Bt COTTON IN INDIA

A STATUS REPORT

(Second Edition)

Asia-Pacific Consortium on Agricultural Biotechnology (APCoAB)
Asia-Pacific Association of Agricultural Research Institutions (APAARI)

C/o ICRISAT, NASC Complex, Dev Prakash Shastri Marg, Pusa Campus
New Delhi - 110 012, India

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2009

J. L. Karihaloo
Asia-Pacific Consortium on Agricultural Biotechnology, New Delhi

P. A. Kumar
National Research Centre on Plant Biotechnology, New Delhi

Asia-Pacific Consortium on Agricultural Biotechnology (APCoAB)
Asia-Pacific Association of Agricultural Research Institutions (APAARI)
C/o ICRISAT, NASC Complex, Dev Prakash Shastri Marg, Pusa Campus
New Delhi 110 012, India

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or write to:

Coordinator
Asia-Pacific Consortium on Agricultural Biotechnology (APCoAB)
C/o ICRISAT, NASC Complex
Dev Prakash Shastri Marg, Pusa Campus
New Delhi - 110 012, India

FOREWORD

The Asia-Pacific Consortium of Agricultural Biotechnology (APCoAB), a program of the Asia-Pacific Association of Agricultural Research Institutions (APAARI), has been working to facilitate exchange of information and promote informed opinion across the region on issues of common interest related to agricultural biotechnology. In 2006, APCoAB published first status report on Bt Cotton in India when 40 Bt hybrids were being cultivated on an area of 1.26 million hectares. Besides tracing the development of Bt hybrids and their adoption by Indian farmers, the report highlighted issues that needed to be addressed to effectively harness the benefits that Bt technology promised.

During the past three years, Indian cotton scenario has changed dramatically, largely due to the adoption of Bt cotton. The number of Bt hybrids released for commercial cultivation till date has crossed 600 with more than 35 seed companies and public sector institutions currently engaged in their development. In addition, the first true breeding variety has also been released by the Indian Council of Agricultural Research (ICAR), a public sector institution. This provides an opportunity to the farmers to save their own seed without losing the efficacy of Bt gene. The area under Bt cotton reached 7.6 million hectares in 2008-09 constituting nearly 81% of the total cotton area in India. As a result, the production also reached 4.9 million tonnes. All these are indicators of the extraordinary impact and acceptance of Bt technology in cotton by the Indian farmers. This is quite comparable to the success of dwarf varieties of wheat and rice during the Green Revolution period. Several studies have established considerable economic benefits of Bt cotton cultivation to the farmers of all strata. Another significant development relates to creation of enabling environment by the Government of India. The Ministry of Environment and Department of Biotechnology simplified the regulatory procedures leading to expeditious commercial release, especially of events with well established biosafety record.

In view of all these new developments, it was felt appropriate to bring out an updated edition of our earlier status report on Bt cotton highlighting contemporary issues related to both technology development and its commercialization.

It is our expectation that this revised edition of **Bt Cotton in India – A Status Report** will be widely circulated and read in the Asia-Pacific region by all stakeholders. The experiences narrated in this report should also help other growing nations in evolving suitable systems of research, testing and commercialization of transgenic crops aiming at sustainability, productivity, food security and poverty alleviation, while safeguarding the environment.

(Raj Paroda)
Executive Secretary
APAARI

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LIST OF ABBREVIATIONS AND ACRONYMS

AFFB	:	Agriculture, Forest and Fisheries Branch
AICCIP	:	All India Coordinated Cotton Improvement Project
APAARI	:	Asia-Pacific Association of Agricultural Research Institutions
APCoAB	:	Asia-Pacific Consortium on Agricultural Biotechnology
ASSOCHAM	:	The Associated Chamber of Commerce and Industry of India
BRL	:	Biosafety Research Level
Bt	:	*Bacillus thuringiensis*
CAAS	:	Chinese Academy of Agricultural Sciences
CICR	:	Central Institute for Cotton Research
CSO	:	Civil Society Organisation
DBT	:	Department of Biotechnology
DLC	:	District Level Committee
ELS	:	Extra Long Staple Cotton
EBAM	:	Event based approval mechanism
EPA	:	Environment (Protection) Act
FAO	:	Food and Agriculture Organization of the United Nations
GEAC	:	Genetic Engineering Approval Committee
GMO	:	Genetically Modified Organism
GM	:	Genetically Modified
HAHB	:	Human and Animal Health Branch
IBSC	:	Institutional Bio-Safety Committee
ICAR	:	Indian Council of Agricultural Research
IEAB	:	Industrial and Environmental Applications Branch
IFPRI	:	International Food Policy Research Institute
IMAB	:	Inter-Ministerial Advisory Board
IMRB	:	Indian Market Research Bureau
IPM	:	Integrated Pest Management
IRM	:	Insect Resistance Management

ISAAA	:	International Service for the Acquisition of Agri-biotech Applications
Mahyco	:	Maharashtra Hybrid Seed Company
MEC	:	Monitoring cum Evaluation Committee
MoEF	:	Ministry of Environment and Forests
NARS	:	National Agricultural Research System
NBAC	:	National Biotechnology Advisory Council
NBRA	:	National Biotechnology Regulatory Authority
NGOs	:	Non Government Organizations
RAU	:	Risk Assessment Unit
RCGM	:	Review Committee on Genetic Manipulation
RDAC	:	Recombinant DNA Advisory Committee
r-DNA	:	Recombinant DNA
RPU	:	Regulatory Policy Unit
SBCC	:	State Biotechnology Coordination Committee
SOP	:	Standard Operating Precedure

I. INTRODUCTION

Cotton is an important fibre crop of India being cultivated over an area of about 9.5 million hectares (mha) representing approximately one quarter of the global area of 35 million hectares under this crop. After China, India is the largest producer and consumer of cotton, the country accounting for a little over 21% of the global cotton production in 2008-09 (Table 1). Much of this success owes itself to the introduction of Bt cotton in 2002 prior to which cotton production suffered huge losses due to its susceptibility to insect pests (CICR, 2009; Table 2). Among the insects, cotton bollworms are the most serious pests of cotton in India causing annual losses of at least US$300 million. The cotton bollworm complex comprises, American bollworm, also called 'false America bollworm' or 'old world bollworm', *Helicoverpa armigera*; pink bollworm, *Pectinophora gossypiella*; spiny bollworm, *Earias insulana* and spotted bollworm, *Earias vittella. Spodoptera litura*, the leaf worm, is mainly a foliage feeder but it also damages cotton bolls. Insecticides valued at US$660 million are used annually on all crops in India, of which about half are used on cotton alone (Manjunath, 2004; Rai *et al.,* 2009). Cost of the 21,500 metric tonnes (active ingredient) of insecticides used on cotton in India in 2001 was US$340 million. Further, the most destructive cotton pest, *Helicoverpa armigera,* is known to have developed resistance against most of the recommended insecticides (Ramasubramanyam, 2004) forcing farmers to apply as many as 10-16 sprays. Incorporating insect resistance has, thus, been the most important objective of cotton

Table 1. World production and consumption of Cotton in 2008-09

Country	Production (million tonnes)	Consumption (million tonnes)
China	7.8	9.9
India	4.9	3.9
United States	2.8	0.8
Pakistan	2.0	2.5
Uzbekistan	1.0	0.2
Brazil	1.2	0.9
Turkey	0.4	1.1
Rest of world	3.1	4.8
Total	23.2	24.1

Source: Cotton Incorporated, 2009.

Table 2. Some major insect pests of cotton

Borers	Foliage feeders	Sap feeders
American bollworm	Leaf worm	Leaf hopper
Pink bollworm	Leaf roller	Aphid
Spiny bollworm	Semiloopers	Whitefly
Spotted bollworm	Leaf perforator	Thrips
Stem weevil	Ash weevils	Red cotton bug
Shoot weevil	Surface weevil	Dusky cotton bug
Stem borer	Hairy caterpillars	Striped mealy bug
	Red hairy caterpillars	Black scale
	Cotton grasshopper	White scale
	Tobacco budworm	Yellow star scale
		Tea mosquito bug

Source: CICR, 2009.

improvement efforts in India. However, no sources of bollworm resistance are available in cotton germplasm or its near relatives.

Bt or *Bacillus thuringiensis* is a ubiquitous soil bacterium first discovered in 1901 by Ishiwata, a Japanese microbiologist (Kumar *et al.*, 1996). Later it was found that some Bt strains (Cry^+) were highly toxic to larvae of certain insect species which are also plant pests. Bt was first sold as a spray formulation in 1938 in France for the management of European corn borer. Subsequent research has revealed that Bt carries proteinaceous crystals (Fig. 1) that cause mortality in those insects which

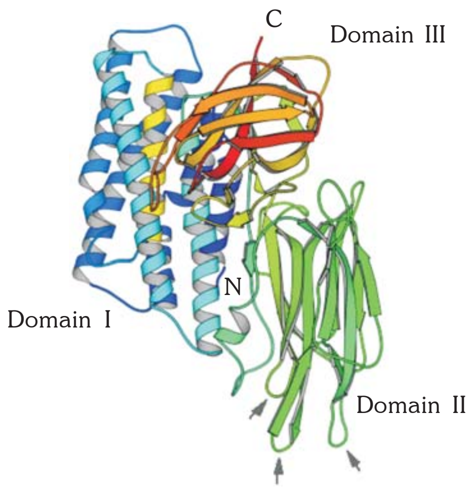

Fig. 1. A typical Bt crystal protein in three dimensional view. Source: Kumar *et al.*, 1996.

carry receptor proteins in gut membranes that bind to Bt proteins. Other organisms that do not contain receptors to Bt proteins are not affected by the toxin. Currently, 183 Bt Cry toxins that belong to 58 classes are known (http://www.lifesci.sussex.ac.uk/home/Neil_Crickmore/*Bt*/) which are specifically toxic to Lepidoptera and Phthiraptera.

The advent of genetic transformation technology made it possible to incorporate *cry* genes and thus the ability to produce Bt proteins in plant cells so that target insect larvae infesting the crop plants are effectively killed. The first Bt crops viz., Bt cotton, Bt corn and Bt potato were commercialized in USA in 1996. Bt crops are currently cultivated in 23 countries over an area of 46 mha (James, 2008).

In India, efforts to harness genetic engineering technology for bollworm resistance in cotton began in 1990s with the import of genetically modified (GM) cotton and initiation of research programs in national laboratories. Till August 2009, 619 cotton hybrids and a true breeding variety, having one or more transgenes for bollworm resistance, were approved for commercial cultivation. The Asia-Pacific Consortium on Biotechnology (APCoAB) published a status report on Bt cotton in 2006 (APCoAB, 2006) when 40 Bt cotton hybrids covered an area of 1.26 mha. Now when Bt cotton cultivation has expanded to an area of 7.6 mha, a revision of the report was felt necessary. The present edition, besides providing updated statistics, highlights newer issues related to technology, production, economic, social and environmental impacts of Bt cotton in India.

II. BIOSAFETY REGULATORY SYSTEM

The potential of biotechnology in improving agricultural production and farmers' incomes is well appreciated (FAO, 2004; World Bank, 2007). It is also recognized that GM technology may entail rare unintended risks and hazards to environment, and human and animal health. These risks include toxicity and allergenicity, emergence of new viruses, development of antibiotic resistance in microorganisms, adverse effects on non-target organisms, erosion of crop diversity, and development of new weeds (Gupta *et al.,* 2008). Several countries including India have adopted elaborate measures to ensure biosafe development, cultivation and use of genetically modified crops.

Biosafety of Bt cotton

Bt cotton is in many ways an ideal candidate for introduction as a transgenic commercial crop. It is basically grown as a fibre crop, while cotton seed oil used for consumption is free of proteins, including Bt protein. Environmental safety concerns are negligible because of the limited movement of heavy cotton pollen and the existence of natural genetic barriers that preclude outcrossing with native Indian cotton. There is also no known compatibility of cultivated cotton with any wild relatives occurring in India. Cotton is not found as a weed in the global production systems and Bt is unlikely to confer any advantage that would result in Bt cotton establishing as a weed.

