination between strategic policy making in the following areas:

- **Sustainable agriculture**
- **Agriculture and trade**
- **Agricultural research**
- **Regulation of biotechnology**

Appendix 4.

COTTON IN MYANMAR

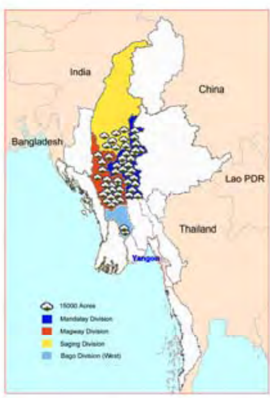
MISS THAN THAN NU

COTTON AND SERICULTURE DEPARTMENT
MYANMA INDUSTRIAL CROP DEVELOPMENT SERVICE

BACKGROUND HISTORY OF COTTON PRODUCTION AND DEVELOPMENT IN MYANMAR

COTTON MAP OF MYANMAR

MAJOR COTTON PRODUCTION REGIONS



DISTRIBUTION OF COTTON BY REGION

(Ha)

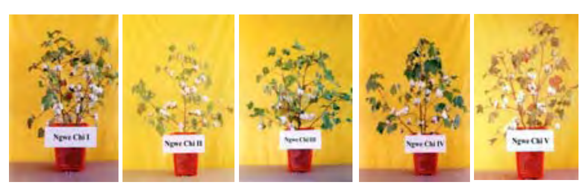
	State/Division	Long Staple Cotton				Short Staple Cotton	Region Total	Percent of Regional Total
		Pre-monsoon	Monsoon	Late-monsoon	Total			
1	Sagaing Division	1720	11451	25267	38438	13921	52359	16.89
2	Mandalay Division	14935	6288	67988	89212	30849	120061	38.72
3	Magway Division	742	4662	85042	90446	31255	121701	39.25
4	Bago Division (West)	0	299	6564	6863	7332	14195	4.58
5	Shan State	0	162	486	648	241	889	0.29
6	Others	0	4	184	188	684	871	0.28
	Cotton Type Total	17398	22866	185531	225795	84282	310076	
	Percent of Cotton Type Total	5.61	7.37	59.83	72.82	27.18		

COMMERCIAL COTTON VARIETIES

G. hirsutum (Long staple cotton)

G. arboreum (Short staple cotton)

5 NEW INTRODUCED VARIETIES



- Current average yield of cotton in Myanmar is 717 kg/ha (30% of the world average)
- The yield losses by bollworm are rather significant, ranging from 30 to 70%

Cotton Varietal Yield Trial Conducted at Shwedaung Cotton Research and Seed Farm

Fiber Quality Parameters and Yield of Bt cotton Variety

Year of experiment	Ginning percent	Staple length (mm)	Strength (lb/mg)	Fineness (micronaire)	Maturity Ratio	Yield Kg/ha
2003	41	29	8.0	3.3	0.95	2015
2004	39	30	8.0	4.0	0.90	3330
2005	34	27	7.95	4.2	1.0	2465
2006	39	29	7.7	4.1	0.86	1890

❖**The yield of Bt cotton is higher than the current average yield of commercial variety**

❖**Bt cotton was found to be susceptible to sucking pests**

Appendix 5.

Cotton, Production, Integrated Pest management in Syria

CRA

Biotech Cotton Regional Consultation – Faisalabad. Pakistan. March 6-8, 2007

Dr.Al-Salti M.N.

Director of Cotton Research Administration

(Cotton Bureau)

GCSAR-CRA

Introduction

•Syrian cotton occupies about 16.5 % of the irrigated area.

•Almost 20% of the economically active population is dependent on cotton for income. 46-47% of raw cotton is exported and it constitutes 10% of total Syrian exports.

•Cotton cultivation in Syria is managed by the Ministry of Agriculture and Agrarian Reform, through the Cotton Research Administration (Cotton Bureau), under the General Commission for Scientific Agricultural Research (GCSAR) .

•Cotton production is divided into three regions: the central north of Syria comprises Aleppo, Idleb and Hama province; the eastern area, which includes Rakka and Deir Ezzore; and the north eastern area comprising El- Hassaka province.

Production, Consumption and Productivity Condition of Cotton in Syria

Year	2000	2001	2002	2003	2004	2005	2006	Average
Production area (Ha.)	270290	257063	199773	210854	234181	237769	215640	232224.3
Productivity (Kg/Ha)								
Un-ginned cotton	4003	3928	4015	4031	4395	4298	3180	3978.6
Ginned cotton	1277	1246	1174	1248	1422	1375	-	1290.3
Sown seed (tons)	27000	25700	16000	16900	18750	19000	16855,7	20029.3
Production (tons)								
Un-ginned cotton	1046541	974971	712634	796172	1004234	990366	615454	877196
Ginned cotton	345000	320329	234577	263214	332961	326822	-	303817.2
Consumption(tons)	129254	142381	130701	150758	179356	180000	-	152075

Varieties Grown

Varieties planted in Syria in different cotton producing regions respond to the need to remedy some adverse environmental conditions such as high temperature (Deir Ezzore 22) and *verticillium* wilt (Rakka 5, Aleppo 33-1), staple length and fiber strength (Aleppo 90, Aleppo 118).

Varieties Released, Characteristics and Origin

Aleppo 33-1:
This variety is a strain selected from the American variety, Acala S.j.4. It is more tolerant to *Verticillium* wilt than Aleppo 40. Therefore; it is distributed in areas which are highly infested by wilt diseases in Hama province. Its staple length and fiber strength are better than Aleppo 40. It has pyramidal shape and big elliptical boll. The height of cotton is about 110 c.m.

Rakka 5:
This variety is a strain selected from the Russian variety, Tashkent 3. This variety is earlier and more tolerant *to Verticillium* wilt than any other variety, but it is less in lint percentage than Aleppo 40. Rakka 5 is grown in Rakka province which is intensively infested by *Verticillium* wilt. The cotton boll is global and pointed, the height of cotton is about 125 c.m.

Deir Ezzore 22:
This variety is a strain selected from the American variety, Delta&Pine 41. It is earlier, more tolerant to heat, higher in yield and lint quantities than Aleppo 40. In Deir Ezzore province. Thus it is pertained for cultivation in this area. It has global shape, the cotton boll is spindle and medium-sized. The height of cotton is 85-90 c.m.

