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# GM technology and sustainable agriculture future: Empirical evidences from Bt cotton farmers in Maharashtra and Gujarat in India

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**World agriculture is passing through a distinct phase of transformation, called the 'second Green Revolution' or Gene Revolution, in which modern biotechnology enables the production of genetically modified (GM) crops/ foods that are claimed to help resolve the pressing problems of food security, malnutrition and abject poverty in different parts of the world. However, there are apprehensions the world over that the GM technology as it unveils may have harmful consequences on sustainable livelihoods in view of the potential threats to food security and subsequent environmental and health challenges. Set in this broader context of GM tech induced agrarian transformation, this paper tries examining some of the potential challenges emerging from the unscrupulous expansion of GM crops in India with reference to Bt cotton. In doing so, the paper draws useful insights from the empirical evidences of the dynamics of Bt cotton adoption in the dominant cotton rowing states of Maharashtra and Gujarat in India. The analysis is based on farm household data gathered from five leading cotton growing districts in the two states. The paper observes that there is no clear way forward to sustain the initial dynamism cast by the introduction of Bt technology in India. A bright future for Indian agriculture with the presence of GM technology in general and Bt technology in particular, would essentially call for many reforms, development strategies and institutional and policy interventions covering a wide spectrum of activities ranging from restructuring the input markets to the output markets. India need also to learn from the experiences of other countries with respect to the performance of GM technology and evolve carefully devised strategies and action plans, which presuppose creation of new institutional or regulatory regimes or reinventing the existing ones so as to make a sustainable impact of the technology on the livelihoods of millions of cotton farmers as well as the century old cotton production sector in India**

**Key words:** GM technology, Bt cotton, sustainable agriculture, yield.

## INTRODUCTION

World agriculture is passing through a distinct phase of transformation, called the second Green Revolution or Gene Revolution, in which modern biotechnology enables the production of genetically modified (GM) crops/ foods that are claimed to help resolve the pressing problems of food security, malnutrition and abject poverty in different parts of the world. This phase of transformation driven by the GM technology becomes more critical in so far as sustainable future of world agriculture is concerned, because, there are growing apprehensions all over the world that the GM technology as it unveils may have harmful consequences on sustainable livelihoods in view of the potential threats to food security and subsequent environmental and health challenges. Serious concerns about the positive impacts of GM technology also stem from the negative externalities caused by the Green Revolution in various parts of the world.

An optimistic view about the first Green Revolution (GR) is that it was a strategic intervention involving technology, scientific knowledge and package of practices in many regions and was instrumental in achieving self-sufficiency in the production of foodgrains and sustaining it for several decades amidst growing population pressure on land, water and other scarce natural resources. Notably, in the first decades of the GR, risks

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to human health and to the environment have been minimal due to somewhat careful use of pesticides, fertilizers and water. Consequently, the GR had little problem in achieving a desirable level of public acceptance that was necessary for the technology to have a significant impact on agriculture growth with necessary linkages. Viewed in that perspective, the GR had been a success in terms of broader coverage of crops and regions and progress in development and diffusion of state of the art technologies, farm mechanization, accelerated investments in rural infrastructure development, spread of Research and Development (R&D) and extension activities, creation and maintenance of governance institutions and centres of excellence in many regions of the world. Thus, the GR created a social space for its own functioning in its own might with tremendous public-sector funding for Research and Development (R&D), extension and smoother diffusion of the agricultural technology to the farmers at reasonable levels of costs.

However, especially since the late 1980s, there has been growing realisation that the world agriculture is heading towards a crisis or an unsustainable growth path. Several decades of GR experience across countries suggest that it had resulted in tremendous strains on the natural resources and unequal distribution of the welfare gains in the society. First and foremost, the beneficial outcomes of GR have mostly favoured the rich and resourceful regions and sections of the society. The Green Revolution also left a number of human health problems unsolved and of course, has exacerbated the socioeconomic and environmental problems in very many cases. The spread of GR was rapid and almost 100% where irrigation was available and it was a casualty where irrigation was unavailable. Further, for a significant part, small and marginal farmers with less and poor resource endowments received few benefits and in some cases became more deprived and poorer, as incentive systems and institutional structures have been less appreciative and supportive of the cause of their economic wellbeing.

