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Prospects for Bt Cotton Technology in India

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Cotton is a very important crop in India; farmers there face the challenge of losses due to various insect pests. The first genetically modified crop in India, Bt cotton, has been introduced to address bollworm infestation. The process of introduction of Bt cotton took six years of experimentation, during which time agronomic, environmental, and biosafety data was generated and reported. The trials conducted prior to commercialization clearly established the superior performance of Bt cotton, as demonstrated by increased yields and reduction in application of pesticides. Transgenic technology is suitable for the Indian farmer despite small farm holdings. The area under Bt cotton is projected to increase rapidly in the coming years.

Key words: Bt, Bt cotton, transgenic crops.

Introduction

Cotton provides a livelihood to more than 60 million people in India by way of support in agriculture, processing, and use of cotton in textiles. Cotton contributes 29.8% of the Indian agricultural gross domestic product, and nearly nine million hectares of land in India is used to produce 14.2 million bales of cotton lint.

Indian cotton production is third in the world in quantity, although the productivity is substantially low. The major reason for this low productivity is damage caused by insect pests—notably *Helicoverpa armigera*, commonly referred to as American Bollworm. Nearly Rs.12 billion worth of pesticides are used in India to control just the bollworm complex of cotton. Mahyco (Maharashtra Hybrid Seed Company), in collaboration with Monsanto, has introduced Bt cotton technology into India. Bt cotton carries the *Cry1Ac* gene derived from the common soil bacterium *Bacillus thuringiensis* var. *kurstaki*, which results in the expression of the *Cry1Ac* protein that confers resistance to the bollworm complex.

Experience in Other Parts of the World

Bt cotton has already been commercialized in six countries: the United States (1996), Australia (1997), South Africa (1997), Argentina (1998), Mexico (1996), China (1998), and Indonesia (2000). Bt cotton is being extensively field tested under permit in Brazil, Colombia, Thailand, and Zambia. Globally, Bt cotton was planted on one million acres (405, 000 ha) in 2000. Due to its excellent performance, the benefits to the farmer of Bt cotton have been consistently superior for the six years of commercialization.

Bt Cotton in India

Bt cotton seeds were first tested in India for germination, vigor, and insect efficacy. Other experiments were conducted to confirm the environmental safety of Bt cotton, including tests of gene flow, persistence of the transformed plants, weediness characteristics, crossability of the transgenic pollen with the nontransgenic relative and near relatives, effect of the pollen on insects and nontarget organisms, and changes in the soil microbial flora (Table 1). These studies were conducted under the unique environmental conditions of India and with the Bt trait in Indian germplasm. Studies of the molecular characterization and stability of the *Cry1Ac* gene were also carried out, as well as feeding studies and tests of food and feed safety, toxicity, and allergenicity.

Bt Cotton—Agronomic Benefits

Trials conducted in several locations in 1998/99, 1999/2000, 2000/01, and 2001/02 demonstrated the following agronomic benefits of Bt cotton:

- good control of bollworm species in different growing areas;
- significantly higher yield and boll retention (compared to control or non-Bt cotton);
- reduction in expense of insecticide application;
- additional revenue (Rs.2,500–4,000/acre) in farm income (compared to non-Bt cotton); and
- no adverse effect on nontarget insects or adjacent non-Bt cotton crops.

Bt Cotton—Approval for Commercial Cultivation

The Genetic Engineering Approval Committee (GEAC), in its 32nd meeting, held on March 26, 2002,

Table 1. Timeline summary for regulatory processes leading to commercial release of Bt cotton in India.