Aleppo 90 :

This variety is earlier and more tolerant to *Verticillium* wilt than any other variety. Aleppo 90 is increased with the average 7% in Al- Hassaka and 5% in Aleppo. This strain excels in the staple length and fiber strength but the average of ginning is less than others with the estimated 1.6%. It has pyramidal shape. The cotton boll is medium-size and has global and pointed shape. The height of cotton is about 85-90 c.m.

Aleppo 118:

This variety is planted in Aleppo and Edleb provinces in 2006. It has high productivity and good technological characteristics. It is tolerant to *Verticillium* wilt. The gin average is good. Its maturity is early. It has cylinder and brunched shape. It has big global pointed boll. The height of cotton reaches to 120 c.m.

Cotton Production Policy

- Cotton growers must attain a license from the ministry of agriculture and agrarian reform to grow cotton.
- The price for seed cotton is guaranteed throughout the whole season, and it is announced for the basic quality grade before preparing the land for cotton growing. All the seed must be sold to the Cotton Marketing Organization (CMO).
- The limit on the last date for plating cotton is mid May.
- Limits on the area for every extension unit which is responsible for pest control.
- Advice concerning good growing methods, and estimating yield for every field.

•Granting better loan facilities to cotton growers by the Agricultural Co- operative Bank of Syria, the loans comprise cash and material loans for the purchase of seeds, fertilizers, pesticides and sacks.

•Overall coordination of the sector is secured by means of an annual "Cotton Congress", attended by 400 to 500 senior officials, as well as the Minister for Agriculture and Agrarian Reform. The congress reviews the results of the past cotton season, including research findings, and is responsible for formulating the policy direction of the industry.

•The Cotton Research Administration produces a bulletin containing recommendation for the next season.

Details of Research Institutions

Cotton Research Administration includes the following research departments:

Agriculture department
The breeding department
Cotton protection department
Observation department
Mechanization department
Cotton Research Administration includes the following laboratories :
The Staple laboratory
Biological Control Laboratory in Aleppo and Deir Ezzore.
Cotton Research Administration includes eight field Research Stations in: Aleppo(2), Rakka, Deir Ezzore(2),Homs and El- Hassaka(2).
The Research Efforts are directed to :
Resisting the varieties to Wilt disease
Resisting the varieties to high temperature (tolerant to heat)
Increasing the production
Good technological specifics
Integrated of Cotton Pest Management (Biological control).

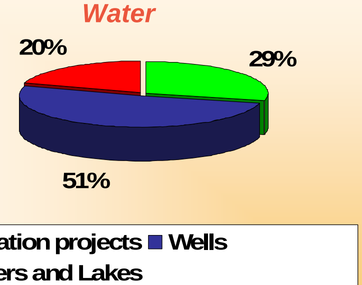
Cropping System and Agronomic Management Irrigation

Water for irrigation is obtained from wells, rivers and lakes.

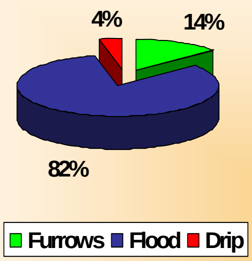
Three irrigation methods used in cotton agriculture: flood, furrows and drip. They represent different irrigation techniques with different water consumption rates. All three methods are used in Syria. The most common is the flood method.

During the growing season (April- September) cotton fields take about 8 to 10 irrigations, with an average water consumption of about 14 000 cubic meters per hectare.

Distribution of Production Area (Ha.) According to Source of Water



Distribution of Irrigation Methods Used in Cotton Agriculture



Fertilization

- Fertilizer recommendations for cotton are formulated by the latest normal rate of recommendation, which is the actual amount Directorate of Soil in cooperation with the Cotton Bureau. The amount applied by farmers, ranges between nitrogen 150- 190 Kg per ha. of N and 30-75 kg per ha. of P2O5.
- The recommendations time of application of nitrogen is 1/3 at sowing date and 2/3 at first flower appearance. The recommendation is meant to discourage early excessive growth and to give the bulk of the nutrient at the beginning of the reproductive phase when the nutritional demands of the crops is high. Phosphor is added at sowing date.
- Application of fertilizers is carried out by hand or by tractor mounted equipments.
- Fertilizers are obtained from the Agricultural Cooperative Bank and that is why the actual amount applied by farmers comers coincides with that of the recommended rate.

Pest Problems

•***Earias insulana***:
the spiny bollworm appeared to be the most important pest species in Syria cotton, and was found to be most numerous in the Deir Ezzore region .

•***Helicoverpa armigera:***
the European bollworm is considered the 2nd most important pest. It was found to be present in all cotton growing areas in Syria. The species can reach economic level in Hama, Hassaka, Rakka, and Aleppo regions.

•***Pectinophora gossypiella:***
the Pink bollworm considered the 3nd important pest in all cotton growing areas in Syria.

•American Bollworm *Helicoverpa armigera* and Spiny Bollworm *Earias insulana* are the most persistently serious pests in cotton field in Syria.

Some Biological Properties of Cotton Bollworms in Syria

American bollworm		Spiny bollworm	Pink bollworm
Hibernation	Pupue in soil	Larvae in soil	Larvae in seed
Mean female fecundity was	1600 Eggs	200 Eggs	500 Eggs
Number of generations per year	3-4	5-6	5-6

Economic Threshold for Various Cotton Pests in Syria

Pest	Economic Threshold
Helicoverpa armigera	10 Alive larvae per 100 fruiting parts
Earias insulana	10 Alive larvae per 100 fruiting parts
Pectinophora gossypiella	10 Alive larvae per 100 fruiting parts
Spodoptera exigua	50 Alive larvae per 100 plants
Aphis gossypii	30% of plants are infested (only seedling stage)
Thrips tabaci	Insecticides aren't recommended even all leaves were Infested except terminal leave (only seedling stage)
Tetranychus spp.	10-20% of leaves are infested per total leaves
Creontiades pallidus	15 insects in 50 sweep net to capture
Bemisia tabaci	No threshold, as insecticides aren't recommended against white fly

Aphids, Trips,. Jassids, and Mites: These insects were observed in all regions but occasionally reached pest status. *Aphids* sp. and trips were mainly encountered on seedling after which populations dwindled. Populations of thrips may in some years reach high levels, that serious damage may be infected. Red spider mites, *Tetranychus sp.*, were found to be present in all cotton growing areas. The species can reach economic level in Hama; Rakka and El-Hassaka regions.
Agrotis ipsilon: Larvae was observed to cause damage to seedling in Hama, Rakka, and Deir Ezzore .However, in general the species was not found to be a pest of significance, while moreover, high seed rates ampply compensated for seedling losses.
Creontiades pallidus: The shedder bug is an important pest in Syrian cotton. It can be observed in Hama, Aleppo, and Rakka regions , while in Deir Ezzore region it can be considered the 2nd most important pest after *Earias insulana.*
***Spodotera exygua*:** The green worm is not an important pest in Syrian cotton. Occasionally the species can reach economic level in Hassaka, and Hama, regions .
Bemisia tabaci: The whitefly is not a serious pest in Syrian cotton. However, it has the potential to reach major pest status. The species was found to be present in all cotton growing regions; however, populations were heavily parasitized by *Aphilinids*. Recently, no pest introductions had taken place into the country.