The massive investments for development of irrigation infrastructures have in fact generated more negative externalities in terms of: a) Sub-optimal or non-performance of canal irrigation systems; b) Over development of groundwater sector leading to depletion of groundwater resources; c) Waterlogging and soil salinity; d) Inter and intra generational inequities in water distribution, etc to mention a few. The Green Revolution has exacerbated these problems as the need (or greed?) for irrigated lands was so high that high-yielding varieties (HYVs) could succeed. The GR has also turned detrimental in its effects as it boosted an intensive agriculture regime in terms of use of chemical fertilisers and pesticides leading to contamination of water bodies and soils as well as human and animal health related issues. An unfortunate consequence of overuse of pesticides in particular areas is that crop pests have developed resistance to the pesticide chemicals, rendering the chemicals ineffective.

It was in this historical context that the GM technology has received scattered attention particularly in countries, such as the US, Canada, Latin America (Argentina, Colombia and Mexico) and some countries in Europe. Most of these countries started growing GM crops on a commercial basis since 1996. The GM revolution as it progress, resembles the Green Revolution in the following ways: (1) It employs new science and technology to create crop seeds that can significantly outperform the types of seeds that preceded it; (2) The impact of the new seed technologies can be critically important for sustaining world agriculture; and (3) For a variety of reasons, these technologies have not yet reached the parts of the world where they could be most beneficial. However, GM revolution may appear to be different from GR in the following ways: (1) The science and technology required to create GM crops/ seeds are far more complicated than the science and technology as being used in the Green Revolution era; (2) GM seeds are seemingly created largely through private enterprises rather than through public-sector efforts; and (3) The political climate in which agricultural science can influence the world by introducing innovations has changed dramatically since the Green Revolution. In this regard, some of the greatest challenges facing the GM revolution are that: (1) Whether it would offer to be a panacea for the ills of world agriculture and how can agricultural production rise to meet the ever growing demand in a framework of equitable, environmentally, socially, and economically sustainable development?; (2) What will be the prospects for the Gene Revolution, taking cue from the successes and failures of Green revolution?; (3) How the GM technology would ensure the sustainable future of global agriculture amidst the growing challenges of conserving biodiversity and inter and intra-generational distribution of natural resources?; (4) What sorts of regulatory regimes and institutional intermediations are there to make a firm grounding of the GM technology, its scaling up in diverse resource endowed regions and there by creating sustainable impacts on socio-economic and hydro-ecological environments?

The present paper is set against this perspective and it makes a modest attempt at examining some of the potential challenges emerging from the unscrupulous expansion of GM technology and their implications for sustainable agriculture. In doing so, the paper draws useful insights from the empirical analysis of the dynamics of Bt cotton adoption in the dominant cotton growing states of Maharashtra and Gujarat in India. The analysis contained in the paper is based on farm household data gathered from the five districts of Vidarbha region in Maharashtra (Wardha, Amaravati, Akola, Yavatmal and Buldhana) and five leading cotton-growing districts in Gujarat (Ahmedabad, Bhavnagar,

**Table 1.** Trends in area, production and productivity of cotton in the world, 1995 - 2006.

| Country | Area (% of million ha) | | Production (% of million MT) | | Productivity (Kg/ha) | |
|---|---|---|---|---|---|---|
| | 1995 | 2006 | 1995 | 2006 | 1995 | 2006 |
| India | 25.48 | 25.44 | 12.36 | 15.47 | 486 | 520 |
| China | 15.29 | 14.47 | 26.83 | 26.46 | 1759 | 2252 |
| USA | 18.27 | 15.97 | 17.48 | 17.9 | 959 | 1380 |
| Pakistan | 8.45 | 8.87 | 10.14 | 10.28 | 1202 | 1427 |
| Brazil | 3.36 | 3.61 | 2.57 | 4.14 | 767 | 1412 |
| Uzbekistan | 4.21 | 4.21 | 6.71 | 5.73 | 1599 | 1677 |
| Sub total (%) | 75 | 73 | 76 | 80 | 1129 | 1445 |
| World (Mha/ MT) | 35 | 35 | 36 | 43 | 1003 | 1231 |

Source*:* Estimated from FAO: www.fao.org/agristat.

