Technological developments and cotton production in India and China

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The textile and apparel industries of India and China play a pivotal role in the economy of both countries. This sector accounts for 30% of India's and 25% of China's total export volume. Unfortunately, sluggish exports, high costs and poor domestic demand are plaguing the Indian textile industry. In this paper we illustrate the various indicators that highlight the abysmal state of cotton industry in India and provide detailed analysis, identifying the underlying causes as well as the possible remedial measures.

Where we are

COTTON was introduced into China from India in the thirteenth century by the Mongol–Tartar dynasty[1]. Today, China is the largest producer of cotton in the world, whereas India is only the third largest. Interestingly, China with half the area under cotton production compared to India, produces 1½ times the amount of cotton, has 1½ times the world market share and thrice the yield. A recent report by the US Embassy in Beijing suggests that the People's Republic of China have 40% more arable land than the official state statistical bureau estimate of 93 million hectares (M ha). Even if area under cotton cultivation is to be adjusted for this, the newly calculated yield of 671 kg/ha is still twice the current cotton yield in India[2]. Imperfections in the methods of picking, cleaning, grading, roving and spinning into yarn, inadequate transfer of technology, long-winded procedure for approval of new technologies, together with extensive adulteration have resulted in the decline of India's hold on the world cotton market.

Cotton yield and production

The area under cotton in India has increased from 5.89 M ha in 1951–52 to 9.12 M ha in 1996–97 (the largest in the world), the production from 0.53 MT to 3 MT, and coverage under irrigation from 9.10% to 35% (Table1). However, the yield has increased from 88 kg/ha in 1951–52 to only 266 kg/ha (ref. 3) in 1996–97 (Table 1). This figure is well below the 943 kg/ha for China and even the current world average of 584 kg/ha (Table 2). Moreover, better agronomic practices and the introduction of high-yielding hybrid varieties based on cotton-breeding techniques resulted in China being able to increase its yield from 225 kg/ha in 1962 to 420 kg/ha in 1965, and 810 kg/ha in 1990 (Figures 1 and 2; Table 3). In China, the cotton-breeding technique was successful because of two reasons; an improved cotton variety and seed for distribution grown on soil rich in humus.

Growing desi/hybrid cotton

There are four cotton species grown in India, of which two are diploid (*Gossypium arboreum* and *G. her-*

Table 1. Year-wise area under cotton cultivation, production, yield and % coverage under irrigation in India

Year	Area (M ha)	Production (MT)	Yield (kg/ha)	% Coverage under irrigation
1951–52	5.89	0.53	88	9.10
1961–62	7.98	0.78	103	13.0
1971–72	7.80	1.12	151	20.3
1981–82	8.06	1.43	166	27.7
1991–92	7.66	2.02	216	33.3
1996–97	9.12	3.00	266	35.0

Source: Department of Agriculture and Cooperation, Statistics at a Glance.

Table 2. Cotton production, yield and world market share (1997–98)

Country	Market share (%)	Area (M ha)	Production (MT)	Yield (kg/ha)
China	24.5	4.56	4.30	943
USA	16.5	5.37	4.13	769
India	15.2	8.9	2.86	321
Pakistan	7.5	2.89	1.59	552
Egypt	1.3	0.36	0.32	873
Turkey	4.6	0.71	0.75	1065
Uzbekistan	5.5	–	–	–
World	100	33.82	19.74	584

Source: Department of Agriculture and Cooperation.

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Table 3. Year-wise cotton production and yield in India and China

	India[a]		China[b]	
Year	Production (MT)	Yield (kg/ha)	Production (MT)	Yield (kg/ha)
1948–49	0.50	79	0.44	155
1951–52	0.53	88	1.30	240
1961–62	0.78	103	0.75	225
1965–66	1.11	151	2.33	420
1979–80	1.43	166	2.70	555
1984–85	1.71*	179*	4.14	810
1989–90	1.74	206	4.50	810
1990–91	1.94	212	5.67	870
1991–92	2.02	216	4.50	660
1996–97	3.00	266	4.30	943

