TITLE: **Problems and Prospects of the Commercial Aspects of Cotton Biotechnology in India**

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Indian cotton profile. India has the largest cotton area with nearly 9.0 m hectare accounting for 25 per cent of the global area. It contributes 16 per cent to the total global produce and ranks third after United States and China. Cotton is planted by 4 million small and medium farmers under diverse agro-climate and agro-practicing conditions in 9 key States and 4 relatively neglible States from South to North. There are some unique features of Indian cottons, such as; cultivation of all four cultivated species (*Gossypium hirsutum, G. arboreum, G. herbacenm* and *G. barbadense*), growth of hybrids developed from intraspecies and interspecies combinations, year long availability of crop in field, hand-picking, intercropping, and large input variations. Nearly 60 per cent cotton area is rainfed but it is well penetrated by hybrid technology. Cotton is cultivated under diverse input conditions such as, zero irrigation, organic nutrients alone, no pesticide to high irrigation, heavy fertilization, 16 – 20 insecticidal sprays and harmonal use. Cotton is also the first crop where genetically modified (GM) technology has been commercialized in hybrids. Currently more than 60% area is occupied by hybrids. Therefore, the diversity through desired is slowing the process technology adoption and replacement of old techniques.

Cotton protection scenario. Cotton crop suffers severe economic damage from several insect pests and diseases, most importantly the bollworms and sucking pests such as jassids, white flies, thrips and aphids. The cotton bollworm complex comprises of American bollworm (*Helicoverpa armigera*); pink bollworm (*Pectinophora gossypiella*); spiny bollworm (*Earias insulana*) and spotted bollworm (*Earias vittella*). *Spodoptora litura*, the leaf worm is mainly a foliage feeder but also damages the cotton bolls. Conventional pest management strategies rely heavily on insecticides. It is estimated that pesticides worth $270m are used annually in India for pest management inspite of highest awareness created for integrated pest management (IPM) and insecticide resistance management (IRM). With only 5% area under cotton in the country, nearly 50% of the total pesticides are applied. It is

also estimated that out of $270m insecticide market of cotton, about 70% is only for bollworm protection. Over the past two decades, the perplexities in pest management intensified with more and more inspect species developing resistance to the chemical insecticides. Excess use of insecticides on the crop created the problem of insecticide resistance rendering them to be ineffective and enhancing the need of repeated applications resulting into the serious problem of economics (unprofitable) and ecology (pollution). The successive cyclic national episodes of epidemics of *Helicoverpa armigera* (American bollworm) in 1987, 1992, 1997 and 2001 were serious warnings to scientific community to find out immediate solutions. Incorporating insect resistance has been the most important objective of cotton improvement efforts in India. However, no sources of resistance to bollworm are found in the available germplasm of cottons or its near relatives thus making it standstill to breed and develop tolerant/resistant lives. Therefore, efforts were directed to harness genetic engineering (GE) technology for bollworm resistance and the transgenics using the gene (cry) from soil bacterium, *Bacillus thuringiensis* (Bt) subspecies *kurstaki*.

Cotton productivity status - prior Bt introduction. Inspite of having the highest area under cotton in India amongst the cotton growing countries, the productivity had been consistently lowest and practically less than half of the world average (600 kg lint/ha) till 2001-02 (pre-Bt. period) (Table 1). Although, the diverse situation in which the cotton is grown makes it difficult to expect very high productivity, but even the best of contiguous cotton area under irrigation command with better inputs in North Zone was no way better than the rainfed resource – poor areas of Central Zone. This has resulted into regular imports of raw cotton ranging from 1 to 2.5m bales and negligible exports till 2002-03.

Experience of Bt cotton commercialization. The Genetic Engineering Approval Committee (GEAC), the apex regulatory organization in India, approved three Bt cotton hybrids of MAHYCO in 2002 for commercial cultivation in Central and South Zones. Two years later, RCH-2, another hybrid of Rasi seeds was approved in the same area. In 2005, the GEAC approved more 16 hybrids thus reaching a total of 20 Bt cotton hybrids with 6 for North Zone also. By 2007, the total number of hybrids reached 131 with fair demarcation of its area and conditions of planting (Table 2). Till 2005, only the MON531 event (specifically chosen transformed plant released as Bollgard -1) was approved. However, diversification both in event and germplasm of hybrids of several companies was achieved in 2006.