Rajkot, Vadodara and Surendranagar). The information gathered pertained to 200 farm households in each state and was confined to the kharif season of 2007 - 2008. However, historic data pertaining to Bt cotton adoption trends have also been gathered following recall method in which, farmers have been asked to provide information for the past 4 - 5 years experience with Bt cotton.

## GROWTH OF GM CROPS: THE GLOBAL SCENARIO

On a global scale, the GM cropped area was estimated at 100 million ha which accounts for about 5% of the global cropped area during 2006. During 2007, the area further increased to 116 million ha. Among the countries, the US continue to dominate biotech agriculture with close to 50% of the GM cropped area, followed by Argentina (16.5%), Brazil (13%) and Canada (6%). India and China are placed next in the global GM crop map with relative shares of 5.3 and 3.3%, respectively. As evident from Table 1, the share of other countries in GM cropped area has been below 2.5% and this group is dominated by the European countries. The lukewarm response among the European countries towards adoption of GM crops is widely known because of the health, environmental concerns and the presence of big US multinational firms. Among the various GM crops, four, *viz*., soyabean, cotton, maize and canola together account for 30% of the GM cropped area. Compared to India, China shows a more diversified crop adoption scenario as it also grow crops other than cotton and tomato as reportedly grown in India.

### Expansion of GM cotton or Bt cotton

Among the various GM crops that gained commercial acceptance, cotton is important for both the developed and developing countries as: a) A cash crop supplementing the livelihoods of millions of farmers, including small and marginal; and b) As a strategic raw-material for the textile industry.

Though cotton is grown in about 100 countries, almost 73% of the world cotton area (35 million ha) and 80% of production (43 million MT) is contributed by six countries, *viz*., US, China, India, Pakistan, Brazil and Uzbekistan (FAO, 2006). Nevertheless, differences exist across countries in terms of the basic crop/commodity performance indicators, such as area, production, productivity, trade, etc for a host of reasons that are quite known. Following the introduction of the GM crops, the Monsanto Company developed the Bt cotton (Bacillus Thuringiensis cotton) and there has been significant rise in Bt cotton area, especially the US, China, India, Australia, Argentina and South Africa. The area under Bt cotton has increased from 0.03 million ha in 2002 - 2003 to 6.2 million ha in 2007 - 2008, accounting for 66% of global cotton area. The wide scale switch over to Bt cotton in these countries may be seen as an outcome of farmer expectations that the technology would make the new cotton varieties insect-resistant and herbicide-tolerant and thereby help increase production and productivity as compared to the conventional and the hybrid non-Bt cotton varieties.

Among the major cotton producing countries, India's status is distinct as the country occupies the prime position in terms of share of cotton area in the world (26%), but lags far behind in terms of production (16%) with lowest productivity (520 kg/ha) in the world (Table 1). The major reasons indicted for India's low-productivity of cotton, inter alia, include: (a) Major share of cotton is grown under rainfed conditions with lack of source of assured water supply; (b) Predominance of smaller and marginal holdings; (c) Inadequate transfer of production technology; (d) Inadequate availability of quality inputs, including seeds, fertilizer, pesticides, etc; and (e) Inadequate financial resources.

### Expansion of Bt cotton in India: An overview

India's cotton sector directly supports about 5 million farmers spread across 9 states and it occupies a pivotal position in the domestic economy as a strategic industrial raw material for the textile industry. With a cultivated area

**Table 2.** Trends in cotton area in major states in India, 1996 - 1997 to 2006 - 2007.

| Year | Area under cotton (Lakh ha) | | | | |
|---|---|---|---|---|---|
| | Gujarat | Maharashtra | Andhra | Punjab | All India |
| 1996 - 1997 | 15.24 (16.7) | 30.85 (33.7) | 10.07 (11.0) | 7.42 (8.1) | 91.66 |
| 1999 - 2000 | 15.39 | 32.54 | 10.39 | 4.75 | 87.31 |
| 2001- 2002 | 16.87 | 29.80 | 10.02 | 6.00 | 87.30 |
| 2003 - 2004 | 16.47 | 27.66 | 8.37 | 4.52 | 76.30 |
| 2005 - 2006 | 19.06 | 28.75 | 10.33 | 5.57 | 86.77 |
| 2006 - 2007 | 23.9 (26.0) | 31.24 (34.1) | 9.62 (10.5) | 5.88 (6.4) | 91.58 |
| (%) change | 56.82 | 1.26 | -4.47 | -20.75 | -0.09 |

Note: Figures in parentheses indicate respective shares in total area.
Source: Compiled from Cotton Corporation of India.