In the late 1970s, about 50% of cotton fields in Syria were being spread with insecticides for control:

- Bollworms (*Helicoverpa armigera* and *Earias insulana*)
- Green worms (*Spodoptera* spp.)
- Thrips and Aphids

The insecticides sprays have resulted in the decline of natural enemies (predators and parasitoids).

Areas (Ha) Controlled by Chemicals Against Different Pests in Cotton Fields

Season / Pest	1987	1995-1996	1997-1998	1999-2000	2001-2002	2003-2004	2005	2006
Green worm	1573	858	1344	0	2	96.5	0	0
Bollworms	11224	2985	799.5	995.5	62.5	253	24	0
Sucking insects	4970	3265	500.5	258.5	15	0	130	112
Mites	2743	42.5	0	339	23.5	4.25	135	515
Cutworm	3776	243	1314	1436.5	976	534.9	0	285
Other insects	6	55.5	100	35	97	54.1	0	0
Total	24292	7339	4058	3064.5	1176	942.7	289	912
Planted areas	128687	211919.5	26259.5	254329	228418	219645	237769	215640
Controlled areas (%)	18.88	3.47	1.53	1.23	0.47	0.43	0.12	0.42

Development of some IPM Elements of Cotton Pests

In 1980s, Syria scientists increased threshold level for various cotton insects correlated at various stages of crop development:

Seasons	Economic threshold of Bollworms (Alive Larvae %)	Areas controlled by chemicals (ha)		Areas controlled by Parasitoids (ha)	
		Aver.	%	*Trichogramma*	*Bracon*
1992-1994	6	7071.67	3.52	0	0
1995-2000	7	4823.8	2.08	240.76	0
2001-2003	10	1046.8	0.44	1271	231.3
2004-2005	10	615.8	0.28	1808	1342.5
2006	10	912	0.42	2697	2573.5

In an attempt to decrease insecticides use, the threshold levels were revised and raised to 10 alive larvae per 100 fruiting parts – an amount that is rarely reached this economic threshold.

Monitoring System

In the 1990s, an important step for establishing the biological control and the monitoring system:

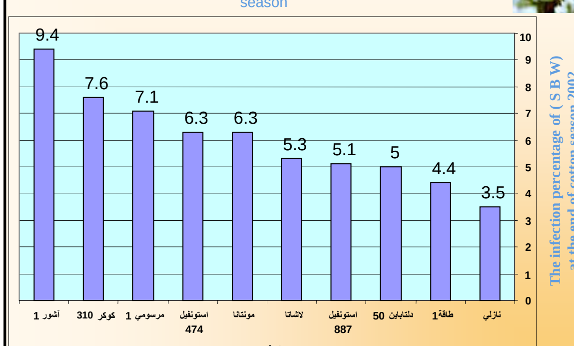
1. Visual infestation.
2. Light traps.
3. Yellow traps.
4. Sweep net.
5. The Lepidopteran moth population through the use of moth traps (Pheromone traps).

Several field studies were conducted since 1984,such as optimum planting date, rotation, hosts plant, suitable cotton variety as well as monitoring insect pests population and its natural enemies with a main objective to minimize insecticides use and conserve local natural enemies.

The egg and larval parasitoids were field released at different locations in Syria after laboratory mass rearing.

High densities of natural enemies was recorded in all biologically controlled cotton fields.

Response of some cotton varieties for infestation at the end of cotton season



Parasitoids of cotton insects in Syria

Syrian Scientists were assured that good science-based practices would be implemented. Various predators (13 species) and parasitoids (7 species) are used in cotton fields:

Order	Family	Name
Hymenoptera	Braconidae	*Habrobracon brevicornis*
		Apanteles spp.
		Chelonus spp.
	Aphelinidae	*Eretomocerus mundus*
		Encarsia lutea
	Trichogrammatidae	*Trichogramma principium*
		Trichogramma semblidis

Predators of cotton insects in Syria

Order	Family	Name
COLEOPTERA	Coccinellidae	*Coccinella septempunctata* L.
		C. undecimpunctata
		Hippodamia variegata Goeze
		Scymnus guadriguttatus Capra
NEUROPTERA	Chrysopidae	*Chrysoperla carnea* Stephens
DIPTERA	Syrphidae	*Syrphus corollae* F.
HEMIPTERA	Lygaeidae	*Geocoris megacephallus* Rossi
		G. pallidipennis Costa
	Miridae	*Deraeocoris punctalatus* Fallen
		Campylomma diversicornis Reuter
	Anthocoridae	*Orius laevigatus* Fieber
	Reduviidae	*Oncocephalus thoracicus* Fieber
	Nabidae	*Nabis capsiformis* Germar

Biological Control

- **Recently, Syria approaches to growing cotton without the use of insecticides.**
- **Areas controlled by Parasitoids (ha):**

Years	*Trichogramma(1)*	*Habrobracon(2)*	*Total/ha.*
2001	1020	273	1293
2002	1400	141	1541
2003	1300	277	1577
2004	1937	975	2912
2005	1679	1710	3388
2006	2697	2573.5	5270.5

(1): Trichogramma principium

(2): Habrobracon (= Bracon) brevicornis

- Larva parasitoid *Bracon brevicornis* is used to control larvae of Bollworms in Syria.
- Experiments with commercial release in cotton fields started in 2001, and the parasitoid has been available in abundance to cotton growers.