Source: [a]Department of Agriculture and Co-operation, Statistics at a Glance.
*We did not have data for the period 1984–90; therefore we have interpreted data for this period.
[b]Department of Science and Technology, Embassy of China in New Delhi, India.

baceum) and the other two tetraploid (*G. hirsutum* and *G. barbadense*). In addition, hybrids generated from crossing tetraploid species *G. hirsutum* (*hirsutum* × *hirsutum*) are also cultivated in the central and southern cotton-growing zones[4,5]. The diploid species referred to as the 'Desi' variety accounts for 25–30% of the production. This variety has low productivity and is not responsive to good agronomic practices in terms of yield. In addition, its fibre is rough and short. However, the negligible cost of desi cotton seeds accounts for its popularity amongst the poorer farmer. The tetraploids account for the remaining 70% of the cotton production in India (varieties 50% and hybrids 50%). These varieties provide fine quality fibre, which is used by the textile industry. Although hybrid seeds are costly, their yield can be as high as 800 kg/ha, depending on the agronomic conditions. However, this too is lower than the 1200 kg/ha yield obtained in the US[4].

Cotton-producing zones: Disparity of growth

There are mainly three cotton-producing zones in India:

(1) North zone (Hirsutum and Arboreum Zones), which includes Punjab, Haryana, northern Rajasthan and part of Uttar Pradesh (UP).
(2) Central zone (Hirsutum, Arboreum, Herbaceum and Hybrid Zones), which includes Gujarat, Madhya Pradesh and Maharashtra.
(3) South zone (Hirsutum, Arboreum, Herbaceum, Barbadense and Hybrid Zones), which includes Andhra Pradesh, Tamil Nadu and Karnataka.

After careful analysis of the data from different parts of the country (Table 4), we have found that although irrigation does increase cotton yield, the percentage increase in yield is not as high as that for other crops such as rice. Since cotton is not an assured crop, farmers are discouraged from growing cotton and switch to rice or sugarcane, when adequate irrigation facilities are provided. It has previously been argued that the primary reason for low yield of cotton in India is due to fact that 65% of the area under cotton cultivation is rainfed. Ironically, Gujarat has one of the highest cotton yields (450 kg/ha), despite two-thirds of its area under cotton cultivation being rainfed. It is surprising to note (Table 4) that cotton yield in the North zone is persistently declining from 383 kg/ha in 1994–95 to 374 kg/ha in 1996–97 to 239 kg/ha in 1998–99, while it is showing an upward trend in the Central and South zones. The downward trend in cotton yield in the northern region, particularly in Punjab, although irrigation facility is in plenty for cotton-growing areas, is because of relatively higher intensity of insects and pests attack, increase of water table (because of excessive application of irrigation, canal seepage, etc.) and lack of availability of good quality hybrid varieties of seeds in cotton-growing areas[4].

Agrochemical consumption by cotton

Cotton yield in India is mainly affected by the problems due to insects and pests. Cotton is a crop to which 45% of the pesticides and 58% of insecticides used in India are applied (Figure 3)[6]. The major culprits are 'bollworm complex' and 'jassids'. Sixty per cent of the insecticide spray is used to control the damage caused by a single group of insects referred to as Lepidopterans[4]. These include the *Heliothis* sp., *Helicoverpa armigera*, *Spodoptera* sp., *Pectinophora* sp. and *Earias* sp., which are collectively referred to as the 'bollworm complex'. To a lesser extent white fly and aphids also affect the cotton crop. Although insecticides are effective in controlling jassids, the damage caused by bollworm (*Heliothis spodoptera* is the major insect in Andhra Pradesh) infestation can be controlled only in the early stages after which it causes extensive damage[4].