**Table 3.** Trends in production of cotton in major states in India, 1996 - 1997 to 2006 - 2007.

| Year | Production (in Lakh bales of 170 kgs) | | | | |
|---|---|---|---|---|---|
| | Gujarat | Maharashtra | Andhra | Punjab | All India |
| 1996 - 1997 | 16.00 (9.0) | 34.25 (19.3) | 33.00 (18.5) | 26.50 (14.9) | 177.90 |
| 1999 - 2000 | 7.85 | 27.50 | 38.00 | 22.50 | 156.00 |
| 2001- 2002 | 9.25 | 32.50 | 34.25 | 26.75 | 158.00 |
| 2003 - 2004 | 10.35 | 50.00 | 31.00 | 27.40 | 179.00 |
| 2005 - 2006 | 20.00 | 89.00 | 35.00 | 33.00 | 241.00 |
| 2006 - 2007 | 26.00 (9.3) | 101.00 (36.0) | 52.00 (18.6) | 35.00 (12.5) | 280.00 |
| (%) change | 62.5 | 194.89 | 57.58 | 32.08 | 57.39 |

Note: Figures in parentheses indicate respective shares in total area. Source: Compiled from Cotton Corporation of India.

of around 9 million ha, India ranks first in world cotton area and is the third largest cotton producer after US and China. Even though India ranks first in cotton area, its productivity is one of the lowest in the world. Almost 65% cotton cultivation is rain dependent. Continued presence of cotton in the Indian subcontinent spread over a crop cycle of 8 - 10 months makes it home for pest, diseases and other biotic stress agents to survive, multiply and cause frequent epidemics (APCoAB, 2006).

In India, the Genetic Engineering Approval Committee (GEAC) of the Ministry of Environment and Forest (MoEF) has made a formal approval for commercial release of Bt cotton in 2002. It was supposed to have major impacts on the cotton sector in the country in terms of effective control of bollworms and thereby leading to rise in production and productivity of cotton.

It may be observed that following the introduction of Bt cotton, there has been tremendous expansion in area under Bt cotton in the country from 44,500 hectare in 2002 - 2003 to about 6 million hectare in 2007 - 2008. By 2007, there were as many as over 100 Bt cotton varieties and 109 non-Bt hybrids available in the markets in India, a vast majority of which have been widely adopted by the farmers in Maharashtra and Gujarat in particular. It may also be observed that following the release of Bt cotton, there has been a tremendous increase in cotton production in all the states and often the increasing output levels have compensated for the decline in area in some states. For instance, though the states, viz., Andhra, Haryana, Rajasthan, Madhya Pradesh, Karnataka and Tamilnadu have experienced decline in area under cotton, the technology impact has been significant in terms of compensating for the decline in area (Tables 2 and 3).

Though cotton is grown in nine states, four states, viz., Maharashtra, Gujarat, Andhra Pradesh and Punjab together accounted for 77% of cotton grown area and 76% of cotton production during 2006 - 2007 (Tables 2 and 3). As evident from the Tables, trends in area and production of cotton indicate contrasting scenarios of growth, as there has been significant increase in cotton production over time while area under cotton tended to stagnate at the national level.

Notably, the rise in production and productivity has been contributed by a perceptible shift from desi/ conventional cotton varieties to hybrids and from hybrid varieties to Bt cotton varieties in these states. While authentic data on the extent of area under Bt cotton across the states is yet to be confirmed, available sources indicate that the area planted with Bt cotton currently account for almost 39% of the gross cotton area in the country. Among the states, adoption rate is reported at as high as 70% in Andhra Pradesh, followed by Maharashtra (57%) and Gujarat (40%).