The safety of Bt toxins in terms of toxicity and allergenicity towards mammals and other non-target organisms is well documented (Glare and O'Callaghan, 2000; Betz *et al.,* 2000). Lack of receptors that bind to Bt toxins and their instant degradation in human digestive system makes them innocuous to human beings. Community exposure to Bt spray formulations over a period of last six decades has not resulted in any adverse effects. Lack of homology to any allergenic protein/ epitope sequences makes Bt toxins non-allergenic. The safety of Bt crop-derived foods has also been well established (OECD, 2007; Lemaux, 2008).

In recent years, the effects of Bt crop cultivation on non-target organisms including insect predators, parasitoids and pathogens have been investigated quite extensively (Clark *et al.,* 2005; Romeis *et al.,* 2006; Marvier *et al.,* 2007; Babendreier *et al.,* 2008; Chen *et al.,* 2008; Lawo *et al.,* 2009; Naranjo, 2009). These studies indicate that Bt is rarely directly harmful to beneficial invertebrates and the effects on non-target organisms are negligible in comparison to those of conventional insecticides.

National regulatory system

In India, the rules governing the handling of genetically modified organisms (GMOs) and products thereof were notified in 1989 under Environment (Protection) Act 1986 (EPA) and guidelines issued subsequently (Ghosh, 2001; http://www.envfor.nic.in/divisions/csurv/geac/notification/html; http://dbtbiosafety.nic.in/). Two nodal agencies, Ministry of Environment and Forests (MoEF) and Department of Biotechnology (DBT), Ministry of Science and Technology are responsible for implementation of the regulations. There are six Competent Authorities to handle various issues viz., Recombinant DNA Advisory Committee, Institutional Biosafety Committee, Review Committee on Genetic Manipulation, Genetic Engineering Approval Committee, State Biotechnology Coordination Committee and District Level Committee. In general, these authorities are vested with non-overlapping responsibilities.

1. Recombinant DNA Advisory Committee (RDAC): This committee is constituted by DBT to monitor the developments in biotechnology at national and international levels. RDAC submits recommendations from time to time that are suitable for implementation for upholding the safety regulations in research and applications of GMOs and products thereof. This committee prepared the first Indian Recombinant DNA Biosafety Guidelines in 1990, which were adopted by the Government for handling of GMOs and conducting research on them. The guidelines were revised in 1998 (available at http://dbtindia.nic.in/thanks/biosafetymain.html; http://www.envfor.nic.in/divisions/csurv/geac/biosafety.html).

2. Institutional Biosafety Committee (IBSC): This committee is constituted by organizations involved in recombinant DNA (r-DNA) research. It has the mandate to approve low-risk (Category I and II) experiments and to ensure adherence to r-DNA safety guidelines. IBSC recommends category III or above experiments to Review Committee on Genetic Manipulation (RCGM) for approval. It also acts as a nodal agency for interaction with various statutory bodies.

3. Review Committee on Genetic Manipulation (RCGM): This committee is constituted by DBT to review all ongoing projects involving high-risk (Category III and above) and controlled field experiments. RCGM approves applications for generating research information on transgenic plants, which may be authorized to be generated in contained green house as well as in small plots. The small experimental field trials, also called Biosafety Research Level I (BRL I), are limited to a total area of 20 acres in multi-locations in one crop season. In one location where the experiment is conducted with transgenic plants, the land used should not be more than 1 acre. RCGM approval is granted for one season and applicant must provide entire details of the experimentation to the committee. Monitoring of field trials is carried out by Monitoring cum Evaluation Committee of RCGM. The latter also directs the generation of toxicity, allergenicity and any other relevant data on transgenic materials based on appropriate protocols. RCGM can lay down procedures restricting or prohibiting production, sale, importation and use of GMOs. It also issues clearances for import/export of etiologic agents and vectors, transgenic germplasm including transformed calli, seed and plant parts for research use only. A set of guidelines for conduct of field trials of regulated genetically engineered plans and Standards Operating Procedures (SOPs) have been approved by RCGM and GEAC in June 2008. The Guidelines describe the application process and general requirements for confined field trials and the SOPs for transport, storage, management, harvest/termination and post harvest management during the conduct of the trials (http:www.igmoris.nic.in/guidelines1.asp).

4. Genetic Engineering Approval Committee (GEAC): This committee functions as a body in the Ministry of Environment and Forests and is responsible for environmental approval of activities involving large-scale use of GMOs in research, industrial production and applications. Large-scale experiments conducted in an area of 2.5 acres per location, also known as Biosafety Research Level II (BRL II), beyond the limits specified within the authority of RCGM are authorized by GEAC. The GEAC can authorize approval and prohibition of any GMO for import, export, transport, manufacture, processing use or sale.

5. State Biotechnology Coordination Committee (SBCC): This committee, constituted in each state where research and application of GMOs are contemplated, has the authority to inspect, investigate and take punitive actions in case of violations of the statutory provisions. The Committee also nominates state government representatives in the committee constituted for field inspection of GM crops.

6. District Level Committee (DLC): This committee is constituted at the district level to monitor the safety regulations in installations engaged in the use of GMOs in research and application. The District Collector heads the committee who can induct representative from state agencies to enable smooth functioning and inspection.

The overall mechanism and functional linkages among various committees and departments concerned with approval of GM crops for commercial release are illustrated in a flowchart (Fig. 2).

In order to streamline the process of regulatory approval without compromising biosafety, the MoEF in April 2009 notified the ‘Event based approval mechanism’ (EBAM) initially for Bt cotton expressing four events namely; *cryIAc* (MON 531

Event), *crylAc* and *cry2Ab* (MON 15985 Event), *cry1Ab+cry1Ac* (GFM Cry1A Event) and *cry1Ac* (Event 1) (http://www.envfor.nic.in/divisions/csurv/geac/New%20 procedure%20under%20EABM.pdf). Accordingly, the elaborate case by case approval system has been done away with for Bt cotton hybrids/varieties containing these events and instead is based on affidavits submitted to the Standing Committee constituted to recommend such commercial release.

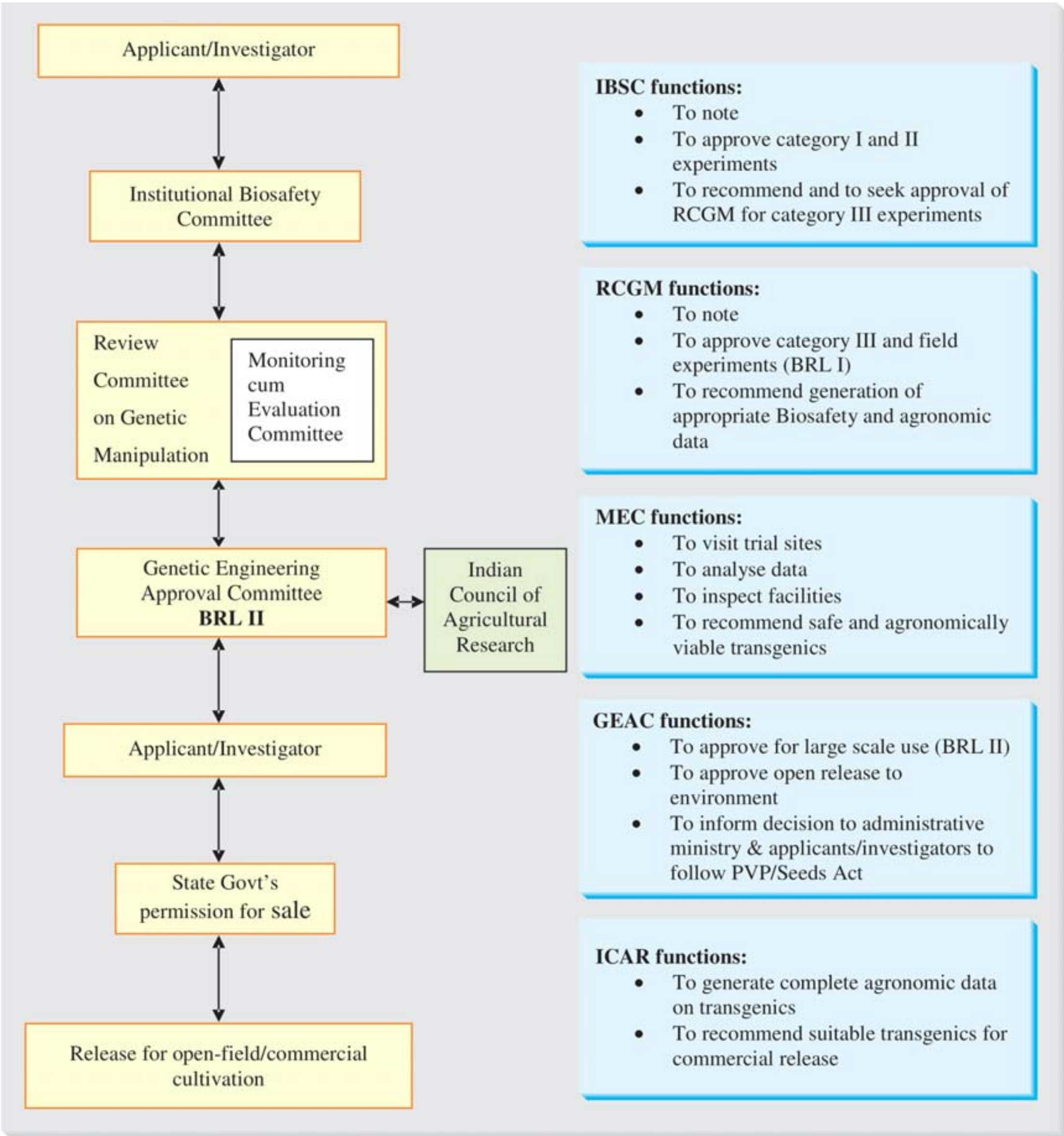

Fig. 2. Procedure of approval of GM crops for commercial release (DBT).

National Biotechnology Regulatory Authority (NBRA)

The establishment of a single window mechanism to provide approvals for GMOs has been a long felt need in India. The Ministry of Agriculture, Government of India, constituted a Task Force on the Application of Agricultural Biotechnology under the chairmanship of Prof. M.S. Swaminathan which recommended in 2004 the establishment of an autonomous and statutory National Biotechnology Regulatory Authority (NBRA). Similar recommendation was made in 2005 by the Task Force on Recombinant Pharma constituted by MoEF under the Chairmanship of Dr. R. A. Mashelkar. In 2005, DBT published a draft National Biotechnology Development Strategy and recommended the establishment of a National Biotechnology Regulatory Authority with four separate divisions. The National Biotechnology Development Strategy was approved by the Government of India in November 2007 and DBT was entrusted with the responsibility of setting up the NBRA (DBT, 2008). According to the Draft Establishment Plan for the NBRA (Fig. 3), it would be headed by an eminent biotechnologist as chairman, supported by two advisory bodies: (1) The Inter-Ministerial Advisory Board (IMAB) and (2) The National Biotechnology Advisory Council (NBAC). The authority will start working initially with three branches: (1) Agriculture, Forest and Fisheries Branch (AFFB) (2) Human and Animal Health Branch (HAHB) and (3) Industrial and Environmental Applications Branch (IEAB); each headed by a chief Regulatory Officer, an eminent scientist with subject matter expertise relevant to the branch. Each branch will have a Regulatory Policy Unit (RPU), responsible for developing and implementing branch specific policies, rules and guidelines. These documents will be prepared on case by case basis with the assistance of Risk Assessment Unit (RAU) comprising multi-disciplinary team of scientists.

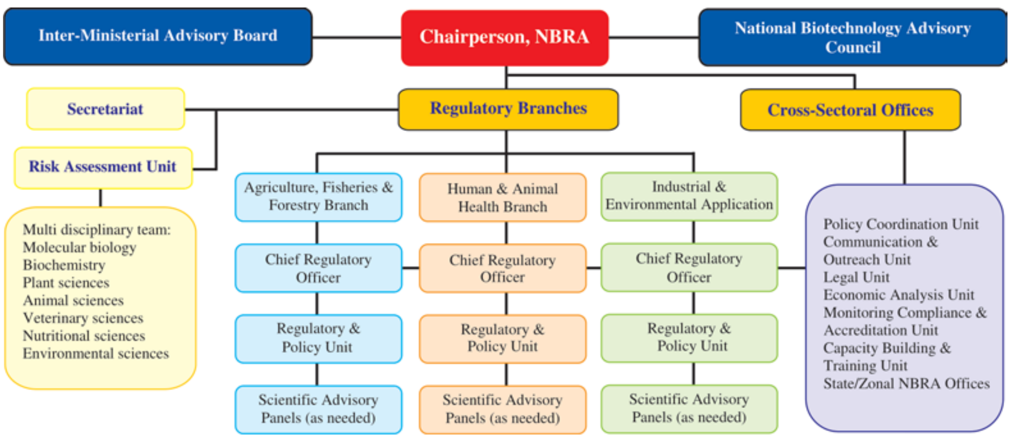

Fig. 3. Proposed structure of National Bioregulatory Authority.
Sources: DBT, 2008.