However, a large variety of insecticides and pesticides products are being sold by many local and multinational companies to minimize and control the damage caused by insects and pests in India. These product categories include organophosphorus, organochlorine, carbamates, pyrethroids, etc. Monocrotophos is widely used and accounts for 22% of the cotton insecticides market, as are endosulphan, chlorpyriphos, quinalphos, cypermethrin, fenvalerate and acephate. Other products introduced in the Indian market include triazophos, profenophos and lamdacyhalothrin. Recently mul-

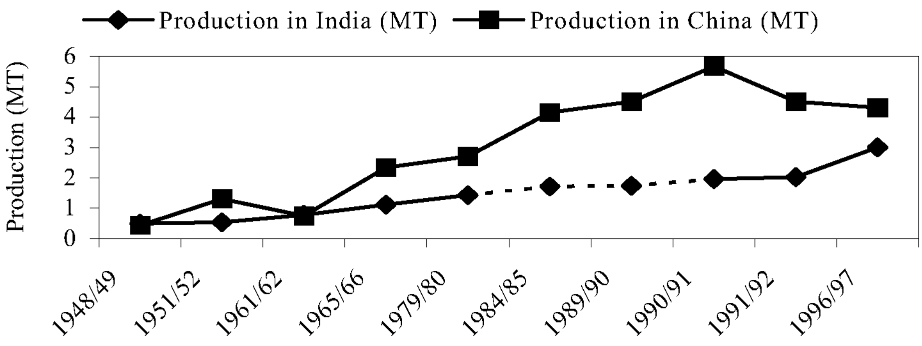

Figure 1. Year-wise cotton production in India and China.

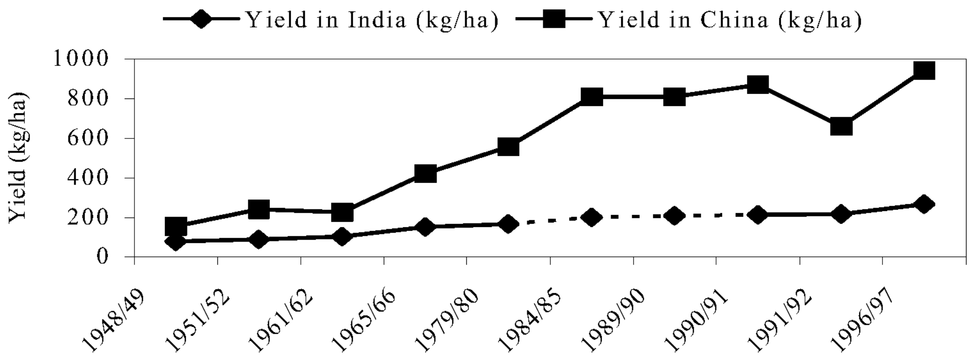

Figure 2. Year-wise cotton yield in India and China.

Table 4. Zone-wise cotton cultivated area (M ha) and yield (kg/ha)

	1994–95		1995–96		1996–97		1997–98		1998–99	
Zone	Area	Yield	Area	Yield	Area	Yield	Area	Yield	Area	Yield
North	1.62	383	2.00	347	1.91	374	1.92	274	1.78	239
Central	4.67	211	5.01	253	5.11	274	5.28	253	5.41	282
South	1.60	457	2.00	386	1.80	389	1.45	435	1.83	361

Source: Singh[4].

tinational companies such as Syngenta (Novartis and Zenessa) have introduced insecticides like Curacron® (profenofos is an active ingredient) and Polytrin® (profenofos + cypermethrin is an active ingredient). Even though many insecticides and pesticides are available in the market, the problem of insects and pests continues. The major difficulties faced by farmers in effective utilization of these agrochemical are – lack of quality spraying equipments, unawareness of integrated pest and insect management practices and cost associated with these agrochemicals, adulteration of insecticides and pesticides and over-spraying. Besides, build-up of pest resistance and resurgence of secondary pests have become serious problems, mainly due to indiscriminate use of pesticides by farmers, lured by marketing strategies of Indian and multinational companies[6].

Factors contributing to yield

There is an urgent need for evolving and applying technological improvements to increase cotton yield in India. Broadly, there are three main factors that mainly contribute to the yield (Table 5)[7–9].

In plants, genetic make-up (quality of seed) and optimization of gene technology contributes 50–60% to the yield[9]. This includes harnessing yield to near full potential by developing cultivars resistant to pests, herbicides and viruses, as well as those tolerant to salinity and drought. Other factors contributing to the yield include agronomic practices and agricultural technologies (25–30%), and biotic (pest infestation) and abiotic (drought, salinity, etc.) stress-related factors (20–25%).