An exceptional trend in area expansion can be observed only for Gujarat, where area has increased by more than 56% during the last decade against significant decline in Punjab (21%) and Andhra (5%) and marginal rise in Maharashtra (1.26%). Gujarat's share in the country's cotton area increased from 17 to 26% during the decade, while that of Maharashtra increased only marginally from 31 to 34%. It is also important to note that the area under cotton remained the same during the two terminal years with significant decline during 2003 - 2004.

Trends in cotton production as shown in Table 3 show that all the four states experienced growth in output, with Maharashtra recording almost three times rise in output. Apparently, much of the rise in cotton output could be decomposed as the 'technology induced yield effect' rather than 'area effect', as the period also coincided with the popularization of 'Bt cotton'. It may be argued that the introduction of Bt technology enables India to come out of the 'age old muddle' of 'low yield trap.

For instance, cotton productivity has almost doubled from 330 kg/ha (1996 - 1997) to 520 kg/ha (2006 - 2007) with the highest levels of productivity reported from Gujarat (718 kg/ha), Punjab (752 kg/ha) and Andhra (619 kg/ha), while Maharashtra reported productivity levels (280 kg/ha) much lower than the national level.

However, it is widely realized that the Bt technology poses serious issues and challenges that need thorough empirical scrutiny especially in the Indian context. There emerge certain questions that: (a) Whether Bt technology is a panacea to the problems faced by the Indian cotton farmers over the past several decades?; (b) What are the important tenets of the technology as propagated by its proponents and as realised by the farmers?; (c) Do the technology has desirable traits of being sustainable in terms of its beneficial outcomes - socio-economic and environmental - and effects to its users?; and (d) Does the technology have a firm grounding in terms of creating an enabling institutional and policy and regulatory environments to make sustainable impacts on the production structure and value addition in the supply chain?

Obviously, some of these issues need a careful scrutiny through empirical analysis based on farm level data from cotton growing regions in the country which are diverse and heterogeneous in terms of farmer character-ristics, agro-ecological factors and other resource endownments. It may also be noted that Bt cotton is an externally imposed technological outcome and its better performance in a given environment presupposes a host of factors that are beyond the control of majority of the resource-poor farmers in the country. Cotton farmers also encounter regular crop failures caused by recurring droughts, severe pest menace and rising costs of critical inputs resulting in huge losses in crop and income. Given this, the optimum yield levels as propagated by the technology is highly ambiguous and if at all is achieved; it makes the farmers to follow an input and cost-intensive farm management regime amidst growing uncertainties in output prices.

## ADOPTION OF BT COTTON IN MAHARASHTRA AND GUJARAT: EMPIRICAL EVIDENCES

Ever since its commercial release, there has been a surge in the empirical literature examining various aspects of performance of Bt technology in various countries. Broadly, there have been three broad streams of empirical studies on the impact of Bt cotton, which may be classified as: (a) Economic; (b) Social; and (c) Environmental.

A critical review of the empirical literature on the impacts of Bt cotton across the major cotton producing countries, including India shows that the technology offers a mixed bag of opportunities along with serious apprehensions about its sustainable developmental outcomes. While the overall positive impact of the technology seems to be highly debated in the Indian context, China shows some positive outcomes. Further, countries such as Argentina and South Africa report dubious outcomes as adoption of Bt cotton is highly restricted in terms of monopoly provision of seeds and imposition of fees for technology transfer.

Studies in the Indian context have shown varying performance of Bt cotton in comparison to non-Bt cotton, including hybrids and traditional desi cotton varieties. By and large, studies indicate that the technology, if at all has been effective in providing higher yields, it was at a huge cost of input use (both fertilizers and insecticides) for control of major pests and diseases. Evidences also show that Bt cotton may be effective only with respect to certain of the bollworms while it does not control sucking pests and certain types of bollworms classified as Spodoptera. In fact, almost all the studies in the Indian context come to a consensus that the legal and administrative challenges emerging from development of GM crops cannot be addressed by the existing administrative and legislative capabilities (see also Joseph, 2007).

Hence, it is important to make an assessment of the farmer experiences and perceptions about the performance of Bt cotton in India. In order to do this, we have undertaken a survey of 200 cotton farmers in Maharashtra and Gujarat covering the entire crop season of kharif 2007 - 2008.