III. DEVELOPMENT AND COMMERCIALIZATION OF Bt COTTON

Global adoption of GM cotton has risen dramatically from 0.8 mha in 1996 to 15.5 mha in 2008 constituting 12.4% of total global hectarage under GM crops (James, 2008). Genetic modification in cotton has been carried out for insect resistance, herbicide tolerance and stacked insect resistance and herbicide tolerance. Bt cotton is the fourth dominant transgenic crop at the global level and is commercially cultivated in 15 countries.

The first approval for commercial cultivation of Bt cotton in India was granted to three cotton hybrids, MECH-12 Bt, MECH-162 Bt and MECH-184 Bt developed by Mahyco (Maharashtra Hybrid Seed Co.), a leading seed company (Barwale, 2002; Jayaraman, 2002). The insect resistance in these hybrids was introgressed from Bt gene *cry1AC* containing Cocker-312 (event MON 531, Bollgard I) developed by Monsanto, USA into parental lines of Mahyco's propriety hybrids (Appendix I). By using an accelerated breeding program and series of biotechnology tools, Mahyco developed stable hybrids with effective toxin expression. Pre-release biosafety and environmental safety testing on aspects of pollen flow, aggressiveness, gene stability, allergenicity, toxicity to small and large animals, protein expression, presence of toxin in by-products, influence on beneficial microorganisms and baseline susceptibility studies were carried out between 1997-2001 as per the guidelines of regulatory authorities.

Nearly 500 field trials were carried out in different agro-climatic regions between 1998 and 2001 to assess the efficacy of MON 531 against bollworms and the concomitant agronomic benefits. Simultaneously, the Indian Council of Agricultural Research (ICAR), an apex national organization in agricultural research, conducted 55 multi-location field trials through their network of All India Coordinated Cotton Improvement Project (AICCIP) for assessment of insecticidal efficacy and economic benefit of Bt cotton (AICCIP, 2002).

AICCIP trials clearly showed that the first generation Bt cotton hybrids provided effective control of bollworms, requiring no or fewer applications of insecticides and also provided high economic benefits to farmers. It was also found that *cry* gene incorporation into Indian cotton did not have any negative effect on fibre quality parameters. On the strength of comprehensive testing, MECH-12, MECH-162, and

MECH-184 were approved by GEAC in April 2002 for commercial cultivation in central and southern cotton-growing zones of India.

Realizing the immense potential of the technology, several Indian seed companies obtained licenses to incorporate the *cry1Ac* gene into their own hybrids. By 2008, the total number of commercially released hybrids reached 278 which also included three new events, Monsanto's Bollgard II, GFM Cry1A of the Chinese Academy of Sciences and Event-1 of Indian Institute of Technology, Kharagpur (Table 3, Appendix II). In addition, approval was granted to the first true breeding Bt-cotton variety 'Bt-Bikaneri Nerma' developed by University of Agricultural Sciences, Dharwad in collaboration with Central Institute of Cotton Research, Nagpur and National Research Centre on Plant Biotechnology, New Delhi (Fig. 4-13).

Table 3. A list of the Bt cotton events approved for cultivation in India

Event name	Event number	Source company/ institution	Genes	Year of approval
Bollgard I	MON 531	Monsanto	*cry1Ac*	2002
Bollgard II	MON 15985	Monsanto	*cry1Ac* and *cry2Ab*	2006
Event 1	Event 1	IIT, Kharagpur	Truncated *cry1Ac*	2006
GFM Cry1A	GFM Cry1A	Chinese Academy of Sciences	*cry1Ab+cry1Ac*	2006
Dharwad Event	Dharwad Event	UAS, Dharwad	Truncated *cry1Ac*	2008
9124	9124	Metahelix	*cry1C*	2009

In 2009, a new *cry1C* event, Event 9124, transferred in two hybrids by Metahelix, Bangalore was approved for commercial cultivation (GEAC, 2009). The total number of Bt cotton hybrids and varieties approved till August 2009 reached 619. Event-wise, the largest number has been developed using MON 15985 followed by MON 531 (Table 4).

Table 4. Number of hybrids/varieties per event approved for cultivation in India (till August 2009)

Event number	Source company/institution	Number of hybrids/varieties
MON 531	Monsanto	205
MON 15985	Monsanto	309
Event 1	IIT, Kharagpur	33
GFM Cry1A	Chinese Academy of Sciences	69
Dharwad Event	UAS, Dharwad	1
Event 9124	Metahelix	2

Fig. 4. MRC-6025 Bt.

Fig. 5. MRC-7301 BG II.

Fig. 6. MRC-7347 BG II.

Fig. 7. MRC-6304 Bt.

Fig. 8. Field view showing MRC-6304 Bt (left) and non-Bt cotton (right). Note the prominently higher boll retention in the Bt hybrid.

Fig. 9. Bt Mallika

Fig. 10. Bt Bikaneri Nerma

Fig. 11. Non-Bt cotton being sprayed for pest control. Source: ISAAA.

Fig. 12. Bountiful yield from Bt cotton. Source: ISAAA.

Fig. 13. Harvested Bt cotton being marketed. Source: ISAAA.

In addition to the six approved events, Bt cotton hybrids carrying three new events, which express dual Bt genes are currently undergoing BRL I and BRL II testing (Table 5). These events express Bt genes to ensure broad spectrum of insecticidal properties, a useful strategy for the management of insect resistance. The event Roundup Ready Flex Bt also carries two copies of EPSPS synthase gene which confers tolerance to the herbicide glyphosate.

Table 5. Bt cotton events currently undergoing field tests in India.

Event name	Event number	Company/institution	Genes
Event 1 + Event 24	Event 1 + Event 24	JK Agri	*Cry1Ac and cry1EC*
Widestrike	Event 3006-210-23 +Event 281-24-236	Dow Agro	*cry1Ac and cry1F*
Roundup Ready Flex Bt	MON 15985 + MON 88913	Monsanto	*cry1Ac,cry2Ab, CP4EPSPS*

Source: http://www.igmoris.nic.in/field_trials.asp.

During 2007-08 cotton was grown on 9.44 mha in nine states of India, of which more than 80% was sown to Bt cotton. Cotton production in this year was 31.5 million bales (mba) or 5.4 million tonnes (mt) (http://www.cotcorp.gov.in/statistics.asp#area1). The largest cotton growing state was Maharashtra (3.19 mha), followed by Gujarat (2.42 mha), Andhra Pradesh (1.3 mha or 18%) and others (Fig. 14). Gujarat achieved the highest production and yield, the latter ranging 330 kg/ha to 786 kg/ha across all states with an average of 567 kg/ha.

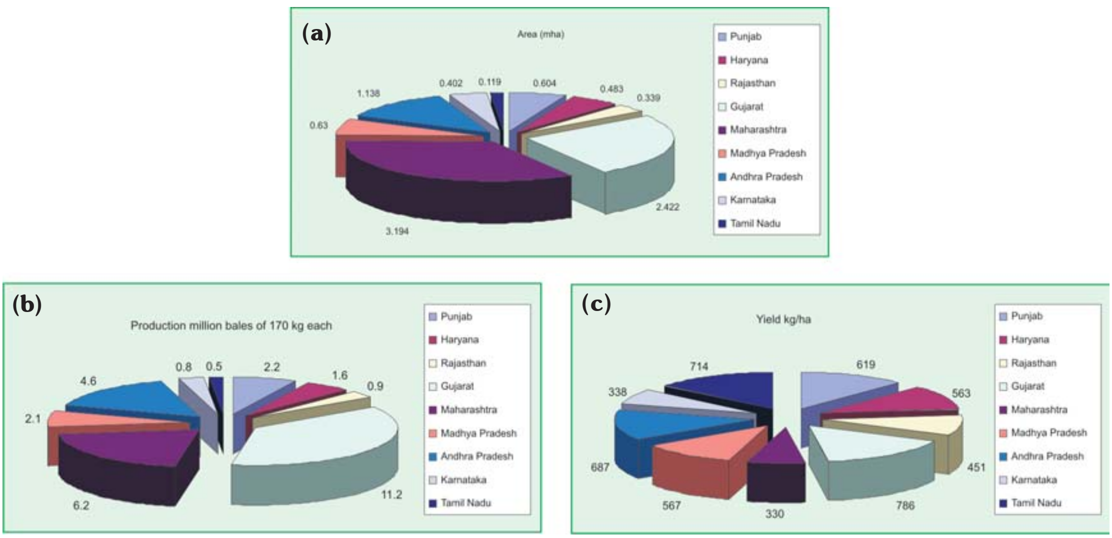

Fig. 14. State-wise cotton (a) area, (b) production and (c) yield during 2007-08.
Source of basic data: hpp://www.cotcorp.gov.in/statistics.asp#area/.

IV. PERFORMANCE AND IMPACT OF Bt COTTON

Several studies have been made on the performance of Bt cotton in India, including its yield and pest resistance, and socio-economic impact. The studies were initially carried out by seed companies as a part of the regulatory approval procedure and later by research centres as well as civil society organisations. Several of the below detailed studies have been reported in peer reviewed journals.

Two sets of field experiments were conducted by Mahyco in 1998-1999 under the monitoring of RCGM. In one set, MECH-12 Bt, MECH-162 Bt and MECH-184 Bt along with their non-Bt counterparts were tested in replicated field trials at 15 sites in nine states. In the other set, one Bt and one non-Bt hybrid along with check were tested on large plots at 25 sites under typical farm conditions. Results of the first set of experiments indicated a 40% higher yield of Bt hybrids (14.64 quintal/hectare (q/ha) over their non-Bt counterparts (10.45 q/ha) (James, 2000). Further, there was a significantly lower incidence of bollworm damage to fruiting bodies in Bt hybrids (2.5% at 61-90 days from planting) than in non-Bt hybrids (11.4% at 61-90 days from planting). The large-plot field trials at 21 sites (4 trials were damaged) yielded similar results with Bt hybrids showing average 37% (range 14% to 59%) higher yield over their non-Bt counterparts (Table 6). The overall pesticide requirement for controlling bollworm was reduced considerably.

Table 6. Results of Bt cotton field trials conducted by Mahyco at 21 sites during 1998-99

State	Number of locations	Yield q/ha			Number of sprays		
		Non-Bt	Bt	Check	Non-Bt	Bt	Check
Andhra Pradesh	6	9.63	11.98	8.68	3	0	3
Gujarat	2	24.91	38.89	28.45	7	1.5	7
Haryana	1	12.42	15.83	9.06	4	0	4
Karnataka	3	10.01	13.62	9.20	3	0	3
Madhya Pradesh	2	14.20	20.30	14.04	2	1	2
Maharashtra	6	17.22	22.30	18.44	4	1	4
Tamil Nadu	1	3.70	10.12	4.40	4	0	4
Average		**13.59**	**18.61**	**13.75**	**4**	**0.5**	**4**

Source of basic data: Naik, 2001.

The data generated from the above detailed multilocation tests were analysed by Naik (2001) to assess the potential economic advantage of Bt cotton in India. The results showed that there was 78.8% increase in the value due to yield and 14.7% reduction in pesticide cost with the growing of Bt cotton as compared to non-Bt cotton (Table 7). When compared with the prevalent farmers' practices, the benefit from Bt cultivation increased to 110%. Taking into account the additional cost of Bt seeds, the farmer would still get more than 70% greater benefits. The author further opined that the reduction in expenditure on pesticides would adequately compensate for the seed/technology cost increase. Hence, the total cost of cultivation of Bt cotton would not increase making it possible for even small farmers to adopt the technology.