Table 5. Factors contributing to yield[7,8]

Factor	Contribution to yield (%)
Genetic make-up and optimization of gene technology	50–60
Agronomic practices and agricultural technologies	25–30
Biotic and abiotic stress-related factors	20–25

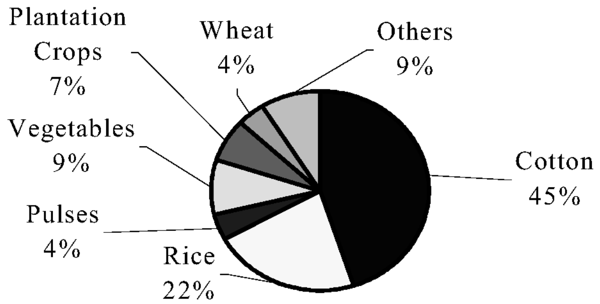

Figure 3. Pesticides consumption (in %) by different crops.

Development of transgenic cotton

Bacillus thuringiensis (*Bt*) is a naturally-occurring soil bacterium that produces a protein that is toxic to Lepidopteran insect pests. *Bt* has been used widely by small-scale and organic farmers in conventional sprayings and is an environmentally benign pesticide. Using the tools of molecular biology, scientists have now been able to introduce the gene for *Bt* protein into cotton. These varieties are referred to as transgenic *Bt* cotton varieties and are resistant to attack by Lepidopteran insect pests[5]. The development of transgenic plants involves the following steps[7]:

(1) Identification of a gene that would impart the desired trait to the crop plant;
(2) Modification of the target gene to enable expression in the crop plant;
(3) Transfer of the gene into the target plant genome (referred to as transformation);
(4) Regeneration of whole plants capable of transmitting the incorporated gene to the next generation.

As mentioned above, insecticides can control bollworm infestation only in the early stages. The *Bt* transgenic, which replaces an insecticide that is sprayed on the crop with the one that is produced inside it, is therefore the only viable option for controlling bollworm infestation at the later stages. The benefit derived from this variety includes the reduced use of highly toxic synthetic insecticides, with a secondary effect of reduction in groundwater and soil pollution. It has been reported that in 1998, *Bt* cotton growers in the US sprayed only once for cotton bollworm, while traditional variety (non-transgenic) growers averaged five sprayings. Interestingly, *Bt* crops also did a better job of pest control than conventional spraying[10].

Bt transgenic is in 'no' way related to the recent invention, commonly referred to as the 'terminator technology'. The terminator technology designed to prevent harvested seeds for germinating, thereby preventing farmers in developing countries from saving their own seeds, has engendered strong opposition from many quarters. However, several transgenic seed companies have unanimously agreed not to proceed with the development of the terminator technology.

Development of transgenic cotton in India

The Department of Biotechnology (DBT) has been the primary agency funding research on transgenic plants in India. During the period 1989–1997, approximately Rs 27 crores, i.e. nearly 4% of the total DBT budget was spent on projects for developing transgenic plants. In addition, other agencies such as Council of Scientific and Industrial Research (CSIR), Department of Science and Technology (DST), and Indian Council of Agricultural Research (ICAR) together provided support to the order of Rs 7 crores towards this objective[11]. Research on *Bt* cotton in India began in 1994. The multi network project, funded by DBT, had its lead centre at National Botanical Research Institute (NBRI), Lucknow. The project ended in 1998 with no transgenic cotton variety. It is believed that the amount invested by DBT (approximately Rs 5 crores) is ~ 2.5 times the offer made by Monsanto (Rs 2 crores) to ICAR in mid 1990s for this technology[12].