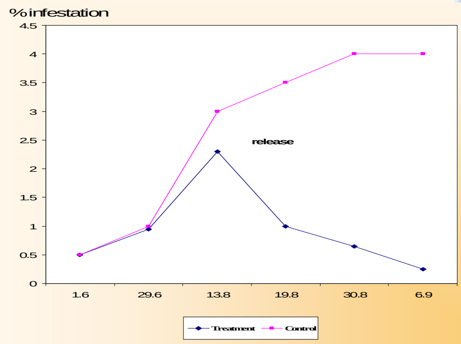
Laboratory and Field Studies on Larval Parasitoid Bracon brevicornis

- Determination of the optimum of adult parasitoids to the number of alternative host 4th larvae.
- Extending parasitoids' storage period to exceed 45 days by exposing to 2Cº under laboratory conditions or under prevailing cold winter conditions.
- Field release rate of *Bracon* between 100-150 female/1000m2 has reduced the number of alive larvae at different release locations in Syria.

Laboratory study on larval parasitoid Bracon brevicornis

Mean of number larval parasitoids emerged	repetitions			Number of host larvea *Ephestia kuehnilla*
	3	2	1	
31	40	27	26	10
38.33	46	38	31	15
33.33	42	33	25	20
46.33	50	56	33	25

The effect of releasing 1500 adults *Bracon brevicornis* parasites on the development of SBW infection at Deir Ezzore area 2000 cotton season



Mass Rearing of Parasitoids

- Mass rearing of *Trichogramma principium* and *Bracon brevicornis* were done on eggs and larvae of Mediterranean flour Moth *Ephestia kuehnilla* respectively.
- Culture media for mass rearing of the alternative host Mediterranean flour Moth *Ephestia kuehnilla* was Seamid (Coarse wheat flour).

Egg parasitoid

Trichogramma:

Thank you

Appendix 6.

Regional Consultation on Genetically Modified Cotton for Risk Assessment and Opportunities for Small-scale Cotton Growers

March 6-8, 2007
Faisalabad, Pakistan

List of Participants

ASIA – South Asia, SEasia, Central Asia

Bangladesh
Mr. Md. Ghulam Rasul
In-charge Deputy Director (Training)
Cotton Development Board
Khamarbari (Rear Building, 4th floor)
Farmgate
Dhaka 1215
Email: edcdb@citechco.net

Mr. Md. Abul Kalam Azad
Senior Seed Production Officer
Cotton Development Board
Khamarbari (Rear Building, 4th floor)
Farmgate
Dhaka 1215
Email: edcdb@citechco.net

China (Mainland)
Dr. Jingyuan Xia
Director General
National Agro-Tech Extension and Service Centre (NATESC)
Ministry of Agriculture
No. 20 Maizidian Street
100026 Beijing
Phone: 86-10-64194505
Fax 86-10-64194544
Email: xiajyuan@agri.gov.cn

India
Dr. Basavaraj Madiwalappa Khadi
Director
Central Institute for Cotton Research
Post Bag No. 2, Shankarnagar Post Office
Nagpur 440010 Maharashtra, India
Phone: +91 7103 275 536
Fax: +91 7103 275529
Email: cicrngp@rediffmail.com

Dr. C. D. Mayee
Co-Chair, Genetic Engineering Advisory Committee and Chairman
Agricultural Scientist Recruitment Board
Krishi Anusandhan Bhawan (KAB)
Pusa Gate New Delhi – 110012
Email: charumayee@yahoo.co.in

Mr. Sanjay Deshpande
Assistant General Manager
Mahyco Seeds Ltd.
Ashok Centre, 4E/15, 3rd Floor, Jhandewalan Extension
New Delhi 110055
Phone: 91-11-23533366
Fax: 91-11-23623804
Email: sanjay.deshpande@mahyco.com

Indonesia

Dr. Emy Sulistyowati
Tobacco and Fiber Crops Research Institute
Jalan Raya Karangploso
P.O. Box 199
Malang 65152 - EAST JAVA
Phone: +62-341-491447
Fax: +62-341-485121
Email: emysulistyowati@yahoo.co.uk

Kazakhstan

Dr. Ibadulla Umbetayev
Director
Cotton Growing Scientific Research Institute
160525 South Kazakhstan Area, Laboratory Street
Maktaaral Region, Village Atakent
Tel/fax: 7-32541-33303,33709
Email: kazcotton1150@mail.ru

Myanmar

Ms. Than Than Nu
Assistant Manager
Myanmar Cotton & Sericulture Enterprise
Shwe Taung Cotton Research Farm
Mandalay Division
Wun Dwin Township.
Phone: 95-1666067
Fax: 95-1666068
Email: mcse@mcse.com.mm

Ms. Myo Myo Kyi
Deputy Supervisor
Myanma Cotton & Sericulture Enterprise
Lungyaw Cotton Research Farm
Mandalay Division
Kyauk SE Township
Phone: 95-1666067
Fax: 95-1666068
Email: mcse@mcse.com.mm

Syria

Dr. M. Naif Al Salti
Director
Cotton Research Administration, AL Medan
Aleppo
Phone: 963-21-4644801
Fax: 963-21-4644813
Email: iyad10@scs-net.org

Ing. Wadah Al-Kadi
Head, Breeding Section
Cotton Research Administration, AL Medan
Aleppo
Phone: 963-21-4644801
Fax: 963-21-4644813
Email: cottonbureau@mail.sy

Thailand

Dr. Banpoth Na Pompeth
Chairman
Advisory and Steering Working Group on the Development of National Biosafety Framework Project
National Biological Control Research Center
Kasetsart University
P.O. Box 9-52, Bangkok 10900
Phone: 66-2579-3649
Fax: 66-2942-8355
E-mail: agrban@ku.ac.th

Turkey

Dr. Isa Ozkan
Manager
Cotton Research Institute
O9900 Nazilli, Aydin
Phone: 90-256-3131750
Fax: 90-256-3133093
Email: ozkani@mynet.com

Vietnam

Dr. Le Quang Quyen
Director
Institute for Cotton Research & Development
Nha Ho, Ninh Son, Ninh Thuan
Tel: 84- (68) 853340/853535
Phone: 84- 68-853152
Mobile: 84-91-3930186
Email: quyencotton@yahoo.com
Email: nhahocrc@hcm.vnn.vn

Dr. Le Trong Tinh
Deputy Director
Institute for Cotton Research & Development
Nha Ho, Ninh Son, Ninh Thuan
Phone: 84-68-853269
Email: tinhcotton@yahoo.com