Table 7. Economic benefits of Bt cotton as estimated from 1998-99 field trials conducted by Mahyco

Item	Value of the yield increase over non-Bt (per ha)	Value of reduced pesticide over non-Bt (per ha)	Total Benefit over non-Bt (per ha)	Benefit over farmer practices
Average of six states	Rs. 11,554.7 (US$262.6)*	Rs. 2148.9 (US$48.8)	Rs. 13,703.6 (US$311.4)	Rs. 16,126.6 (US$366.5)
% over average net return	78.8	14.7	93.5	110.0

Source of basic data: Naik, 2001.

ICAR conducted multilocation field trials in 2001 on the three Mahyco Bt hybrids specifically to make a cost benefit analysis. Yield increases over local check and national check were recorded to the magnitude of 60% to 92% (ISAAA, 2002) and gross income showed a 67% advantage from average Rs.14,112 (US$320.7)/ha in local and national check to average Rs.23,604 (US$536.5)/ha in the Bt hybrids. After adjusting the additional cost of Bt hybrid seed, the net economic advantage of Bt cotton ranged between Rs.4,633 (US$105.2)/ha and Rs.10,205 (US$231.9)/ha (Table 8).

Qaim and Zilberman (2003) reported the results of data from three Mahyco Bt hybrids along with their counterparts and a local check grown on 157 farms in 25 districts of Maharashtra, Madhya Pradesh and Tamil Nadu. On average, Bt hybrids received three times less sprays against bollworm than non-Bt hybrids and local checks (Bt, 0.62; non-Bt, 3.68; local check, 3.63). The number of sprays against the sucking pests was, however, same among the three. Insecticides sprayed on Bt cotton

*An approximate rate of Rs. 44 to 1US$ has been used for conversion of original Rs. figures to US$.

Table 8. Performance of Bt hybrids in ICAR field trials

Variety/hybrid	Yield q/ha	Gross income /ha		Insecticide cost/ha		Additional cost of Bt seed/ha		Net income/ha	
		Rs.	US$	Rs.	US$	Rs.	US$	Rs.	US$
MECH-12 Bt	11.67	21,006	477.4	1,727	39.25	2,425	55.1	16,854	383.0
MECH-162 Bt	13.67	24,606	559.2	1,413	32.1	2,425	55.1	20,768	472.0
MECH-184 Bt	14.00	25,200	572.7	1,413	32.1	2,425	55.1	21,362	485.5
Local check	8.37	15,066	342.4	2,845	64.7	—	—	12,221	277.8
National check	7.31	13,158	299.1	2,001	45.5	—	—	11,157	253.6

Source of basic data: AICCIP, 2002; James, 2002.

were lower by about 70% both in terms of commercial products and active ingredients. More interestingly, the article reported higher average yield of Bt hybrids exceeding those of non-Bt counterparts and popular checks by 80% and 87%, respectively. Analysis of the results showed that the general germplasm effect was negligible and the yield gain was largely due to Bt gene itself. The authors further argued that the expected yield effects of pest-resistant GM crops would be high in South and Southern Asia and Africa and medium to low in developed countries, China and Latin America. In India, the pest damage in 2001 was about 60% in conventional trial plots whereas in the USA and China, estimated losses in conventional cotton due to insect pests amounted to only 12% and 15%, respectively.

The above study was criticized in two subsequent articles (Arunachalam and Bala Ravi, 2003; Sahai, 2003) on the argument that the study sites chosen did not cover the entire spectrum of cotton-growing areas in India, the data collection and analysis were faulty and that the reported yield effect of *Bt* genes was scientifically untenable.

Bennett *et al.* (2004) presented an assessment of the performance of Bt cotton grown under typical farmer-managed conditions during 2002 and 2003. The study analysed commercial field data rather than trial plot data collected from 9,000 farmers' plots in Maharashtra. It met the recommendations of FAO (2004) for market-based studies that would accurately reflect the agronomic and economic environments faced by growers. Over both the seasons, the number of sprays required to control sucking pests (aphids and jassids) was similar for Bt and non-Bt plots. However, the number of sprays required for bollworm was much lower for Bt plots (1.44 for Bt versus 3.84 for non-Bt during 2002 and 0.71 for Bt versus 3.11 for non-Bt during 2003). There was a corresponding reduction in expenditure amounting to 72% and 83% in 2002 and 2003, respectively. However, when balanced with higher cost of Bt cotton seed, the results showed higher average costs for Bt cultivation compared to non-Bt cultivation (15% and 2% in 2002 and 2003, respectively). The real benefit came from the higher yield of cotton in Bt plots; in 2002, the average increase in yield for Bt over non-Bt was about 45% while in 2003 this was 63%. Taking into account the seed cost and variable cotton prices, the results showed a much higher gross margin for Bt growers [Rs.50,904(US$1156.9)/ha] than for non-Bt growers [Rs.29,279(US$665.4)/ha] during 2003. Similar results were reported by Bennett *et al.* (2006) from a survey conducted in Maharashtra, Gujarat, Madhya Pradesh and Karnataka, the most prominent Bt cotton growing states. The authors further noted regional variation in Bt cotton benefits along with differences in soil quality and input use

Bambawale *et al.* (2004) reported performance of MECH-162 Bt along with non-Bt MECH-162 and a conventional variety/hybrid under integrated pest management (IPM) in farmers' participatory field trials conducted in Maharashtra. Under IPM, 11.5% of the fruiting bodies were damaged in MECH-162 Bt compared to 29.4% in conventional cotton and 32.88% in non-Bt MECH-162. Population of sucking pests was also lower in MECH-162 Bt. Seed cotton yield in MECH-162 Bt (12.4 q/ha) was much higher than that of non-Bt MECH-162 (9.8 q/ha) and conventional cotton (7.1 q/ha). Net returns after taking into account cost of production and protection were Rs.16,231(US$368.9)/ha in MECH-162 Rs.12,433(US$282.6)/ha in non-Bt MECH-162 and Rs.10,507(US$238.8)/ha in conventional cotton.

The Deccan Development Society and the AP Coalition in Defence of Diversity conducted a three year study (2002-03 to 2004-05) in four cotton-growing districts of Andhra Pradesh viz., Warangal, Adilabad and Nalagonda and Kurnool covering 440 farmers growing Bt and non-Bt cotton under irrigated and rainfed conditions (Qayum and Sakkhari, 2005). The study concluded that: (i) on small farms under rainfed conditions, Bt cotton yielded nearly 30% less than non-Bt, (ii) there was a 7% cost reduction on pesticides with the adoption of Bt, and (iii) the earning with non-Bt cotton cultivation were 60% more than with Bt cultivation.

The Gokhle Institute of Politics and Economics, Pune conducted comparative study of Bt and non-Bt cotton during Kharif 2003 in two prominent cotton growing districts of Maharashtra, Yavatmal and Budhana (Vaidya, 2005a,b). The study involving 150 cotton farmers reported that substantially higher profits (79.2%) were realized from Bt cotton cultivation [Rs.31,880(US$724.5)/ha] compared to non-Bt cotton cultivation [Rs.17,790(US$404.3)/ha]. However, similar returns were not observed under rainfed conditions and the report called for comprehensive study "covering the crop under both irrigated and rainfed areas to find out whether Bt cotton can be cultivated without any risk under rainfed conditions." The study further noted complaints of bollworm and other pest disease attacks in Bt cotton.

Ramagopal (2006) carried out studies on economics of Bt Cotton cultivation in two major cotton producing districts of Andhra Pradesh, Guntur and Warangal, both of which have experienced high incidence of farmer suicides. It was observed that cotton yields harvested by Bt growing farmers were higher than that harvested by non-Bt farmers. The net income derived by Bt farmers was Rs.26,406 (US$600.13)/ ha while it was Rs.9,059 (US$205.88)/ha for the non-Bt farmers. Income differences among irrigated and unirrigated category of farmers were also marked in Bt growing group.

Qaim *et al.* (2006) studied the influence of differences in pest pressure, pattern of pesticide use and germplasm on performance and economic benefits of Bt cotton. The net revenue from Bt crop adoption was calculate as Rs.5,294 (US$120.31)/ha, significantly higher than Rs.3,133 (US$71.20)/ha from conventional cotton. The results, based on the first season of Bt cotton adoption in India in 2002, showed that Bt technology leads to significant pesticide reduction, yield gain and income increases. However, significant variability in the results was caused by variation in germplasm in which Bt was incorporated, agroecological conditions and farmers' spraying habits.

Gandhi and Namboodiri (2006) surveyed 694 cotton growing farmers from Gujarat, Maharashtra, Andhra Pradesh and Tamil Nadu. The yields of Bt cotton were significantly higher than that of non-Bt cotton under both irrigated and non-irrigated conditions (Table 9). The profit from Bt cotton cultivation ranged Rs.15,247 (US$346.52) to Rs.32,065 (728.75US$)/ha while that from non-Bt cotton ranged Rs.5,426 (US$123.32) to Rs.18,244 (US$414.64)/ha. The farmers perceived

Table 9. Impact of Bt cotton adoption in three cotton growing states (percent Impact)

	Gujarat	Maharashtra	Andhra Pradesh
Yield	35.43	42.67	2.32
Value of output	38.30	42.79	21.33
Total cost	13.47	5.81	3.25
Pesticide cost	-18.07	-22.38	28.17
Seed cost	128.07	118.53	192.53
Price	2.48	-0.1943	0
Profit	73.81	120.08	78.18

Source: Gandhi and Namboodiri, 2006.

advantages of Bt cotton with respect to pest incidence, pesticide need, cotton yield, quality and profitability. Many farmers, however, reported disadvantage in the seed cost.

Raney (2006) reviewed the earlier studies made on economic impact of Bt cotton in developing countries. The author concluded that the first economic studies were based on farm field trial data and as such did not reflect the actual farm experiences with commercial cultivation. These studies estimated potential yield benefits of 80%. Later farm level research found smaller, but significant, yield advantage even for unofficial varieties.

Two studies on "Bt Cotton Farming in India" were released by The Associated Chambers of Commerce and Industry of India (ASSOCHAM) in 2007 (http://mosanto.mediaroom.com/index.php?s=43&item=508&printable). The study by Indian Market Research Bureau (IMRB) International covered about 6,000 farmers from 37 districts and reported approximately 50% yield increase in Bt cotton compared to non-Bt cotton. The number of sprays was 5 less per acre and the net revenue was higher by Rs.7,757 (US$176.30)/acre with Bt adoption. The satisfaction level of Bt users regarding crop performance was an average 93%. The second study was conducted by Indicus Analyticus and analysed socioeconomic impact of Bt cotton adoption on about 9,000 farmers across 467 villages in eight states. The impact of Bt cotton farming was found to be positive on availing of education and health services. Bt farmers were better off on socioeconomic front and were likely to adopt better farming practices.

Frisvold and Reeves (2007) examined the impacts of Bt cotton production on world and domestic cotton prices at 2005 adoption levels. The Total Factor Productivity Growth from Bt cotton was estimated at 3.3% with 0.9% and 0.7% increase in textile and apparel production, respectively. While, there was a gain of more than US$200 billion in India due to Bt cotton adoption, the increased worldwide production led to a 3% decline in the world cotton prices.

Brookes and Barfoot (2008) emphasised the environmental effects of GM crops, including insect resistant cotton. Among all the GM crops cultivated globally, insect resistant cotton was found to have resulted in the greatest environmental gain in terms of reduction in pesticide use. Further, India experienced the highest average traits advantage of 54% on yield, whereas in the other countries it ranged between 0% and 27%. The increase in farm income at the national level due to Bt cotton adoption in 2006 was calculated at US$839.89 million.

Subramanian and Qaim (2009) analyzed the welfare and distribution effects of Bt cotton adoption in a typical village economy. The study showed that besides consistent economic gains (Table 10), the Bt adopting regions experienced increased

Table 10. Yield, insecticide use and net revenue from Bt and conventional cotton plots

	2002-2003		2004-2005		2006-2007	
	Bt	Conven-tional	Bt	Conven-tional	Bt	Conven-tional
Yield (kg/ha)	1627.94	1212.92	1835.80	1360.33	2079.72	1457.71
Insecticide use (kg/ha)	5.11	10.30	5.06	10.35	3.01	3.83
Net revenue (/ha)	Rs.13082.02 (US$297.31)	Rs.7741.62 (US$175.94)	Rs.12161.84 (US$276.40)	Rs.5317.79 (US$120.85)	Rs.17595.55 (US$399.89)	Rs.10331.89 (US$234.81)

Source of basic data: Subramanian and Qaim, 2009.

aggregate employment, household incomes including for poor and vulnerable farmers.