According to sources, the transgenic cotton variety has already been developed at Central Institute of Cotton Research (CICR), Nagpur[13]. This is further substantiated by an article in the *Business Line*[14] stating that scientists at CICR have been able to incorporate two *Bt* genes, *Cry1Ab* and *Cry1Ac*, directly into local Indian cotton varieties such as LRA 5166 and LRK 516 (Anjali). These cotton varieties are to be ready for field trials in about two years. Interestingly, in another article published in *the Hindu Survey of Indian Agriculture*[15], the author of the article speaks of 'earnest' research in transgenics, but does not report the mentioned product. In addition, in our further discussion with scientists, the poor regeneration capability of traditional Indian cotton varieties was cited as the biggest hurdle thus far in the development of transgenic cotton (step 4 in the process described above)[16]. Moreover, DBT, which has extensive regulatory powers in the development of transgenics in India, is unaware of any transgenic cotton variety developed at CICR.

Furthermore, two new projects to develop and commercialize transgenic cotton have recently been initiated in India[16]. One of these projects is funded by DBT and coordinated by the University of Delhi, South Campus. The second project funded by National Agricultural Technology Programme (NATP) is being coordinated by ICAR. Interestingly, CICR, Nagpur is also a part of the NATP project for the development of transgenic cotton. However, neither project intends to utilize remnants of progress made in the 1994–1998 DBT project, i.e. the synthetic *Bt* gene which NBRI, Lucknow claims to have synthesized or the transgenic *Bt* cotton 'developed' at CICR, Nagpur[17]. It can indeed be argued by some that the investment made by DBT in the development of *Bt* cotton had a spillover effect of biotechnology capacity building in India, or at least at the micro level in the centres that were assigned the project. Besides, a Cotton Technology Mission has been launched by the Ministry of Textile in 1999–2000 to coordinate programmes and activities aimed at improving research, production, marketing and processing of cotton. The Cotton Technology Mission is remarkably well conceived, covering a wide spectrum of activities in mission mode approach. About Rs 593 crores has been earmarked and the whole mission is explicitly divided into four mini missions[18]:

- Mini Mission 1: ICAR will act as nodal agency for intensive research and development to generate new varieties of short duration, high-yielding, disease and pest-resistant hybrids with appropriate fibre quality parameters. Rs 40 crores has been earmarked for the purpose of cotton research and technology generation.
- Mini Mission 2: The Department of Agricultural and Cooperation of the Ministry of Agriculture will act as the nodal agency to provide adequate and timely information input to the farmers, for transfer of technology through demonstration and training and commercialization of generated technology. Rs 465 crores has been earmarked for transfer of technology and development.
- Mini Mission 3: The Ministry of Textile will work as the nodal agency to improve marketing infrastructure of the existing market and a new market would be developed for cotton products. Rs 69.25 crores has been earmarked for these activities.
- Mini Mission 4: The Ministry of Textile will work as the nodal agency for modernization and upgradation of existing ginning and pressing units. Rs 18.75 crores has been earmarked for this purpose.

In spite of the fact that farmers suffer from the lack of availability of high-yielding, insect and pest-resistant transgenic hybrid varieties, the government priorities on Technology Mission on Cotton are still different. More than 78% of the fund is assigned and allocated for the purpose of technology transfer and development or commercialization, whereas the said technology is not yet developed in India and the government is reluctant to buy it from outside. India continuously lacks good quality, high-yielding varieties of hybrids, based on cotton-breeding techniques and insect and pest-resistant transgenic hybrid/varieties.

In fact, India was the first country in the world to deploy hybrids and at present some 90 varieties of cotton belonging to all four botanical species (*Gossypium arboreum*, *G. herbaceum*, *G. hirsutum* and *G. barbadense*) are being cultivated. Of these, only 25 varieties account for 98 per cent of the total output. The other 65 varieties have poor fibre strength and are of short fibre length. Some of these varieties were once popular, but have now outlived their usefulness. There is a need to de-notify these varieties and develop their substitutes. There are some new varieties of hybrids such as Omshankar (CSHH-29), DHB 105, G.Cot.DH-7 and Arogya by CICR institutions, KC-2 and MCU-12 by Tamil Nadu Agricultural University and MCU-5 through somatic embryogenesis by South Campus, University of Delhi[19,20].