Acceptance and adoption of Bt-technology has been much faster than anticipated. The author (Mayee and Rao, 2002 in a seminar on Bt-cotton in 2002), predicted in the very first year of Bt-commercialization that by 2006-07, Bt-cotton shall occupy around 17 per cent of the total area of cotton. In reality, it has already covered more than 40 per cent in 2005-06 itself and estimated to cover 55 per cent or 5.2 m ha in the current season (Table 3) with more than 2.5 m farmers using the biotech product.

Increased area under Bt-Cotton proportionately increased the cotton lint yield in all the states with dramatic increases in Gujarat and Punjab where the adoption was high. The average production and productivity of the country surpassed the targets fixed by Government under Technology Mission on Cotton (TMC) (Table 4). This is also the first time that the gap between per ha yield of experimental (research) plots, technology transfer plots (extension demonstrations) and the farmers fields average yield has been practically vanished in Indian cotton production (Table 5).

Notwithstanding the doubts raised by some workers and organization, the overall findings of all studies on performance and ground reality of adoption of the technology, it is amply clear that Bt-cotton reduces the number and cost of pesticide sprays and achieves a

better control of bollworm infestation leading to higher quality cotton yield, a major factor contributing to economic advantage of Bt-cotton cultivation in India.

Lessons learnt from Bt commercialization. The technology evoked unprecedented interest and emotions among a large section of Indian public including scientists, sociologist, economists, politicians, environmentalists and industry personnels. There are still some mis-apprehensions. Although many of them can be ignored, some need attention if at all the technology has to be sustainable. The genetic background in which the gene is incorporated is often not desirable for agronomic traits and often the toxin expression levels are short-lived. Concern has also been expressed for non-availability of the technology in true breeding varieties in order to save seed cost. Similarly for resistance management refuge technology is recommended which is not adopted as it is cumbersome for farmers. Many argue that the small holdings of farmers and the crop diversity inclusive of bollworm susceptible host availability render the refuge technique irrelevant in Indian context. There are also serious concerns of sale of unapproved Bt-cotton in India which is a direct violation of the EPA rules. Nearly a parallel industry of unapproved Bt-cotton seed has emerged basically to counter the high cost of legal Bt-cotton seeds. The danger is, however, spurious sale of any kind of mixed seed in the name of Bt-cotton which may induce loss of faith in this useful technology. With approval of Bollgard II and other events of Cry 1 Ac such as; Event 1 of JK Seeds and GFM event of Nath Seeds, it is likely to curtail the illegal sale of unapproved Bt-cotton. Moreover, GEAC has recently taken a decision (July 2006) to go ahead with 'Event based' approval process for Cry 1 Ac Mon531 Event instead of case-to-case basis. With widespread cultivation of Bt-cotton, the environment and biosafety testings shall not be necessary for the approved event and therefore quick releases based on bioefficacy will reduce the delays in bringing new germplasm with superior Bt-background. This will induce competition and suppress spread of unapproved cultivars. Coupled with the

efforts of Govt. of India through Technology Mission of Cotton (TMC) launched in 2000, the success of the Bt-technology lies not only in enhancing productivity but also improving quality by reducing trash and contaminants. The 2005 ITMF survey on contamination points out to these facts. International Cotton buyers have also expressed satisfaction with the quality and now offer competitive prices, which were traditionally discounted by 5 – 6 per cent b'coz for lower quality. Thus to summarize, the Indian Experience on GM-cotton is considered 'Highly Satisfactory'. Notwithstanding the issues of IPR, Public-Private sector controversy, opposition to biotech product on the whole by some, any failure of crop to be attributed to transgene, the biotechnology of cotton has bright prospects and farmers are keen to adopt the new technologies.

Future prospects of commercialization. In future the impact of biotechnology in cotton is expected to be more magnified in India. Many variants of BT genes, like *cry1AC, cry1aa3, cry1F, cry1Ia5* etc including bivalent BT varieties are at various stages of development. Attempts are on in different labs to exploit transgenes against sucking pests which continue to be the menace in cotton. Among diseases, leaf curl due to whitefly transmitted Gemini virus is the major limitation to cotton cultivation in North India. Research on development of transgenic cotton through RNA interference or antisense approach is under way. Attempts are being made to develop transgenic plants improved for drought tolerance. Work on development of markers for drought tolerance, better fiber quality traits and disease resistance have been initiated that would aid in marker-aided selection and molecular breeding for improved yield and quality cotton in India. Bacterial blight resistance genes in cotton are being characterized that would aid in map-based cloning. Sensitive molecular diagnostic tools have been developed for detection of major pathogens of cotton. Employment of these tools for rapid and timely detection will lead to efficient management of diseases by effectively intercepting and destroying them at source. Amongst

the future biotech crops, the prospects of commercialization of biotechnology in cotton are bright and the hurdles for its growth is being removed.