AFRICA

Egypt

Dr. Mahmoud Oraby Ismail Ali
Director
Cotton Research Institute
9 El Gamaa Street
Giza, Cairo
Tel/Fax: 202-5725035

Dr. Osama A. Momtaz
Agricultural Genetic Engineering Institute
Agricultural Research Centre
9 Gamma Street, Giza 12619
Phone: 202-568-9519
Fax 202-5727831 7607649
Email: omomtaz@hotmail.com, gert@ageri.sci.eg

Ethiopia

Mr. Ridwan M. Abdulle
Coordinator, Field Crops Research Program
Ethopian Agricultural Research Oragization
Were Research Center, P. O. Box 2003
Addis Ababa
Phone: 251-1-114841, 120049
Fax: 251-111-4839
Email: ridalfia@yahoo.com

Dr. Zerihun Desalegn
Breeder Agronomist
P O Box 877
Adama
Email: zerihun99@yahoo.com

Kenya

Mr. Raphael G. Ngigi
Cotton Breeder
Kenya Agricultural Research Institute
KARI-Mwea
P. O. Box 298
Kerugoya
Tel: 254- 60–48057 or 48067
Fax: 254 60–48425
Email: karimwea@yahoo.com

Nigeria

Dr. Shehu Garki Ado
Director
Institute for Agricultural Research
Ahmadu Bello University
PMB 1044 Zaria
Phone: 234-8038333663,
Fax: 234-69-550737
Email: shehuado@hotmail.com

South Africa

Mr. Phenias Gumede
Cotton Grower
C/o Cotton South Africa
P. O. Box 912232
Silverton
Phone 27-829455476
Fax: 27-355721236
Email: c/o Mr. Hennie Bruwer
henniebruwer@cottonsa.org.za

Dr. Siphiwe F. Mkhize (No sponsorship)
Minister Counselor (Agriculture)
Embassy of the Republic of South Africa
3051 Massachusetts Avenue NW
Washington DC 20008
Tel: 1 202 274 7989
Fax: 1 202 363 8620
Email: smkhize@saembassy.org

Sudan

Dr. Ahmed Mohamed Mustafa
Cotton Breeder
Cotton Research Program
Agricultural Research Corporation
P. O. Box 126
Wad Medani
Phone: 249-511-43215
Fax 249-511-43213
Email: a_m_mustafa@yahoo.com

Dr. Elfadil A. Babiker
National Coordinator for Cotton Research
Gezira Research Station, Cotton Research Program
Agricultural Research Corporation
P. O. Box 126
Wad Medani
Phone: 249-511-43215
Fax 249-511-43213
Email: elfadabd@yahoo.com

Tanzania

Dr. Everina P. Machibya Lukonge
Cotton Breeder
ARI-Ukiriguru
Box 1433 Mwanza
Phone: 255-28-2500528
Fax: 255 - 28 – 2501079
Email: elukonge@yahoo.com

Ms. Epifania Temu
Entomologist
ARI-Ukiriguru
Box 1433
Mwanza
Phone: 255-28-2500528

Fax: 255 - 28 – 2501079
Email: epytemu@yahoo.com

Uganda
Dr. Lastus K. Serunjogi
Director
National Agricultural Research Organization
P. O. Box 295i
Entebbe
Phone: 256-456-1192
Fax 256-456-1444
Email: lastus2006@yahoo.com

Zambia
Dr. Bruce Moses Siamasonta
Senior Breeder
Cotton Development Trust
P. O. Box 670057
Magoye, Mazabuka
Mobile Phone: 260 097 754042
Phone: 260- 3230777
Fax: 260 -3230683
E-mail: cdt@zamtel.zm

Mr. West Chitah
Director
Cotton Development Trust
P. O. Box 670057
Magoye, Mazabuka
Mobile Phone: 260 097 754042
Phone: 260- 3230777
Fax: 260 -3230683
Email: cdt@zamtel.zm

Zimbabwe
Mr. Darlington Mutetwa
Quton Seed Company
3 Lawson Avenue
Milton Park
Harare
Tel +263 4 253933/4
Email: dmutetwa@cottco.co.zw
dtonimute@yahoo.com

Mr. Antony Mudzana
Quton Seed Company
3 Lawson Avenue
Milton Park, Harare
Tel +263 4 253933/4
Email: dtonimute@yahoo.com

INVITED PARTICIPANTS

Dr. Jorge Cadena Torres
Research Coordinator
Corporacion Colombiana de Investigación
Agropecuaria (CORPOICA)
Km. 14, vía a Mosquerada
Bogotá, Colombia
Phone: 57-1-4227374
Email: jcadena12000@yahoo.com.mx

Dr. James McD. Stewart
University of Arkansas
Department of Crop, Soil and Environmental
Sciences
115 Plant Science Building
Fayetteville AR 72701 USA
Phone: 479-575-5722
Fax: 479-575-7465
Email: jstewart@uark.edu

Dr. Willy de Greef
Executive Director
International Biotech Regulatory Services (IBRS)
The Plant Biotechnology Institute for Developing
Countries (IPBO)
Department of Molecular Genetics
Ghent University
K.L. Ledeganckstraat 35
B-9000 Ghent, Belgium
Email: willy.degreef@ibrs.be

Mr. Derek Eaton
Researcher, International Trade & Development
European Consortium for Agricultural Research in
the Tropics -ECART
Agricultural Economics Research Institute
Wageningen University & Research Centre
P.O. Box 29703
The Hague, 2502LS
The Netherlands
Phone: 31-70-3358243
Fax: 31-70-3358196
Email: derek.eaton@wur.nl

INTERNATIONAL ORGANIZATIONS

Dr. Marc Giband
CIRAD-CA
EMBRAPA Algodao
Rua Osvaldo Cruz 1143
Centenario
Caixa Postal 174

58.107-720 Campina Grande, PB
Brazil
Phone: +55-83-33154364
Fax: +55-83-33154367
Email: marc.giband@cirad.fr and
giband@cnpa.embrapa.br (use both please)

Dr. M. Rafiq Chaudhry
Head
Technical Information Section
International Cotton Advisory Committee
1629 - K Street, NW, Suite 702
Washington DC 20006 USA
Phone: 1-202-292-1687
Fax +1-202-463-6950
Email: rafiq@icac.org