However, new DNA-based tools such as AFLP, SSR analysis techniques and electrophoretic data recording and computing which make processing and handling of a large number of samples possible, have not been used because of high capital investment in deploying these tools[5]. Therefore, to induct these new technologies, to utilize integrated DNA-based technologies and phenotype-based technologies and upgrade existing technologies, there is an urgent need to give priority to research and development of new high-yielding and insect and pest-resistant varieties of hybrids, based on plant breeding and transgenic technologies that give the desired result, i.e. a better cotton plant[5]. Hence the government should reevaluate and reexamine the priorities of resources allocation, merely 6.5% for research and development *vis-à-vis* 75% for transfer of technology and development that is yet not available[18].

Development of transgenic cotton in China

The Chinese Academy of Agricultural Sciences (CAAS) began research on *Bt* cotton in 1991 (ref. 21). Bollworm infestation in the early 1990s decreased cotton yield in China from 870 kg/ha in 1991 to 660 kg/ha in 1992 (Table 3). As a result. China suffered direct losses of approximately US $630 million in 1992–93. Immediate corrective action initiated by the Chinese authorities resulted in research and development of transgenic cotton being included in the 863 High Technology R&D programme[22]. By the end of 1996, two *Bt* cotton varieties had been developed by CAAS and one of them, 'Guokang', was given permission for commercialization. CAAS has Chinese, but no US patent for its *Bt* cotton variety[23]. Although no document proof exists, there are concerns, however, that CAAS might have infringed upon Monsanto's technology.

Agricultural entomologists agree that if the effectiveness to *Bt* toxin is to be maintained, *Bt* crops will have to be managed in a way that discourages pest resistance[5]. The Environmental Protection Agency, a regulatory body in the US, requires *Bt* crop producers, at least in the US to develop resistance management programmes. This involves the creation of refugia or the area planted with crops that do not carry the *Bt* gene. This helps ensure that much of the insect population is not exposed to the *Bt* variety, and will not be under any selection pressure to develop resistance to it[5].

In China, unlike the US, insect resistance management schemes, which are important to prolong the effectiveness of *Bt* toxin are non-existent. Representatives from both CAAS and Monsanto claim that resistance management is not necessary due to the rapid development and replacement of *Bt* genes and the farming systems followed in China. However, there is ample evidence that suggests that pests develop resistance to just about any pesticide thrown at them. Furthermore, agricultural entomologists have predicted that pest resistance to *Bt* could appear in the field within three to five years of injudicious widespread use and would therefore tend to disagree with such a viewpoint[10].

China, with a population of 1.2 billion, approximately 22% of the world's population, has placed genetically modified plants (GMPs) as a top priority in its development agenda. The Chinese government is investing approximately US $1 million (approximately Rs 4.5 crores) annually to support R&D in transgenic plants[24]. The policy on GMPs was initiated during the regime of Deng Xiaoping, the late Chinese leader. The leadership was keen to ensure that the country would not face shortages in agricultural production[25]. In 1992 China became the first nation to grow transgenic crops for commercial use, by planting a tobacco variety engineered to resist viruses[10]. Upon assessing the bio-safety of transgenic plants, the Chinese government began allowing the commercial production of genetically modified plants in 1994. *Bt* cotton was first introduced on a commercial scale in China in the same year. However, the seeds were not popular due to the low germination rates. Ji Dai, a commercial Cotton Seed Technology Company in China, now guarantees *Bt* cotton seeds sold to have a germination rate exceeding 80% (ref. 26). To date, China has approved six licenses for the commercial production of transgenic products.

In 1996, Monsanto started a joint enterprise, namely Ji Dai Cotton Seed Company Ltd, with a government seed company, which allowed it to produce and market cotton seed in China. At the end of 1997, Monsanto received permission from the Chinese government to commercialize its bollgard cotton (*Bt* cotton variety 33B) in Hebei Province. According to reports in local newspapers, in the first season of plantation in 1998, Monsanto's transgenic cotton variety was cultivated on approximately 130,000 ha (approximately 40% of the cultivated area in Hebei, one of China's largest cotton-growing provinces).