In addition to farmer level benefits, the spurt in national cotton production has improved very substantially India's position in international cotton and cotton goods trade. Exports of cotton registered a sharp increase from a meagre 0.05 mba in 2002-03 to 8.5 mba in 2007-08 amounting to an increase in earnings from US$ 10.39 million to US$ 2.20 billion (PIB, 2009; Table 11). The Indian textile industry, for which cotton is the major raw material and generates considerable revenue and employment, also gained from cotton production boom. The industry directly employs over 35 million people and contributes 4% to DGP and 13.5% to export earnings (PIB, 2009). In the recent past, the industry had been plagued by obsolescence, labour problems and lack of raw material (Gupta, 2006). However, with increasing availability of Bt-cotton since the last few years there has been a transformation of the textile industry. The cotton textile exports, constituting more than two-thirds of all textile exports of India, increased in value from US$3.4 billion in 2002-03 to US$4.7 billion in 2007-2008 (Table 11).

Table 11. Value of cotton export and import (in US$ million)

Item	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08
Export						
Cotton raw including waste	10.39	205.08	94.05	656.00	1348.75	2203.07
Cotton yarn, fabrics and madeup	3351.05	3394.87	3450.11	3944.78	4215.40	4655.56
Import						
Cotton raw including waste	255.73	341.67	252.73	158.93	746.42	226.67
Cotton yarn and fabrics	87.80	142.10	195.79	279.13	318.33	318.98

Source of basic data: Ministry of Textiles, Government of India (http://ministryoftextiles.gov.in)

Conclusion

The above detailed studies clearly establish the positive impact of Bt cotton in all cotton growing areas and under diverse agroclimatic conditions, albeit with variable gains. Primarily by conferring resistance to bollworm, the number of pesticide sprays that a farmer has to give to his cotton crop has reduced and the harvested cotton yield has increased substantially. Farmers' earnings and profitability from Bt cultivation have been significantly higher than those from cultivation of non-Bt cotton. The gains have also translated into better access to social services. That the impacts have been widespread is evident from the national level cotton statistics. Since the introduction of Bt cotton in farmer fields in 2002, there has been near tripling of cotton production from 2.3 mt in 2002-03 to 5.4 mt in 2007-08 while the area has increased from 7.7 mha to just 9.4 mha (Fig. 15). During these years the area under Bt hybrids has expanded to more than 80% of the total cotton area (Fig. 16) and the yields have increased from 302 kg/ha to 567 kg/ha. Not surprisingly, the number of farmers growing Bt cotton has shown a phenomenal increase (Fig. 16). To cater to the seed demands, dozens of seed companies have entered Bt cotton seed industry producing new hybrids with licensed or sometimes their own Bt events.

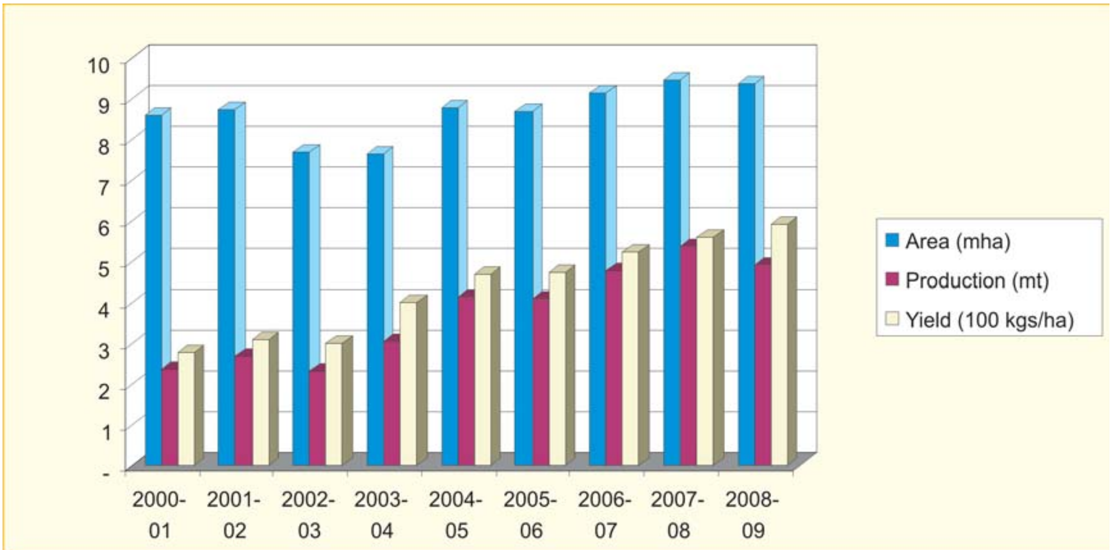

Fig. 15. All India area, production and yield of cotton.
Source of basic data: http://www.cotcorp.gov.in/statistics.asp#area.

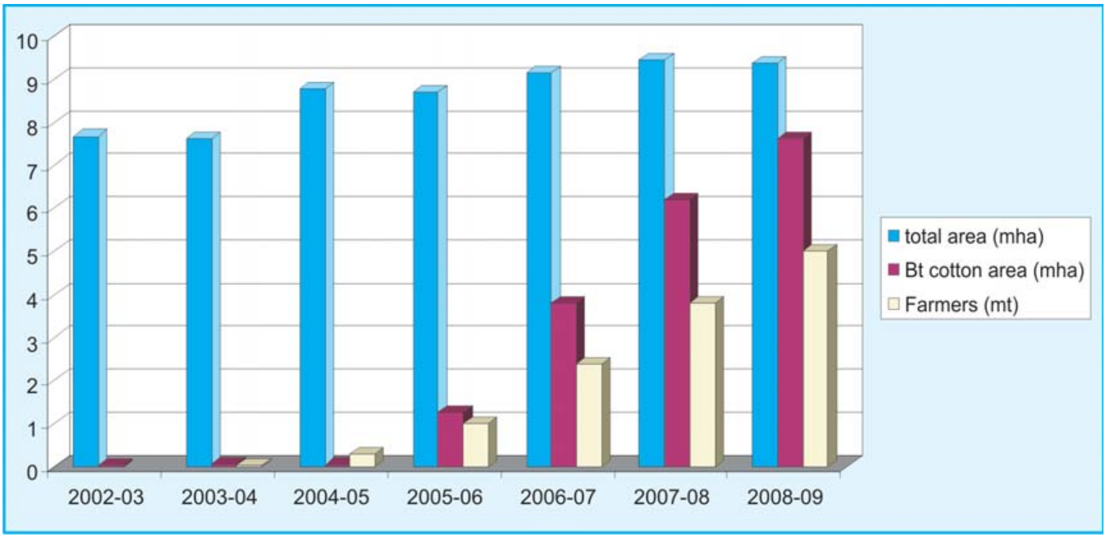

Fig. 16. Total cotton area, area under Bt cotton and number of farmers adopting Bt cotton in India
Source of basic data: http://www.cotcorp.gov.in/statistics.asp#area/; James, 2008.

V. CONCERNS AND THE WAY AHEAD

Bt cotton has evoked unprecedented interest and debate among a large section of Indian public comprising biotechnologists, plant breeders, economists, social scientists, environmentalists, civil society and farmer organizations. A number of concerns were highlighted in the first edition of this publication quite a few of which have now been addressed. For example, Bt cotton seed price has reduced substantially making it more affordable to the farmers. Adoption of Event based approval mechanism by GEAC has greatly simplified commercialization of hybrids/varieties incorporating events with already proven biosafety. Issues like production and economic advantages of Bt cotton should now be regarded as settled since, as detailed in the previous chapter, sufficiently exhaustive and reliable evidence is available to support its benefits. Some negative developments like sheep deaths and farmers' suicides widely reported in popular media have been found to be unrelated to Bt cotton cultivation (see box). Nevertheless, there are still some issues that need to be addressed to fully harness the opportunities provided by biotechnology and genetic potential of the crop. Some of these issues are highlighted below.

Genetic background

During the initial years of Bt cotton cultivation some hybrids were reported to perform poorly under unirrigated conditions while others yielded inferior quality cotton staple (Arunachalam and Bala Ravi, 2003). These observations suggest that the genetic backgrounds in which the *cry* gene was initially introduced were not the most desirable ones. This aspect has been addressed to a large extent during the past few years by the entry of several seed companies into Bt cotton development. The seed companies have used elite germplasm and adopted effective back crossing strategies to eliminate undesirable traits of the original Coker and introduce desirable traits of yield, quality and adaptation. However, there is still considerable scope of yield and quality improvement through the use of improved germplasm in view of the fact that cotton yield in India (567 kg/ha) is still far lower than that of USA (902 kg/ha).

Genetic diversity

One of the apprehensions expressed about the adoption of GM technology is the likelihood of one or a few GM genotypes becoming the dominant cultivars thus

Sheep Death and Farmer Suicides

Consumption of Bt cotton leaves was alleged to be responsible for mortality of sheep in Warangal district of Andhra Pradesh (Kuruganti, 2007). The state department of agriculture, which investigated the case at the behest of GEAC, had the Bt cotton samples analyzed by four public sector laboratories. The samples were found to contain high levels of nitrates, nitrites, hydrogen cyanide residues and organophosphates, which may have come from the soil, fertilizer or pesticides used in cotton cultivation and were the cause of animal deaths (GEAC, 2007). Since the farmers use significantly lower quantities of insecticides on the Bt cotton crop, nitrates and nitrites could have been the likely toxicants.

There have been allegations that Bt-cotton has contributed to farmer suicides in some parts of India. A recent report by International Food Policy Research Institute (IFPRI, 2008) provided a comprehensive review of evidence on Bt cotton and farmer suicides, taking into account information from diverse sources. The study revealed that there is no evidence in available data of a "resurgence" of farmer suicides in India during 2002-2007. Secondly, Bt cotton technology has been very effective in India; however, the context in which Bt cotton was introduced has generated disappointing results in some particular districts and seasons. The analysis clearly showed that Bt cotton is neither a necessary nor a sufficient condition for the occurrence of farmer suicides. In contrast, many other factors have likely played a prominent role.

leading to reduction of crop diversity in farmers' fields. Reduction in traditional crop diversity has in the past been associated with the large scale adoption of high yielding varieties during Green Revolution. However, the history of Bt cotton adoption in India suggests that such fears may prove unfounded. Since 2002 when the first Bt hybrids were commercialized in India by one seed company, several others have transferred Bt genes into many diverse germplasm lines from different sources. Zilberman *et al.* (2007) suggested that the erosion of diversity due to adoption of GM technology would be insignificant once a multitude of GM varieties become available from the seed sector. Empirical analysis has revealed that while during the first years of Bt cultivation, a reduction in on-farm varietal diversity took place, this effect was partially offset by more Bt varieties becoming available over the years (Krishna *et al.,* 2009).

True breeding varieties

The need for development of true breeding Bt cotton varieties to ensure that farmer-saved seed has desirable level and uniform expression of insect toxin was elaborated in the previous edition of this status report. It is heartening to report that the first public sector Bt cotton variety 'Bt Bikaneri Nerma' has been approved for commercial cultivation. It is hoped that several more such varieties will become available soon to provide wider choice to farmers in different cotton growing regions of the country.

Resistance development

Extensive cultivation of Bt-cotton can impose a continuous and intense selection pressure on bollworms leading to the latter's development of resistance to the toxin (Kumar, 2004). A study was carried out during 2001-2007 to monitor the variability in susceptibility of cotton bollworm, to CrylAc toxin in populations collected from 53 cotton growing districts of India (Mayee, 2009). The study indicating a decrease in the proportion of susceptible populations warrants judicious implementation of insect resistance management (IRM) strategies such as refugia, gene stacking, high toxin dosage and integrated pest management. These are elaborated below.