Mr. Sietse van der Werff
Senior Project Manager
Common Fund for Commodities
Postbus 74656
1070 BR Amsterdam
The Netherlands
Phone: 31-20-5754953
Fax: 31-20-6760231
Email: sietse.vanderwerff@common-fund.org

Dr. Randy A. Hautea
Global Coordinator, SEAsiaCenter
International Service for the Acquisition of Agri
Bio-tech Applications (ISAAA)
C/o International Rice Research Institute
Los Banos 4030, Laguna
Philippines
Phone: 63-49-5367215
Fax: 63-49-5367216
Email: r.hautea@isaaa.org

Dr. Claudia Canales
Senior Program Officer
SEAsiaCenter
International Service for the Acquisition of Agri
Bio-tech Applications (ISAAA)
C/o International Rice Research Institute
Los Banos 4030, Leguna
Philippines
Phone: 63-49-5367215
Fax: 63-49-5367216
Email: c.canales@cgiar.org

Dr. Muhammad Aslam Bhatti
Cotton Pathologist, Cotton Breeding Technology
Monsanto Company
800 North Lindbergh Boulevard
St. Louis, Missouri 63167 USA
Phone: 314-694-5948
Fax: 636-795-8135
Email: muhammad.a.bhatti@monsanto.com

PAKISTAN

Mr. Afzaal Ahmed Naseem
Deputy Director, (National Biosafety Centre)
Pakistan Environmental Protection Agency
Islamabad
Email: pakepa@isb.compol.com

Dr. Ahmad Saleem Akhtar
Director, Plant Protection Institute
Ayub Agriculture Research Institute (AARI)
Faisalabad

Dr. Akhlaq Hussain Shah
Director General
Federal Seed Certificate & Registration
Department
Islamabad
Email: akhlaq7@mail.com

Mr. Ali Hassan,
Director
Cotton Agriculture and Cooperative Department
Government of Balochistan
Quetta, Fax: 081-9201805

Dr. Ali Nawaz Channa
Professor
Department of Plant Breeding & Genetics
Sindh Agriculture University, Tando Jam
Email: channaasif@hotmail.com

Mr. Amer Shahbaz
Director, Jullundur Seed Corporation
Arif Wala
Email: jplseed@fsd.paknet.com.pk

Mr. Amir Mahmood Mirza
Director & Lead for Commercial Acceptance
Monsanto Pakistan
Lahore, Fax: 042-5877152

Dr. Ansar Parvez
Member
Pakistan Atomic Energy Commission
Islambad

Dr. Anwar Nasim, S.I
Chairman, National Commission on
Biotechnology
Advisor Science, COMSTECH Islamabad

E-mail: anwar_nasim@yahoo.com

Mr. Ashraf Yahya
Chief (Agriculture) Planning Commission
Islamabad

Mr. Asif Ali
Associate Professor Department of Plant Breeding and Genetics
University of Agriculture
Faisalabad, Fax: 041-9200187

Mr. Asif Majeed
Kanzo Ag., Sher Shah Road
Multan

Mr. Azhar Iqbal
Business Development Manager (Seeds)
ICI Pakistan Limited
Lahore, Fax: 042-6307104

Ms. Azra Mehmood Sheikh
Moaza Vaslian, Near Sutlej Bridge
Bahawalpur,
Director
Regional Agricultural Research Institute
Bahawalpur, Fax: 062-9255221
E-Mail: dirrari@mul.paknet.com.pk

Dr. Ehsan-ul-Haque,
Director
Nuclear Institute for Agriculture Biology
Faisalabad, Fax: 041-2654213

Dr. Ejaz Parvez
Director General
Pest Warning & Quality Control of Pesticides
Multan, Fax: 061-9210193

Dr. Faqir Muhammad Azhar
Professor and Chairman
Department of Plant Breeding and Genetics
University of Agriculture
Faisalabad, Fax: 041-9200187

Mr. Farhat Ullah Khan
Cotton Grower
555-C, Faisal Town, Lahore

Mr. Fayyaz Bashir Warrach
Secretary, Agriculture Department
Government of the Punjab, Lahore

Mr. Ghulam Shabir Memon
Associate Botanist
Cotton Section Agriculture Research Institute (ARI)
Tandojam, Fax: 0222-766476

Mr. Gul Muhammad Baloch
Coton Botanist
Agriculture Research Institute
Tandojam, Fax: 0222-766476

Dr. Iftikhar Ali
Principal Scientist
Nuclear Institute for Food and Agriculture (NIFA)
Peshawar, Fax: 091-2964059

Mr. Ijaz Ahmad Rao
22-B Model Town B Bahawalpur 63108
Email: luckystarpk@yahoo.com

Dr. Iqrar A. Khan
Director General Agri. & Biotech)
Pakistan Atomic Energy Commission
Islamabad

Dr. Kauser A. Malik
Member, Planning Commission
Islamabad
Email: kamalik@comsats.net.pk

Dr. Khalid Hussain Gill
Director General
Ayub Agriculture Research Institute (AARI)
Faisalabad, Fax: 041-2653874

Mr. Khalid Mahmood
Manager Agriculture Sector
SMEDA, Ministry of Industries
Lahore, Fax: 0426304926-7

Mr. Khalil-ur-Rehman
Director Jullundur Seed Corporation
Arif Wala

Mr. M. Wajid
Modren Seed Company

Mr. Manzoor Khuro
ARO Tandojam

Mr. Masood A. Rana
Cotton Commissioner
Ministry of Food Agriculture and Livestock
Islamabad, Fax: 051-9210616

Mr. Mazhar Hussain Naqvi
Advisor to Chairman
Pakistan Atomic Energy Commission
Islamabad, Fax: 051-9205385

Dr. Mehboob Ali
Ex Director, Central Cotton Research Institute
Multan, Fax: 061-9200342

Mr. Mohammad Ahmed
Chairman, Cotton Committee (APTMA)
Sindh Balochistan Zone
Karachi
Email;aptma@cyber.net.pk

Mr. Mohammad Rahim.
Director General, Agriculture
NWFP, Peshawer

Mr. Muhammad Afzal
Head Market Development
Bayer Crop Science Pakistan (Pvt) Ltd.
Karachi, Fax: 021-5060638

Mr. Muhammad Arshad
Director
Central Cotton Research Institute
Multan
Email: ccri@mul.paknet.com.pk