It is revealed from the study conducted in USA that Monsanto's *Bt* cotton variety yields 30% more than local varieties and farmers benefit approximately US $56 per ha from lower pesticide use and yield increase. According to a study conducted by scientists at Auburn University, Alabama, USA, gain from planting *Bt* cotton is approximately US $56 per ha, of which 42% goes to farmers, 35% to Monsanto (which held the gene patent) and 7% to consumers[27]. There is no such apparent and practical study conducted to assess the direct monetary benefit from grown *Bt* cotton in China. Although, according to current information, lint yield for *Bt* cotton seeds was in the range 1050 to 1125 kg of lint per ha compared to the provincial average of 825 kg/ha, increasing yield by 4 to 12% compared to conventional cotton[28,29]. It is also inferred that not only is yield higher, but also application of insecticides is reduced from at least 12 applications to just one or two. Consequently, it released from cost of spraying, the enhanced labour of spraying of chemical every other day and the fibre is superior in strength and colour to the local varieties[28–31]. This reduction resulted in saving of 1200 to 1500 RMB per ha, equivalent to US $145 to US $182 per ha (ref. 32).

Monsanto has obtained a Chinese as well as US patent on its *Bt* cotton variety. However, Chinese legislation does not prevent the propagation of seed materials by farmers. In 1998, approximately 50% of the *Bt* cotton farmers maintained the seed for their own use, since it was both economically beneficial and technically and legally possible to use farm-saved seeds. Where China seems to have lost out is in the large-scale commercialization of its own *Bt* cotton variety. It is thought that the distribution of CAAS's *Bt* cotton seems to have suffered from institutional and policy constraints, which has resulted in its being adopted much more slowly than intended. The coverage for Guokang, Chinese *Bt* cotton variety, was only 13,333 ha in 1998, approximately 10 times less than that of Monsanto's 33B variety. Both cotton varieties have their own strengths and weaknesses. Monsanto's *Bt* cotton variety, developed for large-scale farming systems in the US, performs well only in areas with irrigation and plastic mulching and is not adaptable to unfavourable environments. Chinese *Bt* cotton is more adaptable to small-scale farming systems with relatively poor conditions and is higher-yielding than Monsanto's Bollgard cotton, in unfavourable areas[21].

Transgenic cotton – World scenario

In 1999, at least 39.9 M ha worldwide was planted with transgenic crop, while in 1997, it was merely 11 M ha. The area under transgenic crop has substantially increased by 3.5-folds in terms of hectares from 1997 to 1999. Tables 6 shows the relative hectarage and proportion of transgenic crops grown in developed and developing countries during the period 1997 to 1999. It clearly illustrates that from 1997 to 1999 the substantial share, almost 85% of global transgenic crops, has been grown in developed countries. In 1999, area under transgenic crops was 4.5-fold more than the area grown in developing countries. The number of countries growing transgenic crops increased from 6 in 1996 to 9 in 1998 and 12 in 1999. It is noteworthy that four countries, two developed countries, USA and Canada, and two developing countries, Argentina and China, grow 99% of transgenic crops (Table 7). However, the proportion of transgenic crops grown in developing countries increased from 14% in 1997 to 17% in 1998 and 18% in 1999 (ref. 33).

Monsanto, Novartis, Avantis and DuPont are the four major corporations in the world transgenic seed market and witnessed global sales of US $1.5 billion in 1998, which are expected to reach US $20 billion by 2010 (ref. 34). According to these estimations, it seems that the market is very promising for these companies and the global area under transgenic crop would be increasing accordingly (Table 8).

Table 6. Global area of transgenic crops in 1997–1999 (developed and developing countries)[33]

	1997		1998		1999	
Country	Area (M ha)	%	Area (M ha)	%	Area (M ha)	%
Developed	9.5	86	23.4	83	32.8	82
Developing	1.5	14	4.8	17	7.1	18
Total	11.0	100	28.2	100	39.9	100

Table 7. Global area (M ha) under transgenic crops in 1997–1999

	1997		1998		1999	
Country	Area	%	Area	%	Area	%
USA	8.1	74	20.5	74	28.7	72
Argentina	1.4	13	4.3	15	6.7	17
Canada	1.3	12	2.8	10	4.0	10
Australia	0.1	<1	0.1	<1	0.2	<1
China	<0.1	<1	<0.2	<1	0.6	<2
Mexico	<0.1	<1	<0.1	<1	<0.1	<1
Spain	0.0	0	<0.1	<1	<0.1	<1
France	0.0	0	<0.1	<1	<0.1	<1
South Africa	0.0	0	<0.1	<1	<0.1	<1
Total	11.0	100	28.2	100	39.9	100

Source: James Clive[33].