Years	Studies undertaken	Government of India oversight committees[a]
1995–1996	Application and permit for importation of Bt cotton seed containing the *Cry1Ac* gene	DBT
1996–2000	Greenhouse breeding for integration of the *Cry1Ac* gene into Indian germplasm, seed purification, and stock increase	DBT
1996–2000	Limited field studies for potential of pollen escape, aggressiveness, and persistence	RCGM (DBT)
1998–2001	Biochemical and toxicology studies	RCGM (DBT), GEAC
1998–2000	Multilocation field trials: agronomic and entomology performance of first-generation Bt cotton hybrids, conducted by Mahyco and State agriculture universities	RCGM (DBT), MEC
2000–2001	Soil rhizosphere evaluations and protein expression analyses from multilocation field trials	RCGM (DBT), GEAC
2001	Advanced stage multilocation field performance trials of first-generation Bt cotton hybrids, conducted by ICAR	GEAC, ICAR, DBT, MEC
2002	Submission of final biosafety, environmental safety, gene efficacy and performance documentation to GEAC; commercial release of first-generation Bt cotton hybrids by GEAC	GEAC
2002–ongoing	Continued field performance trials of second-generation Bt cotton hybrids for regulatory approval	RCGM (DBT), GEAC, ICAR, MEC

[a] DBT = Department of Biotechnology; GEAC = Genetic Engineering Approval Committee; RCGM = Review Committee for Genetic Modification (constituted by DBT); ICAR = Indian Council of Agriculture Research; MEC = Monitoring & Evaluation Committees (constituted by GEAC and RCGM).

made the landmark decision of approving cultivation of Bt cotton in India; three hybrids (MECH 162 Bt, MECH 184 Bt, and MECH 12 Bt) were approved for cultivation with the stipulation that certain conditions be met (Figure 1; Table 2). These hybrids are high yielding and produce medium-long- to long-staple fiber.

The GEAC also approved production of seed; subsequently, seed for cultivating 100,000 acres (40,485 ha) was available for planting by Indian farmers. The seed

Figure 1. Comparison of a Bt cotton hybrid (right) with its non-Bt hybrid counterpart (left) at first picking stage during a regulatory field trial in India. Three intra-*hirsutum* Bt cotton hybrids were approved for commercialization by the government of India in 2002.

Table 2. Commercial cultivation of Bt cotton hybrids in India, 2002 (hectares).

State	MECH-12	MECH-162	MECH-184	Total
Maharashtra	112	9,300	5,334	14,746
Madhya Pradesh	60	404	1,756	2,220
Karnataka	—	3,828	80	3,908
Andhra Pradesh	44	5,564	—	5,608
Gujarat	76	4,136	4,642	8,854
Tamil Nadu	—	2,042	660	2,702
Total	292	25,274	12,472	38,038

was distributed in the states of Maharashtra, Madhya Pradesh, Karnataka, Andhra Pradesh, Gujarat, and Tamil Nadu in the kharif 2002[1] planting season. The areas planted to Bt cotton were 14746, 2220, 3908, 5608, 8854, and 2702 hectares spread over the three hybrids.

This year's cotton-growing season in India was affected by high rainfall in some areas and a long dry spell followed by heavy downpours (resulting in unfavorable conditions for cotton cultivation) in other areas. The overall pest pressure this year for bollworm complex was also low. However, across the cotton-growing areas, control of the bollworm complex was observed in Bt cotton; the amount of spraying required, if any, was significantly lower for Bt than for non-Bt cotton hybrids. Bt cotton yields were significantly higher than those of non-Bt cotton, and the average increase in yield was about 30% over non-Bt hybrids in similar conditions. The quality of Bt cotton was cleaner with better

1. *Kharif refers to a crop that is harvested at the beginning of winter.*

color, and Bt cotton provided rates commensurate with the quality of the fiber based on the hybrids available.

Table 3. Bt cotton results from kharif[a] 2002 season, June-December (yield in quintals[b]).

State	Non-Bt yield	Bt yield	Yield increase with Bt	Non-Bt sprays	Bt sprays	Spray reduction with Bt	Economic benefit per hectare[c]
Andhra Pradesh	14.42 (5–25)	20.52 (12.5–32.5)	6.10	4.81 (1–8)	2.08 (0–4)	2.73	Rs.16,747
Gujarat	19.80 (3.7–37.5)	28.35 (10–44)	8.55	3.42 (1–7)	2.09 (0–5)	1.33	Rs.18,430
Karnataka	10.50 (1.3–30)	17.82 (7.5–40)	7.32	2.53 (0–6)	1.00 (0–3)	1.53	Rs.16,170
Madhya Pradesh	15.00 (10–50)	25.82 (35–62.5)	10.82	3.29 (1–9)	0.93 (0–3)	2.36	Rs.24,000
Maharashtra	14.47 (2.5–45)	20.82 (2.5–62.5)	6.35	2.78 (0–7)	0.99 (0–4)	1.79	Rs.14,490
Tamil Nadu[d]	—	—	—	—	—	—	—
Total	13.25	21.35	8.10	3.10	1.17	1.93	Rs.18,130