Dr. Muhammad Asghar Malik
Professor
Department of Agronomy
University of Agriculture
Faisalabad
Email: drasgharmalik@yahoo.com

Mr. Muhammad Ashraf
Pioneer Pakistan Seed Limited
Sahiwal, Fax: 040-45301035

Mr. Muhammad Asim
Technology Development Lead
Monsanto Pakistan AgriTech (Pvt) Ltd.
Lahore, Fax: 042-5877152

Mr. Muhammad Aslam
General Manager
Jullundur Seed Corporation
Arif Wala

Mr. Muhammad Hanif
Manager Seeds
Ali Akbar Group Lahore, Fax: 042-5321324-5

Mr. Muhammad Ibrahim
Ex Agric. Chemist (Soils)
Ayub Agric. Res. Institute
Faisalabad
Email: m1946ibrahim@yahoo.com

Mr. Muhammad Ikram
Business Manager
Resham Seed Corporation
Rahim Yar Khan

Mr. Muhammad Iqbal
Cotton Botanist
Cotton Research Station
Multan,

Mr. Muhammad Munir
Director (Plant Protection)
Pakistan Agricultural Research Council,
Islamabad, Fax: 051-9202968

Mr. Muhammad Murtaza Khan
Director Coordination
Punjab Seed Corporation
Lahore, Fax: 042-9212570

Dr. Muhammad Saghir,
Cotton Botanist
Cotton Research Station
Multan

Mr. Muhammad Shafique Tahir
Cotton Research Institute
Faisalabad

Mr. Muhammad Zahid
Chief Executive
Neelum Seeds
District Vehari, Fax: 065-2212031

Mr. Mumtaz Khan Manhas
Cotton Grower
Tiba Sulatan Pur, Mailsi

Mr. Mushtaq Ahmed Chaduhry
Director
Rice Research Institute
Kala Shah Kaku
District Lahore, Fax: 042-7980361

Dr. M. Nawaz A. Malik
Kanzo Ag.
Multan
Email: kanzoag@yahoo.com

Dr. Noor-ul-Islam
Director
Cotton Research Institute
Faisalabad
Email:crifsd@yahoo.com

Mr. Parvez Khaliq
Technical Staff Officer to Member (Plant Sciences)
Pakistan Agricultural Research Council
Islamabad, Fax: 051-9202968

Dr. Rakhshanda Bilal.
Pakistan Atomic Energy Commission
Islamabad

Email: rakhshanda.bilal@gmail.com

Dr. R.W. Briddon
Visiting Professor (HEC)
National Institute for Biotechnology and Genetic Engineering (NIBGE)
P.O. Box, 577, Jhang Road,
Faisalabad
Tel: +92-41-2651475-79 (Ext 214)
Fax: +92-41-2651472
Email: robbriddon@nibge.org

Mr. Saeed Akhtar
Chief Executive Officer
SAWA-AG Network
Sahiwal
Email: sawa@brain.net.pk

Dr. Shahid Mansoor
Head, Biotechnology
National Institute for Biotechnology and Genetic Engineering
Faisalabad
Email: smansoor@nibge.org

Mr. Shafiq Ahmad
Production Manager
Pioneer Pakistan Seed Limited
Sahiwal, Fax: 040-45301035

Mr. Sheikh Muhammad Akber
Member, Cotton Committee (APTMA)
Sindh Balochistan Zone
Karachi, Fax: 021-5611305

Mr. Shoukat Ali Anjum
Kanzo Ag.
Multan, Fax: 061-6537294

Mr. M.Yaseen,
CEO, Modern Seed Company
Multan,

Mr. Tanveer Ahmed Malik
Associate Professor Department of Plant Breeding and Genetics
University of Agriculture
Faisalabad, Fax: 041-9200187

Mr. Tariq Mehmood
Co-Chairman, Cotton Committee (APTMA)
Sindh Balochistan Zone
Karachi, Fax: 021-5611305

Mr. Tayyab Husnain
Professor
National Centre of Excellence in Molecular Biology
Lahore, Fax: 042-5421316

Mr. Syed Waseem
DG khan Campus of University of Agriculture
Dera Ghazi Khan,

Mr. Zafar Hayat
Director
Farmers Associates of Pakistan
Link Shami Road, Lahore Cantt

Dr. Zafar M. Khalid
Director
National Institute for Biotechnology and Genetic Engineering
Faisalabad
Email: director@nibge.org

Dr. Yusuf Zafar
Director, Agriculture and Biotechnology
Pakistan Atomic Energy Commission
Islamabad
Email: y_zafar@yahoo.com

Zahoor A. Swati
Director
IBGE NWFP Agricultural University
Peshawar

Dr. Zahoor Ahmad
Principal, Agriculture College
University of Sargodha
Sargodha
Email: z_ahmad@yahoo.com

Dr. Zahoor Ahmad Baluch
Director Research
Pakistan Central Cotton Committee
Karachi
Email: drzahoorbaluch@yahoo.com

Appendix 7.

REGIONAL CONSULTATION ON BIOTECH COTTON FOR RISK ASSESSMENT AND OPPORTUNITIES FOR SMALL SCALE COTTON GROWERS

March 6-8, 2007

National Institute for Biotechnology and Genetic Engineering (NIBGE)
Faisalabad, Pakistan

Implementing Agencies:

- *National Institute for Biotechnology and Genetic Engineering (NIBGE)*
- *International Cotton Advisory Committee (ICAC)*
- *International Service for the Acquisition of Agri-biotech Applications (ISAAA)*

Funding Agency

- *Common Fund for Commodities (CFC)*

5 March 2007: Arrival of participants

5 March, Monday

TIME	ACTIVITY
2000	Welcome Dinner, Chenab Club, Faisalabad

Day 1
6 March, Tuesday

TIME	ACTIVITY	
0800-0830	Registration	
0830-840	Guests to be seated	
850-1000	**Inaugural Session**	
	Recitation from Holy Quran	
	Welcome Remarks	**Mr. Asif Qadri** **Mr. Sietse van der Werff** Common Fund for Commodities
		Dr. M. Rafiq Chaudhry International Cotton Advisory Committee
		Dr. Randy A. Hautea Global Coordinator, ISAAA
		Dr. Yusuf Zafar Director, Agri-Biotech, PAEC
	Inaugural address	**Dr. Ansar Parvez** Member Science, PAEC
	Vote of thanks	**Dr. Zafar M. Khalid** Director NIBGE