SUMMARY

Cotton is the most important commercial crops in India. It is grown on 9.0 m ha by more than 4.0 million farmers. Indian textile industry is cotton based but due to low cotton productivity (300 kg lint/ha) it relying on imports of raw cotton. The cotton bollworms, key pests in India, on an average induced 20 – 70 per cent losses and pesticide worth US$275 m (50 per cent of the total) are used on the pest control. Bt-cotton was officially permitted for commercial cultivation in April, 2002 after series of biosafety, environmental safety and bioefficiency tests. Extensive trials conducted in farmer's field revealed dual benefit; reduction in cost of pesticides with better pest control and increased yield. This has resulted into both vertical and horizontal expansion of the technology. The number of hybrids increased from initial 3 to 131 in 5 years as also the area under Bt-cotton from around 30,000 ha to 52,00,000 ha. There is diversification in the technology itself, as the hybrids containing not only Cry 1 Ac, Mon531 event but also Bollagard II (15985 event), Event 1 of J K Seeds and GFM event of Nath Seeds has been commercialized. After the large scale adoption of Bt-cotton the average productivity of Indian cottons has jumped from 300 kg/lint ha before 2001 to now 500 kg lint/ha in 2006. The crop output has surpassed the TMC projections set by Government of India as the number of bales of 170 kg each increased from an average of 15 m to 28 m between 2001 to 2006. The country's export increased from 0.1 m to 4.8 m bales with reduction in imports from 2.5 m bales to 0.5 m bales. Performance appraisals carried out in the last five years in farmers field revealed that Bt-cotton is efficient, safe and useful technology. It effectively controls bollworm, reduces pesticide consumption and pollution and enhances yield of quality cotton. In the last three years international buyers have expressed satisfaction and ITMF survey 2005 has pointed out a fall in the contamination

levels and trash contents. Therefore, the first biotech product of cotton proved commercially viable and the prospects for transgenics against drought tolerance, disease resistance, fibre quality etc. are bright.

Table 1. Cotton area, production and productivity before Bt-technology introduction.

Year	Area (m ha)	Prod. (m bales)	Yield (Kg. lint/ha)[z]
1992 - 93	7.6	14.0	315
1994 – 95	7.9	13.9	300
1996 – 97	9.0	16.3	320
1998 – 99	9.2	15.6	287
2000 – 01	8.5	13.1	260
2002 – 03	7.7	12.5	276

[z]**Average yield of the decade stagnant at 260 – 320 kg lint per ha as against the World average of 600 kg.**

Table 2. Approved Bt-cotton events/hybrids and number of sponsors of technology in India

Bt Cotton / Year	2002	2003	2004	2005	2006	2007
Total no. of Bt cotton hybrids	3	3	4	20	62	131
Total no. of cotton events	1	1	1	1	4	4
Total no. of companies	1	1	1	3	15	24

Bollgard-I (Mon 531), Bollgard-II (Mon 15985)

Event-1 (JK Seeds), GRM Event (Nath Seeds)

Table 3. High adoption rate of Bt-cotton in India

Year	Area under Bt-Cotton	% of total area	No. of farmers
2002-03	29,307	0.38	Few only
2003-04	85,927	1.13	≥40,000
2004-05	5,34,731	6.00	3,00,000
2005-06	12,50,833	14.10	10,00,000
2006-07	38,00,000[y]	41.50	24,00,000
2007-08	52,00,000[z]	55.76	26,00,000

[y]Constitute 60% of the total hybrid area in the country

[z]Projected area in current year

Table 4. Post Bt-performance of cotton production and productivity

Year	Area (m/ha)	Production (m/bale)	Yield (kg lint per ha)
Pre-TMC & BT (10 Years) (1992-2001)	7.90	14.80	319
2002-03	7.67	13.60	302
2003-04	7.63	17.90	399
2004-05	8.92	24.30	463
2005-06	8.87	24.40	467
2006-07	9.16	28.00	520
2007-08[z]	9.40	31.00	560

1 bale : 170 kg lint

[z]Cotton Advisory Board (Ministry of Textile, Govt. of India) Projection

Target set for 10th plan in TMC (2006-07) 21.0 M bales

Table 5. Reduction of gap between research plots, extension plots and farmer fields yield (lint kg/ha) over years.

Years	Research plots	Frontline Demonstrations	National Average
2001-02 (Pre-Bt)	411	342	309
2002-03	504	447	322
2003-04	477	488	404
2004-05	501	480	460
2005-06	495	498	475
2006-07	500	530	520