Note. All figures given in the table are based on a survey conducted by Mahnyco in the six states where Bt cottonseed cotton was sold in the kharif 2002 season.[a] The total sample size was 1,069 farmers. Averages are on weighted average basis. Figures in parentheses represent the range for yield (quintals per hectare) and number of sprays.

[a] Kharif refers to a crop that is harvested at the beginning of winter.

[b] 1 quintal = 100 kg.

[c] Economic benefit per hectare was calculated on the basis of an average cotton rate of Rs.2,000/q and an average cost of each bollworm complex spray of Rs.1,000/ha.

[d] Cotton picking still in progress in Tamil Nadu at date of writing.

The data in Table 3 shows that in addition to the substantial increase in yield, there is a significant decrease in the number of insecticide sprays associated with the use of Bt cotton—the overall average indicates a yield increase of 8.1 quintals[2] of cotton and a reduction of 1.93 sprays. These two factors add to the total economic benefit. Table 3 indicates that there is an average additional income of more than Rs.18,000/ha for Bt compared to non-Bt cotton.

Projection of Bt Cotton for Next Three Years

Today, Bt cotton comprises 0.78% of the hybrid cotton area (Table 4). It is projected that the 2003/04 and 2004/05 seasons will have Bt coverage of 6.40% and 11.65%, respectively.

Table 4. Projection of Bt cotton planting area in India (hectares).

	2002/03		2003/04		2004/05	
Hybrids	**Area**	**%[a]**	**Area**	**%[a]**	**Area**	**%[a]**
MECH-12	292	0.01	80,000	1.66	80,000	1.66
MECH-162	25,274	0.52	160,000	3.33	160,000	3.33
MECH-184	12,472	0.25	28,000	0.58	40,000	0.83
New hybrids[b]	—	—	40,000	0.83	280,000	5.83
Total	38,038	0.78	92,000	6.40	560,000	11.65

[a] % = percentage of area under hybrid cotton. Percentages are based on the present total of 4.8 million hectares of hybrid cotton area in India.

[b] New hybrids will be made available only on the approval of the Ministry of Environment and Forests. Figures for new hybrids also include the sales figures of the hybrids developed by the sublicensees.

Conclusion

The benefits of Bt cotton in India are in line with those enjoyed by farmers worldwide who have cultivated Bt cotton. The area under Bt cotton cultivation is expected to increase—it is likely that an area of 500,000 hectares will be covered by 2005, leading to increased production and reduced costs in an environmentally favorable manner. This will positively affect the livelihood of millions of small farmers by improving their net incomes.

2. *1 quintal = 100 kg.*

Bt cotton is undoubtedly the most extensively studied cotton variety today. Rigorous scientific studies conducted in India and abroad demonstrate that Bt cotton and its products are safe for the environment, humans, animals, and agriculture. In fact, the use of Bt cotton is a positive step towards environmental protection because it makes possible the reduction of the insecticide load in the environment and reduces handling of such chemicals by farmers. This reduced use of insecticides will enhance the effectiveness of biological controls and implementation of Integrated Pest Management (IPM) programs. The higher farm income observed in the experiments has now been demonstrated by the large-scale use of Bt cotton by Indian farmers, and the incorporation of the gene is proving an effective and environmentally friendly plant protection tool resulting in greater cultivation of Bt cotton in the coming years. The cotton trade is looking forward to the productivity and quality benefits of Bt cottonseed. Efforts are being made to incorporate another gene (Bollgard II) to improve efficacy and postpone possible resistance problems. As newer products are approved in the regulatory system, it is likely that farmers will have greater choice to plant hybrids according to market quality requirements.