1000-1030	Group picture and refreshments	
1030-1300	**Scientific Session I**	Session: **Chair Mr. Fayyaz Bashir**, Secretary Agriculture, Co-chair: **Dr. Khalid H. Gill**, DG, AARI, Faisalabad
1030-1100	Global status of commercialized biotech cotton	**Dr. Randy A. Hautea** Global Coordinator and Director, *SEA* Center ISAAA
1100-1130	Biotechnology Applications in Cotton: Concerns and Challenges	**Dr. M. Rafiq Chaudhry,** Head, Technical Information Section of the ICAC
1130-1200	Biosafety regulation - A country model that is practical, responsible, and effective- Learning from the experience of others	**Dr. Willy de Greef** The Plant Biotechnology Institute for Developing Countries, Belgium
1200-1230	Biotechnology: A look into the future	**Prof. James McD. Stewart** University of Arkansas, USA
1230-1300	Regulatory procedure for genetically modified corps in India	**Dr. C.D. Mayee** Co-Chair, GEAC, India
1300-1400	Lunch break	
1400-1700	**Scientific Session II**	Chair: **Dr. Kauser A. Malik,** Member, (Food and Agriculture), Planning Commission Pakistan Co-chair: Dr**. Rakhshanda Bilal** Director Technical, PAEC
1400-1430	Biotech cotton, trade, socio-economic and market acceptance issues	**Mrs. Jolly Subune** Managing Director Cotton Development Trust Uganda (to be presented by **Dr. Lastus K. Serunjogi**
1430-1500	Concerns, risks and issues regarding adoption of Bt cotton - focus on implications of IPRs and need for awareness raising and dialogue	**Dr. Derek Eaton** Researcher, International Trade & Development Agricultural Economics Research Institute (LEI), Netherlands
1500-1530	Tea Break	
1530-1700	Do we really need biotech cotton?	**Panel members** **Dr. Willy de Greef** **Dr. Randy A. Hautea, ISAAA** **Dr. Kauser A. Malik, Pakistan** **Mr. Mumtaz Khan Manais, Pakistan**
2000	Dinner hosted by NIBGE Serena Hotel, Faisalabad	

Day 2

7 March, Wednesday

TIME	Scientific Session III	RESOURCE PERSON
0900 – 1530	**Case studies from the developing and developed countries**	Chair: **Prof. James McD. Stewart, USA** Co-chair: **Dr. Iftikhar A. Khan,** Dean Agriculture, UAF, Pakistan
0900-0920	Development of transgenic Bt Cotton in China and its implications for IPM	**Dr. Jingyuan Xia** Director General, National Agro-Tech Extension and Service Centre, Ministry of Agriculture, China
0920-0940	Bt Cotton adoption in India	**Dr. K. B. Khadi** Director, Central Institute of Cotton Research, India
0940-1010	Experience with Bt cotton in Colombia	**Dr. Jorge Cadena** CORPOICA, Colombia
1010-1030	Biotechnology work in Turkey	**Dr. Isa Ozkan** Manager, Cotton Research Institute, Turkey
1030-1100	Tea break **Scientific Session IV**	 Chair: **Dr. Anwar Nasim** Chairman, National Commission on Biotechnology (NCB), Pakistan Co-chair**: Dr. Rafiq Chaudhry, ICAC**
1100-1130	Current status and prospects of biotech cotton in Pakistan	**Dr. Yusuf Zafar** Director, Agri-Biotech, PAEC, Pakistan
1130-1150	Grower's view on biotech cotton	**Mr.Phenias Gumede,** South Africa
1150-1210	Grower's view on biotech cotton in Pakistan	**Mr. Farhatullah Khan** Cotton grower, Mian Channu, Pakistan
1210-1230	Biotech cotton and challenges for Africa	**Dr. Osama Mumtaz** ARC, Egypt
1230-1250	Biotechnology: Research limitations	**Dr. Lastus K. Serunjogi** Director National Agricultural Research Organization, Uganda
1250-1330	Brief Country report Country report-1 Country report-2 Country report-3	Country representatives

1330-1415	Lunch	
1415-1700	**Scientific Session V (Workshop)**	
1415-1500	From A to Z - The major challenges and lessons learned from experience- Discussion led by facilitator	**Dr. Willy de Greef** Facilitator
1500-1530	Coffee/break	
1530-1700	Concluding discussion and way forward	**Dr. Anwer Nasim** **Dr. Masood Amjad Rana** **Dr. Yusuf Zafar** **Dr. Zahoor Ahmed Baloch** **Dr. Randy A. Hautea** **Dr. Marc Giband**
2000	Dinner Chenab Club	

Day 3

8 March 2007, Thursday

	Scientific Session VI	Chair: **Dr. Iqrar A. Khan** DG, Agri-Biotech, PAEC, Pakistan Co-chair **Dr. Zafar M. Khalid,** Director NIBGE
0900-0920	Biotechnology research: Investing for the future	**Dr. Marc Giband** CIRAD, France
0920-0940	Science communication and technology acceptance	**Dr. Claudia Canales** Germany
0940-1000	The threat of cotton viruses and its solution	**Dr. Rob Briddon**, NIBGE, Pakistan
1000-1030	Concluding Remarks	**Dr. Rafiq Chaudhry** **Dr. Yusuf Zafar** **Dr. Randy Hautea**
1030-1100	Coffee break	
1100-1200	Visit to NIBGE labs	
1200-evening	Visit to Lahore (only foreign participants)	

Participants will be able to leave Faisalabad and depart to their countries in the afternoon

Common Fund for Commodities
P.O. Box 74656
1070 BR Amsterdam
The Netherlands
Tel: (31 20) 575 4949
Fax: (31 20) 676 0231
http://www.common-fund.org

International Cotton Advisory Committee
1629 - K Street, NW, Suite 702
Washington DC 20006
USA
Tel: +1 202 463 6660
Fax: +1 202 463 6950
http://www.icac.org

International Service for the Acquisition of Agri-biotech Applications
c/o IRRI, DAPO Box 7777, Metro Manila, Philippines
Phone: +63 2 845 0563 • Fax: +63 2 845 0606
http://www.isaaa.org

National Institute for Biotechnology and Genetic Engineering
P.O.Box #577, Jhang Road
Faisalabad, Pakistan
http://www.nibge.org