- ***Refuge crop:*** One of the conditions for environmental release of Bt cotton is that each such field is to be surrounded by a belt of non-Bt cotton of the same variety to serve as 'refuge' for bollworm. The size of the refuge belt should be either five rows of non-Bt cotton or 20% of total sown area whichever is more (Ghosh, 2001). The refuge strategy is designed to ensure that Bt-susceptible insects will be available to mate with Bt-resistant insects, should they arise. Available genetic data indicates that susceptibility is dominant over resistance (Tuli *et al.,* 2000). The offsprings of these matings would most likely be Bt-susceptible, thus mitigating the spread of resistance in the population. It has been very widely reported that these norms are not followed in practice, which could lead to rapid build-up of Bt toxin resistance in bollworm. However, some workers have questioned the need for refuge in the Indian farming situations (Manjunath, 2004, 2005). *H. armigera*, the most predominant bollworm in India has a large number of alternative hosts like chickpea, pigeonpea, sorghum and tomato which serve as its natural refuge. Consequently, GEAC first approved the use of any popular non-Bt hybrid as refuge (GEAC, 2006). Later, planting of pigeonpea as refuge in place of non-Bt cotton varieties was approved (GEAC, 2009).
- ***Gene diversification:*** Worldwide, several insecticidal protein genes for pest resistance, have been first identified and are at different stages of deployment in crops, including cotton (Kumar *et al.,* 2009). Further, gene stacking or pyramiding in which two or more insecticidal proteins are expressed in the plant is being adopted to obviate the development of resistance by the target pest (Kumar *et*

al., 2009). Some examples of gene pyramided Bt-cotton are 'Bollgard II' (Cry1Ac and Cry2Ab) and 'Widestrike' (Cry1Ac and Cry1F). Judicious combination and introduction of these genes in cotton will confer long-term durability to pest combating technology.

In addition to insect resistance, introduction of other biotic stress traits will make Bt-cotton more robust and long-lasting. Attempts are underway in different laboratories to exploit transgenes conferring tolerance to sucking pests and leaf curl virus, which pose major problems to cotton cultivation in north India.

- ***Integrated pest management:*** The best approach to prevent resistance development in transgenic crops including cotton is to apply some of the well-known IPM measures such as crop rotation and sanitation, botanical pesticides, biological control agents along with minimal sprays of insecticides (Kumar, 2003). IPM will delay resistance development and ensure long term durability of the Bt hybrid/variety.

Secondary pests and diseases

Continuous cultivation of Bt-cotton has at some places led to increased incidence of sucking and other pests such as mired bugs, mealy bugs, thrips and leaf eating caterpillar, and appearance of leaf reddening and Parawilt (Nagrare, et al., 2009). CrylAc toxin expressed by Bt-cotton is not toxic to sucking pests and the Bt hybrids currently available are only moderately toxic to leaf eating caterpillar. In the past, use of synthetic pyrethroids had kept caterpillars and several other miscellaneous pests under control. Cessation of the use of pyrethroids and other conventional insecticides on Bt-cotton has resulted in the increased incidence of secondary pest damage. Since such pests have enormous potential of becoming major pests of cotton, breeding and management strategies need to be adopted to minimize losses caused by them. Similarly, while Parawilt has not been a new disease in India (Mayee, 1997), its impact can be more in Bt cotton because of latter's higher boll retention. Proper soil, water and nutrient management is known to reduce the incidence of Parawilt.

Illegal Bt cotton

The high demand for Bt cotton seed has spawned a parallel industry of illegal/ spurious Bt seed which is of dubious origin and quality. Tests conducted at Central Institute of Cotton Research, Nagpur have revealed such seeds to comprise F1 and F2 progenies of Bt hybrids or their mixtures (details available at: http://www.envfor.nic.in/divisions/csurv/geac/vrguj.doc). Use of such seed can put the farmer to considerable loss since germination, Bt trait expression, and general crop performance is not assured. Further, no biosafety measures are adopted during its cultivation. Not having been approved by GEAC, production, sale and use of such seeds is a violation of rules and liable to punitive action under the EPA.

Illegal/spurious Bt cotton seed was in the market even before the first approval for commercial cultivation of Bt cotton was granted by GEAC (Jayaraman, 2001, 2004). In 2005, against 90,000 packets of legal Bt cotton sold in Yavatmal district of Maharashtra, the number of illegal packets sold was 250,000 (Sainath, 2005).

The problem of illegal/spurious Bt cotton seed has somewhat diminished during the last few years due to reduction in seed cost and availability of several very well performing legal Bt hybrids suitable for all cotton growing regions of the country. However, it is still a cause of concern since 1.58 mha were reported to be sown to illegal/spurious seed in Gujarat during 2008 (http://www.business-standard.com/india/storypage.php?tp=on&autono=36076).

Seed marketing

Bt seed being entirely produced by the private sector, its marketing and cultivation technology transfer have been carried out almost exclusively by private sector companies. There have been reports of aggressive and sometimes misleading marketing tactics which have left the farmers confused about the choice of seed, crop management practices and output expectations (Stone, 2007). This is unlike the green revolution era when seed production, distribution and extension chain from breeder's field to farmer's field was more organized with extensive support from public sector scientists and extension workers. There is an urgent need to effectively monitor and regulate Bt cotton seed marketing so that the farmers are better informed about appropriate seeds and crop management practices.

Other issues

While genetic improvement has substantially enhanced cotton productivity during the last few years, it is still far below that of USA and China. Interestingly, cotton cultivation in both the countries is based on true breeding varieties. Hence, besides biotechnology and hybrid technology, there is a need to evaluate breeding and crop management options successful in other countries.

Efforts need to be accelerated towards incorporating drought tolerance, improved fibre quality and other desirable traits through genetic modification or marker assisted breeding. Further, there is much to be achieved with respect to the quality of cotton fibre. The current demand for extra long staple cotton (ELS) is 1.0 mba whereas the production in 2007-08 was only 0.6 mba. The micronaire value of long and extra long categories, and tenacity are higher in foreign cotton than in Indian cotton. Indian cotton is regarded to be among the world's most contaminated with high percentages of trash and microdust (Sreenivasan, 2006-07). Bale-to-bale and lot-to-lot variability in quality attributes is greater in Indian cotton. These issues need to be addressed to enable India achieve desired levels of cotton productivity, quality and competitiveness in the world textile and apparel market.

VI. EPILOGUE

The history of Bt cotton in India is a unique example of rapid technology acceptance and diffusion with several positive fall outs. It has even prompted Mr P. Chidambaram, the Indian Finance Minister to urge scientists to replicate the success of Bt cotton in cereal and food crops (http://www.indiaenews.com/india/20070607/55231.htm). Despite the large volume of empirical data proving it success, the persistent stories of "Failure of Bt cotton in India" has been attributed by Herring (2009) to "....a critical role for "epistemic brokers," or hinges, between local, national, and international advocacy groups within larger transnational advocacy networks".

As mentioned in the previous edition of this status report, any technological innovation takes time to stabilize and become widely acceptable. The pace at which Bt cotton has been accepted and adopted in India has been phenomenal. Along with the government policy, scientific support has been quite forthcoming. ICAR is funding several programs on cotton biotechnology, breeding and insect pest management. ICAR funded mission mode network programs are being operated in partnership with other national and international agencies and universities. Similarly, DBT has funded several biotechnology projects aimed to develop cotton resistant to biotic stresses, gene stacking, silencing of vital genes (acetylcholinesterase, ornithine decarboxylase and chitin synthase) of cotton bollworm by plant-mediated RNAi, and IPM. The results of these efforts should be seen in the very near future.

We still need to have good public awareness programs, well-regulated seed distribution system and conducive market for the produce. Strict adherence to the prescribed procedures and regulatory measures at all stages of development and cultivation of GM crops is an imperative. Equally important is the cooperation among seed developers in public and private sectors, extension workers and CSOs in garnering and disseminating factual and reliable information about the products and their performance.

It is hoped that the attempt made by APCoAB/APAARI in bringing together this information will serve to generate more interaction among different stakeholders to benefit from the technology as also resolve various issues and concerns as expressed in this status report. Ultimately, it should lead to greater realization of the potential of biotechnology for enhancing farm production, improving livelihoods and creating safer environment. Further, in the regional context, dissemination of this report should prove useful to other NARS of the Asia-Pacific where genetic modification technology is under various stages of development and adoption for increased productivity and resource conservation.

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Appendix I

Development of first Bt cotton hybrids MECH-12 Bt, MECH-162 and MECH-184 Bt

1. Technology Involved

The core genetic engineering experiments which culminated in development of insect pest-resistant cotton (Bt cotton) were conducted by Monsanto, USA and comprised isolation of gene from *Bacillus thuringiensis* and its further development to ensure its expression in the fully grown plant. The plasmid construct comprised:

- The *cry1Ac* gene, which encodes for an insecticidal protein, Cry1Ac.
- The 35S promoter from Cauliflower Mosaic Virus that drives expression of the *cry1Ac* gene in all parts of the plant leading to the production of Bt protein.
- The *nptII* gene, the selectable marker, which encodes the enzyme neomycin phosphotransferase II (NPTII). It is used to select transformed cells/plants on media containing the antibiotic kanamycin.
- The *aad* gene which encodes the bacterial selectable marker enzyme 3"(9)-O-aminoglycoside adenyltransferase (AAD) and allows selection of bacteria containing the Cry1Ac plasmid on a medium containing spectinomycin or streptomycin.

Cotton tissue cultures (variety Cocker-312) were infected with the soil bacterium, *Agrobacterium tumefaciens* containing the plasmid with the above sequences. The transformed cotton lines were screened to identify those with desirable insect control and agronomic performance.

2. Chronology of Events

Following several years of field trials with Bt cotton, based on the recommendations of RCGM, GEAC in its 32nd meeting on 26 March, 2002 approved the commercial cultivation of three Bt cotton hybrids: MECH-12 Bt, MECH-162 and MECH-184 Bt (Barwale *et al*., 2004; http://www.envfor.nic.in/divisions/csurv/geac/bgnote.pdf). The sequence of events that led to the development and approval of these is listed below:

1996: After obtaining permission from DBT, Mahyco imported 100 g of Cocker-312 seed containing the *cry1Ac* gene from Monsanto, USA. Crossing with Indian cotton breeding lines to introgress *cry1Ac* gene was carried out and 40 elite Indian parental lines were converted for Bt trait.

1996–1998: Greenhouse, risk-assessment studies and limited field trials (1 location) were conducted using Bt cotton seeds from converted Indian lines for pollen escape studies, aggressiveness and persistence studies, biochemical analysis, toxicological studies and allergenicity studies

1998–1999: Multi-location field trials were conducted at 40 locations in nine states to assess agronomic benefits and safety.

1999–2000: Field trials repeated at 10 locations in six states.

July 2000: GEAC gave approval for conducting large-scale field trials on 85 ha and also to undertake seed production on 150 ha.

2001: Large-scale field trials were conducted covering 100 ha. Field trials were also conducted by All India Coordinated Cotton Improvement Project of the ICAR.

2002: GEAC approved three Bt-cotton hybrids for commercial cultivation after taking into account the data on their performances.

3. Trial Results

Mahyco conducted the following biosafety, risk management and field performance trials on the Bt hybrids submitted for approval of GEAC. These studies were carried out in the laboratories and experimental fields designated by RCGM/GEAC. Besides, the socio-economic impact of Bt cotton cultivation was also assessed.

A. Biosafety Assessment

(i) Studies on Environmental Safety

Mahyco got the following studies conducted at a number of scientific institutes as per the protocol approved by RCGM.

- *Pollen escape/out-crossing:* Multi-location experiments conducted in 1996, 1997 and 2000 revealed that out-crossing occurred only up to two meters, and only 2% of the pollen reached a distance of 15 m. As the pollen is heavy and sticky, the range of pollen transfer is limited. The studies concluded that there is essentially no chance that the *Bt* gene will transfer from cultivated tetraploid species such as the present Bt hybrids to traditionally cultivated diploid species.
- *Aggressiveness and weediness:* To assess the weediness of Bt cotton, the rate of germination and vigour were compared with non-transformed parental lines by laboratory test and in soil. The results demonstrated that there are no substantial differences between Bt and non-Bt cotton for germination and vigour. Hence, there is no difference between Bt and non-Bt cotton with regard to their weediness potential.