Table 8. Estimated value of global transgenic crop market, 1997–2010

Year	Market value (US $ M)	Increase (US $ M)
1997	670	–
1998	1500	830
2000	3000	1500
2010	20000	17000

Source: James Clive[34].

India's struggling in qualifying for the race

In India, three private-sector firms, Rallis India Ltd, Proagro PGS and Monsanto–Mahyco, have made investments in transgenic crop research and development. Monsanto, in collaboration with Mahyco (Maharastra Hybrid Seed Company) has been able to back-cross the US 'Cocker' variety, bearing the *Bt* gene (*Cry1Ac*), into hybrid parents developed by Mahyco (Mahyco4 and Mahyco11). The back-crossed varieties and hybrids are currently being field-tested for yield increase, insect tolerance and bio-safety, in about 40 locations throughout the country.

Data from the field trial for *Bt* cotton hybrids have shown a 70 to 100% decrease in pesticide application towards the bollworm complex. In addition, mean yield performance for all *Bt* hybrids was found to be 40% greater than that for all non *Bt*-hybrids[5]. Meanwhile in the last week of July 2000, the Union Ministry of Environment and Forest has permitted Mahyco to undertake large-scale field trials and generate environmental safety data on genetically-engineered transgenic *Bt* cotton in various agro-climate regions of the country. The Genetic Engineering Approval Committee (GEAC) of the Ministry has accorded the decision, which is based on the clearance given by the Review Committee on Genetic Manipulation (RCGM) after 40 successful field trials. While granting approval for large-scale field trials, GEAC has also prescribed stringent conditions for compliance. GEAC has also decided that demonstration of transgenic cotton technology to the farmers can be allowed only after the bio-safety issues have been thoroughly examined. Mahyco has also been asked to undertake nutritional studies in buffaloes and cows to determine whether transgenic cotton seeds and their oil have any effects on animal health, milk production and quality of milk, the health of the people *vis-à-vis* toxicity studies on other animal species like poultry and fish. In a significant decision, the GEAC has decided to rigorously monitor the result of large-scale field trials, using a network of state agricultural universities during the next one year[35].

Therefore, it is very likely that transgenic cotton would be commercialized in India after the course of one year, making an entry four years later than China. Ironically, this is the first transgenic crop to be given such permission in the country.

Summary and conclusions

While India is among the largest agricultural producers in the world, its output is very low in comparison with China. New technologies are urgently needed to increase the output in the face of shrinking land and water resources. It seems that the Chinese have adopted biotechnology as a key component of their new agricultural policy. Not only have they developed their own transgenic cotton variety, but have also allowed Monsanto to enter the Chinese market. They seem unafraid of challenges from private-sector companies as long as the objective of agricultural production levels in order to meet their demands are met. In India, however, the scenario is very different. Poor agronomic conditions, adulteration of insecticides, lack of hybrids in the North zone, poor irrigation facilities and long-winded procedures for approval of transgenics are the major problems plaguing cotton yield. In the next decade, it is possible that *Bt* cotton, which is to be introduced in India later this year, may become ineffective as a result of widespread insect resistance. We need to take the initiative and plan ahead to allow the development of products in the pipeline, which rely on different *Bt* variants. Simultaneously, a close and continuous watch on the development of transgenic crop varieties is needed to assess the potential public health benefits and the potential risks of inadvertently introducing allergens into foods, causing unexpected allergic reactions. To overcome the dilemma of possible benefit and risk of transgenic crop varieties, a strong political will is needed and difficult political decisions must be made based on sound technical analysis of these transgenic varieties. This would involve active cooperation of the DBT in terms of simplification of procedures and transparency of project approvals.

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