- *Effect of Bt on non-target organisms:* Studies conducted during the multi-location field trials revealed that the Bt cotton hybrids do not have any toxic effects on the non-target species, namely sucking pests (aphids, jassids, white fly and mites). The population of secondary lepidopteran pests, namely tobacco caterpillar remained negligible during the study period in both Bt and non-Bt hybrids. The beneficial insects (lady bird beetle and spiders) remained active in both Bt and non-Bt varieties.
- *Presence of Bt protein in soil:* Studies were conducted to assess the possible risk of accumulation of Bt protein in the soil, by insect bioassays. Bt protein was not detected in soil samples indicating that the Cry1Ac protein was rapidly degraded in the soil in both the purified form of the protein and as part of the cotton plant tissue. The half-life for the purified protein was less than 20 days. The half-life of the Cry1Ac protein in plant tissue was calculated to be 41 days which is comparable to the degradation rates reported for microbial formulations of Bt.
- *Effect of Bt protein on soil microflora:* Studies were conducted to evaluate any impact of Bt protein leached by roots of Bt cotton on the soil microflora. There was no significant difference in population of microbes and soil invertebrates like earthworms between Bt and non-Bt soil samples.

(ii) Studies on Food Safety

For evaluating food safety, the studies conducted included: compositional analysis, allergenicity studies, toxicological studies, presence of Bt protein in Bt cotton seed oil, and feeding studies on cows, buffaloes, poultry and fish. Salient results of these studies are as follows:

- *Compositional analysis:* Studies revealed that there was no change in the composition of Bt and non-Bt seeds, with respect to proteins, carbohydrates, oil, calories and ash content.
- *Allergenicity studies:* Allergenicity studies were conducted on Brown Norway rats. No significant differences in feed consumption, weight gain and general health were found between animals fed with Bt cotton seed and non-Bt cotton seed. At the end of the feeding period, the relative allergenicity of traditional cotton hybrids and Bt cotton were compared to Bt and non-Bt protein extract in active cutaneous anaphylaxis assays. Results of the study concluded that there is no significant change in endogenous allergens of Bt cotton seed compared to non-Bt cotton seed.
- *Toxicological study:* A goat feeding study was conducted for understanding the toxicological effects of Bt cotton seed. The animals were assessed for gross

pathology and histopathology. No significant differences were found between animals fed with Bt and non-Bt cotton seed.

- *Presence of* Cry1Ac *protein in Bt cotton seed oil:* Studies have indicated that Cry1Ac protein was not found in refined oil obtained from Bt cotton seeds.
- *Feeding studies on cows, buffaloes, poultry and fish:* The feeding experiments using Bt cotton seed meal were conducted at National Dairy Research Institute, Karnal on lactating cows; Department of Animal Nutrition, College of Veterinary Sciences, G.B. Pant University of Agriculture & Technology, Pantnagar, on lactating buffaloes; Central Avian Research Institute, Izzatnagar on poultry and Central Institute of Fisheries Education (CIFE), Mumbai, on fish. These experiments indicated that Bt cotton seed meal was nutritionally as wholesome and safe as the non-Bt cotton seed meal.

B. Other Safeguards

(i) Baseline Susceptibility Study

The Project Directorate of Biological Control, Bangalore carried out baseline-susceptibility study of *Helicoverpa armigera* to Cry1Ac protein in 1999 and 2001. Geographical populations of American bollworm (*Helicoverpa armigera*) collected from nine major cotton growing states of India, viz. Punjab, Haryana, Rajasthan, Madhya Pradesh, Gujarat, Maharashtra, Andhra Pradesh, Karnataka and Tamil Nadu were exposed to insecticidal protein Cry1Ac through bioassays. LC_{50} (mean lethal concentration) ranged from 0.14 - 0.71 and LC_{90} from 1.02 to 6.94 μg of Cry1Ac/ml of diet (Jalali et al., 2004). The median molt inhibitor concentration (MIC_{50}) ranged from 0.05 to 0.27, and MIC_{90} from 0.25 to 1.58 μg of Cry1Ac/ml of diet. The effect concentration (weight stunting related) EC_{50} ranged from 0.0003 to 0.008 and EC_{90} from 0.009 to 0.076 μg Cry1Ac/ml of diet.

(ii) Confirmation of the absence of “Terminator Technology”

As per requirements, molecular detection test in the Bt cotton hybrids were performed for *cre* recombinase gene which is an integral component of the so called “terminator technology”. The study was carried out by the Department of Genetics, University of Delhi (South Campus), Delhi. The PCR analysis of DNA samples isolated from individual seedlings derived from Bt cotton hybrids showed that these lines were positive for *Cry1Ac* genes but did not contain *cre* sequence. This conclusively demonstrated the absence of “terminator gene” in Bt cotton hybrids.

C. Field Performance and Socio-economic Impact

On the recommendation of RCGM, two sets of replicated field trials were conducted in 1998-1999 to test the performance of the three Bt hybrids, MECH-12 Bt, MECH-

162 Bt and MECH-184 Bt. In addition, ICAR conducted multilocation field trials in 2001 on these hybrids especially to make a cost benefit analysis of Bt cotton which as detailed in Chapter IV proved the effectiveness of Bt technology in reducing bollworm infestation and the number of insecticide sprays, and increasing cotton yields and net incomes.

4. Conditions Stipulated by GEAC

The approval given to three Mahyco Bt hybrids for commercial release was accompanied by 15 conditions. MoEF also reserved the right to stipulate additional conditions and the right to revoke the approval, if the implementation of the conditions was not satisfactory.

Appendix II

Bt cotton hybrids approved by GEAC for commercial cultivation (up to December 2008)

Hybrid	Event	Year	Zone	Company
ABCH-1165 Bt, ABCH-1220 Bt	MON 531	2007	Central and South	Amar Biotech
ABCH-3083 Bt	MON 531	2008	South	Amar Biotech
Amar-1065 Bt BG II	MON 15985	2008	Central and South	Amar Biotech
ABCH-1020 Bt BG II	MON 15985	2008	South	Amar Biotech
ACH-33-1Bt, ACH-155-1 Bt	MON 531	2006	Central and South	Ajeet Seeds
ACH-11-2 BG II	MON 15985	2006	Central	Ajeet Seeds
ACH-33-2 BG II(Ajeet-33)	MON 15985	2007	North and South	Ajeet Seeds
ACH-21	MON 531	2007	South	Ajeet Seeds
ACH-21-1	MON 531	2007	Central	Ajeet Seeds
Ajeet 155 BG II	MON 15985	2007	Central	Ajeet Seeds
ACH-111-2	MON 15985	2008	Central	Ajeet Seeds
ACH-177-2	MON 15985	2008	Central and South	Ajeet Seeds
ACH-177-1 BGI	MON 531	2008	Central	Ajeet Seeds
ACHB 901-1 Bt, ACH-1 Bt	MON 531	2008	South	Ajeet Seeds
ACH-155-2 BG II	MON 15985	2008	South	Ajeet Seeds
ACH-1019 Bt	GFM Cry1A	2008	Central	Navkar Hybrid Seeds
Akka BGII	MON 15985	2008	Central and South	Ankur Seeds
Ankur-09 Bt	MON 531	2005	Central	Ankur Seeds
Ankur-651 Bt	MON 531	2005	North and Central	Ankur Seeds
Ankur-2534 Bt	MON 531	2005	North	Ankur Seeds
Ankur-2226 BG	MON 531	2007	North	Ankur Seeds
Ankur-3032 Bt, Ankur HxB 1950	MON 531	2008	Central	Ankur Seeds
Ankur 3042 Bt, Ankur HB 1902 Bt,	MON 531	2008	South	Ankur Seeds

Ankur HB 1976 Bt				
Ankur 5642 BGII	MON 15985	2008	North and South	Ankur Seeds
Ankur 8120 BG II	MON 15985	2008	North	Ankur Seeds
Ankur 10122 BG II	MON 15985	2008	South	Ankur Seeds
Brahma Bt	MON 531	2006	Central and South	Emergent Genetics
Bt Bikaneri Nerma (variety)	Dharwad	2008	North, Central and South	Central Institute for Cotton Research
Dhruv Bt (ZCH-50064)	GFM Cry1A	2007	Central and South	Zuari seeds
Dyna Bt	MON 531	2007	Central and South	Vibha Seeds
GK 205 Bt, GK 204 Bt	MON 531	2006	Central	Ganga Kaveri Seeds
GK 209 Bt, GK 207 Bt	MON 531	2006	South	Ganga Kaveri Seeds
GK 206 Bt	MON 531	2007	North	Ganga Kaveri Seeds
GK 212 BG II	MON 15985	2008	North	Ganga Kaveri Seeds
GK 205 BG II	MON 15985	2008	Central	Ganga Kaveri Seeds
GK 217 BG II	MON 15985	2008	South	Ganga Kaveri Seeds
GBCH-01 Bt	GFM Cry1A	2008	Central	Green Gold
IT 905 BG I	MON 531	2007	North	Pro Agro Seeds
Jai BG, Akka BG	MON 531	2007	Central and South	Ankur Seeds
Jassi BGII, Ankur 8120 BG II	MON 15985	2008	North	Ankur Seeds
JK Varun Bt	Event 1	2006	Central	JK Agri Genetics
JKCH-1947 Bt	Event 1	2006	North	JK Agri Genetics
JK Durga Bt	Event 1	2006	South	JK Agri Genetics
JKCH-99 Bt	Event 1	2006	South and Central**	JK Agri Genetics
JKCH-666 Bt, JKCH-226 Bt	Event 1	2007	Central	JK Agri Genetics
JKCH-1050 Bt	Event 1	2007	North	JK Agri Genetics
JKCH-1945 Bt, JKCH-226 Bt	Event 1	2008	North	JK Agri Genetics
JK-Indra Bt	Event 1	2008	Central and South	JK Agri Genetics
JKCH-2245 Bt, JK Chamundi Bt, JK Gowri Bt	Event 1	2008	South	JK Agri Genetics
JK Durga Bt	Event 1	2008	Central	JK Agri Genetics
JKCH-634 Bt (JK Iswar Bt)	Event 1	2007	South	Nath Seeds

Kashinath (NFHB-109BT)	GFM Cry1A	2007	Central and South	Nath Seeds
KCH-135 Bt	MON 531	2007	Central and South	Kaveri Seeds
KCH-707 Bt	MON 531	2007	Central	Kaveri Seeds
KCH-135 BG II	MON 15985	2008	Central and South	Kaveri Seeds
KCH-707 Bt (BG II)	MON 15985	2008	Central and North	Kaveri Seeds
KDCHB-9810 Bt, KDCHH 9632 Bt	MON 531	2006	Central and South	Krishidhan Seeds
KDCHH 9821 Bt	MON 531	2006	Central	Krishidhan Seeds
KDCHH-441 BG II	MON 15985	2006	Central	Krishidhan Seeds
KDCHH 9810	MON 531	2007	North	Krishidhan Seeds
KDCHB-786 Bt	MON 531	2007	Central and South	Krishidhan Seeds
KDCHB-407 Bt	MON 531	2007	South	Krishidhan Seeds
KDCHH-441 BG II	MON 15985	2008	North and South	Krishidhan Seeds
KDCHH-9632 BG II	MON 15985	2008	Central and South	Krishidhan Seeds
MRC-6301 Bt	MON 531	2005	North and Central	Mahyco
MRC-6304 Bt	MON 531	2005	North	Mahyco
MRC-6322 Bt, MRC-6918 Bt	MON 531	2005	South	Mahyco
MECH-12 Bt*, MECH-162 Bt, MECH-184 Bt*	MON 531	2006	Central and South	Mahyco
MRC-6025 Bt, MRC-6029 Bt	MON 531	2006	North	Mahyco
MRC 7301 BG II, MRC 7326 BG II, MRC-7347 BG II	MON 15985	2006	Central	Mahyco
MRC-7351 BG II	MON 15985	2006	Central** and South	Mahyco
MRC-7201 BG II	MON 15985	2006	South	Mahyco
MRC -7160 BG II	MON 15985	2007	South	Mahyco
MRC-7017 BG I, MRC-7031 BG II	MON 15985	2007	North	Mahyco
MRC-7041 BG II, MRC-7045 BG II	MON 15985	2008	North	Mahyco
MRC-7918 BG II	MON 15985	2008	Central and South	Mahyco
MRC-7929 BG II	MON 15985	2008	South	Mahyco
MLCH-318 BGII, Brahma BG II	MON 15985	2008	South	Monsanto Genetics
MLCH-317 BGII,	MON 15985	2008	Central	Monsanto Genetics

Atal BG II, Paras Lakshmi BG II				
NAMCOT- 402	MON 531	2007	North	Namdhari Seeds
NAMCOT 612 BG II, NAMCOT 607 BG II	MON 15985	2008	South	Namdhari Seeds
Navkar 5 Bt	GFM Cry 1A	2007	Central	Navkar Hybrid Seeds
Navkar 5 Bt	GFM Cry 1A	2008	North	Navkar Hybrid Seeds
NCEH-2R Bt	GFM Cry 1A	2006	Central	Nath Seeds
NCEH-6R Bt	GFM Cry 1A	2006	North	Nath Seeds
NCEH-3R Bt	GFM Cry 1A	2006	South and Central**	Nath Seeds
NCEH-26 Bt, NCEH-31 Bt	GFM Cry 1A	2008	North	Nath Seeds
NCEH-21, NCEH 23, NCEH-14	GFM Cry 1A	2008	Central	Nath Seeds
NCEH-13 Bt, NCEH-34 Bt	GFM Cry 1A	2008	South	Nath Seeds
NCHB-991, NCHB-992, NCS-955	MON 531	2007	Central	Nuziveedu Seeds
NCS-138 Bt	MON 531	2006	North	Nuziveedu Seeds
NCS-145 BG II(Bunny)	MON 15985	2007	North, South	Nuziveedu Seeds
NCS-145 BG II	MON 15985	2007	North	Nuziveedu Seeds
NCS-913 Bt	MON 531	2006	North, Central and South	Nuziveedu Seeds
NCS-145 Bunny Bt, NCS-207 Mallika Bt	MON 531	2005	Central and South	Nuziveedu Seeds
NCS-950**	MON 531	2007	North and Central	Nuziveedu Seeds
NCS-954, NCS-929 Bt	MON 531	2007	Central and South	Nuziveedu Seeds
NCS-207	MON 15985	2007	Central	Nuziveedu Seeds
NCHB-990 Bt, NCHB-992 Bt	MON 531	2007	South	Nuziveedu Seeds
NCS-145 Bt 2, NCHB-945 Bt	MON 15985	2008	Central	Nuziveedu Seeds
NCS-854 Bt 2	MON 531	2008	Central and South	Nuziveedu Seeds
NCHB-940 Bt, NCHB-945 Bt, NCS-906 Bt, NCS-907 Bt, NCS-908 Bt, NCS-909 Bt, NCS-910 Bt	MON 531	2008	South	Nuziveedu Seeds
NCS-207 BG II	MON 15985	2008	South	Nuziveedu Seeds

NCS 138 Bt	MON 531	2008	Central	Nuziveedu Seeds
NPH 2171 Bt	MON 531	2006	Central and South	Prabhat Seeds
NSPL-405 Bt, NSPL-36 Bt, NSPL-999 BG I	MON 531	2007	Central and South	Nandi Seeds
NSPL-405 BG II, NSPL-999 BG II	MON 15985	2008	Central and South	Nandi Seeds
NSPL-36 BG II	MON 15985	2008	Central	Nandi Seeds
NSPL 9 BG I, NSPL 603 BG I, NSPL 666 BG I	MON 531	2008	South	Nandi Seeds
Ole Bt	MON 531	2007	North and South	Vibha Agrotech
PRCH-31 Bt	MON 531	2007	Central	Pravardhan Seeds
PRCH-102 Bt	MON 531	2006	Central	Pravardhan Seeds
PRCHB-405	MON 531	2008	South	Pravardhan Seeds
PRCH 504 BG II, PRCH 505 BG II	MON 15985	2008	Central and South	Pravardhan Seeds
PCH-2270 Bt	Event 1	2006	South	Prabhat Seeds
PCH 115, PCH 205 (earlier known as PCH-207), PCH-930 Bt	MON 531	2007	Central and South	Prabhat Agri Biotech
PCH-923	MON 531	2007	Central	Prabhat Agri Biotech
PCH 406 Bt	MON 531	2007	North	Prabhat Agri Biotech
PCH-2171 Bt 2, PCH 205 Bt 2	MON 15985	2008	Central	Prabhat Agri Biotech
PCH-409 Bt	MON 531	2008	South	Prabhat Agri Biotech
PCH-2270 Bt 2, PCH 105 Bt2	MON 15985	2008	South	Prabhat Agri Biotech
RCH-2 Bt	MON 531	2004	Central and South	Rasi Seeds
RCH-20 Bt, RCH-368 Bt	MON 531	2005	South	Rasi Seeds
RCH-118 Bt, RCH-138 Bt, RCH-144 Bt	MON 531	2005	Central	Rasi Seeds
RCH-134 Bt, RCH-317 Bt	MON 531	2005	North	Rasi Seeds
RCH 111 BG I, RCH-371 BG I, RCHB-708 BG I	MON 531	2006	South	Rasi Seeds
RCH-308 Bt, RCH-314 Bt	MON 531	2006	North	Rasi Seeds
RCH-377 Bt	MON 531	2006	Central	Rasi Seeds

RCH-386 BG I	MON 531	2007	Central	Rasi Seeds
RCH-2BG II	MON 15985	2007	Central and South	Rasi Seeds
RCH-515 BG II	MON 15985	2007	Central	Rasi Seeds
RCH-530 BG II, RCH 533 BG II	MON 15985	2007	South	Rasi Seeds
RCH-134 BG II, 569 BG II	MON 15985	2008	North	Rasi Seeds
RCH 395 Bt	MON 531	2008	Central	Rasi Seeds
RCH-578 BG II, RCH-584 BG II	MON 15985	2008	Central	Rasi Seeds
RCH-596 BG II	MON 15985	2008	South	Rasi Seeds
Rudra Bt	MON 531	2007	Central and South	Pravardhan Seeds
SBCH-292 Bt	GFM Cry 1A	2008	South	Safal Seeds
SDS 1368 Bt, SDS 9 Bt	MON 531	2007	North	Nandi Seeds
SDS-9 BG II, SDS-36 BG II	MON 15985	2008	North	Nandi Seeds
Sigma Bt	MON 531	2007	North, South and Central	Vibha Agrotech
SP 504 BI(Dhanno) Bt	MON 531	2007	Central	Proagro Seeds Co.
SP 504 B1	MON 531	2007	South	Bayer Bioscience
SP-923 Bt (IT 923 Bt)	MON 531	2007	Central	Bayer Bioscience
SP 700 B1	MON 531	2008	South	Bayer Bioscience
SP 503 B1	MON 531	2008	South and Central	Bayer Bioscience
SP 1037 B2	MON 15985	2008	Central and South	Bayer Bioscience
SP 504 B2	MON 15985	2008	Central	Bayer Bioscience
SP 499 B1 (Goldmine)	MON 531	2008	Central	Bayer Bioscience
SP 904 B1 (HXB)	MON 531	2008	Central	Bayer Bioscience
SWCH-4314	MON 531	2008	Central	Seed Works India
SWCH-4531 Bt	MON 531	2008	South	Seed Works India
Sarju BG	MON 531	2008	Central	Solar Agrotech
Mahasangram BG	MON 531	2008	Central and South	Solar Agrotech
Tulasi 4 Bt, Tulasi 117 Bt	MON 531	2006	Central and South	Tulasi Seeds
Tulasi 9 BG 1	MON 531	2006	Central	Tulasi Seeds
Tulasi 9 BG II, Tulasi 118 BG II	MON 15985	2008	Central and South	Tulasi Seeds
Tulasi 9 Bt, Tulasi 118 Bt,	MON 531	2008	South	Tulasi Seeds

Tulasi 45 Bt				
Tulasi 4 BG II	MON 15985	2008	Central and North	Tulasi Seeds
Tulasi 45 BG II	MON 15985	2008	North	Tulasi Seeds
Tulasi 5 Bt	MON 531	2008	Central	Tulasi Seeds
Tulasi 7 BG II	MON 15985	2008	South	Tulasi Seeds
UPLHH-1	GFM Cry 1A	2008	North	Uniphos Enterprises
UPLHH-12 Bt, UPLHH-5 Bt	GFM Cry 1A	2008	South	Uniphos Enterprises
UPLHH-2 Bt	GFM Cry 1A	2008	Central	Uniphos Enterprises
VBCH-1009 Bt, VBCH-1010 Bt	MON 531	2007	Central	Vibha Seeds
VBCH-1006 , VBCH-1017	MON 531	2008	Central	Vibha Agrotech
VBCH-1016 , VBCH-1018	MON 531	2008	Central and South	Vibha Agrotech
VBCH-1006 BG, VBCH-1008 BG	MON 531	2008	North	Vibha Agrotech
VBCH-1501	MON 15985	2008	North and South	Vibha Agrotech
VBCH-1010 BG, VBCH 1203 BG 1	MON 531	2008	South	Vibha Agrotech
VBCH-1504	MON 15985	2008	North	Vibha Agrotech
VBCH-1505 BGII, VBCH-1506 BG II	MON 15985	2008	South	Vibha Agrotech
VICH-111 Bt	MON 531	2006	Central and South	Vikki Agrotech
VICH-5 Bt, VICH-9 Bt	MON 531	2006	Central and South	Vikram Seeds
VICH-15 Bt	MON 531	2007	Central	Vikram Seeds
VICH-11 BG	MON 531	2008	North	Vikram Seeds
VICH-11 BG II, VICH-9	MON 15985	2008	North	Vikram Seeds
VICH-15 BG II, VICH-5 Bt (BG II)	MON 15985	2008	Central and South	Vikram Seeds
Monsoon Bt	GFM Cry 1A	2008	Central and South	Yashoda Hybrid Seeds
ZCH-50072 Bt	GFM Cry 1A	2008	Central and South	Zuari Seeds
ZCH-50005	GFM Cry 1A	2008	Central	Zuari Seeds
322 Bt, 110 Bt, 563 Bt	MON 531	2007	Central	BioSeeds Research
6317 Bt	MON 531	2007	North	BioSeeds Research
6488 Bt Research	MON 531	2007	North Central and	South BioSeeds
340 Bt, 113 Bt, 302 Bt	MON 531	2007	South	BioSeeds Research

6188 Bt	MON 531	2007	Central and South	BioSeeds Research
6488-2, 2510-2, 2113-2	MON 15985	2008	North	BioSeeds Research
322-2, 113-2, 340-2	MON 15985	2008	South	BioSeeds Research
311-2 BG II, 557-2 BG II	MON 15985	2008	Central	BioSeeds Research
621 BG II	MON 15985	2007	Central and South	Krishidhan Seeds

*Approval not renewed for Andhra Pradesh.

**The hybrids have been approved for Central Zone by GEAC in its 76th meeting held on 11.5.2007.

North Zone: Haryana, Punjab.

Central Zone: Gujarat, Madhya Pradesh and Maharashtra.

South Zone: Andhra Pradesh, Karnataka and Tamil Nadu.

Source: http://igmoris.nic.in/files/commercially released varities of Bt Cotton hybrids_31.07.08.pdf.

ASIA-PACIFIC CONSORTIUM ON AGRICULTURAL BIOTECHNOLOGY

The Asia-Pacific Consortium on Agricultural Biotechnology (APCoAB), was established in 2003 under the umbrella of the Asia-Pacific Association of Agricultural Research Institutions (APAARI) — an initiative of Food and Agriculture Organization that has been promoting appropriate use of emerging agri-technologies and tools in the region.

APCoAB's mission is "To harness the benefits of agricultural biotechnology for human and animal welfare through the application of latest scientific technologies while safeguarding the environment for the advancement of society in the Asia-Pacific Region".

APCoAB's main thrust is:

- To serve as a neutral forum for the key partners engaged in research, development, commercialization and education/ learning of agricultural biotechnology as well as environmental safety in the Asia-Pacific region.
- To facilitate and promote the process of greater public awareness and understanding relating to important issues of IPR's *sui generis* systems, biosafety, risk assessment, harmonization of regulatory procedures, and benefit sharing in order to address various concerns relating to adoption of agricultural biotechnology.
- To facilitate human resources development for meaningful application of agricultural biotechnologies to enhance sustainable agricultural productivity. as well as product quality, for the welfare of both farmers and consumers.