The cotton growing regions in the two states show clear distinctions in terms of the socio-economic profile and resource endowment status of the cotton growers. For instance, the average cotton area held by a farmer in the

**Table 4.** Differences in expected and realized yield of Bt and Non-Bt cotton varieties in Maharashtra and Gujarat.

| Bt/ Non-Bt | Descriptives | Expected yield (Qtl/ acre) | Realized yield (Qtl/ acre) | Difference between two (%) |
|---|---|---|---|---|
| **Maharashtra** | | | | |
| Bt cotton varieties* (n = 48) | Mean | 4.43 | 2.69 | -39.28 |
| | STDEV | 1.98 | 1.67 | 27.64 |
| | CV (%) | 44.71 | 62.08 | -- |
| Non-Bt varieties* | Mean | 3.85 | 2.26 | -41.30 |
| (n =25) | STDEV | 1.75 | 1.83 | 36.92 |
| | CV (%) | 45.58 | 80.90 | -- |
| **Gujarat** | | | | |
| Bt cotton varieties* | Mean | 12.25 | 8.37 | -31.7 |
| (n = 56) | STDEV | 5.12 | 4.69 | -8.5 |
| | CV (%) | 41.80 | 56.02 | -- |
| Non-Bt varieties* | Mean | 6.73 | 10.87 | 61.6 |
| (n =38) | STDEV | 6.92 | 10.89 | 57.4 |
| | CV (%) | 7.03 | 11.47 | -- |

Note: The analysis was based on the number of Bt and non-Bt cotton varieties (n) as being grown by the farmers during 2007 -2008. Source: Sample Survey, covering 200 Bt cotton farmers in Maharashtra and Gujarat States in India.

the Vidarbha region in Maharashtra has been 2.7 ha compared to 5.08 ha in Gujarat. Bt cotton farmers in Gujarat have greater access to irrigation facilities (73%) compared to those in Maharashtra (49%).

More importantly, access to irrigation facilities varied considerably across the districts in Maharashtra. For instance, Buldhana has the highest share of cotton grown under irrigation (76%) compared to Wardha (56%), Akola (51%), Amaravati (32%) and the lowest in Yavatmal (19%). Further, Bt cotton farmers in Gujaratshow a greater dependence on cotton as 75% of their household income comes from cotton compared to only 41% in Maharashtra (ranging from 34 to 56% across districts).

Ever since the introduction of Bt cotton, the farmers have shown greater interest to grow Bt cotton in both the states. A clear distinction can be drawn here as regards the farmer preferences to Bt varieties. The percentage of sample farmer who were growing Bt cotton was about 54% in Gujarat compared to Maharashtra (hardly 2%) during 2003 - 2004. However, the scenario changed suddenly and by 2007 - 2008, the adoption rate has reached 90% in Gujarat and 74% in Maharashtra. The scenario of Bt adoption in Gujarat becomes furthermore interesting as almost 59% of the Bt cotton area is planted with unapproved or illegal seeds. Whereas, the Bt adoption situation in Maharashtra appears to be some-what straightforward and the regulatory systems have better control over the seed market compared to Gujarat.

## Bt cotton: Expectations and realisations

An important aspect needing careful scrutiny in the performance analysis of Bt cotton is the multiplicity or proliferation of Bt and non-Bt varieties in the field. The seed market is highly dynamic in that newer varieties are introduced into the market year after year. In view of this multiplicity of varieties, it becomes rather complex to understand the yield and related secondary attributes of the varieties, thus making it difficult to arrive at a realistic measure of performance of Bt cotton. As majority of the seed sellers/ dealers are not ‘well informed’ in terms of the key attributes of the varieties, they are also unable to educate the farmers. On the other, farmers in the absence of adequate information about the varieties and their attributes relating to yield, resistance to the pests and other biotic and abiotic stresses, tend to grow as many varieties as their tiny plots could accommodate. In view of these complexities, though Bt cotton would show up a significantly higher yield over non-Bt at the aggregate level (when all the plots are combined), there would be significant yield difference between varieties. In fact, a vast majority of the empirical analysis on the impact of Bt cotton at least in the Indian context ignores this important aspect while reporting the yield performance of Bt vs non-Bt cotton varieties.

We had asked a specific question regarding the yield performance of Bt and non-Bt varieties which we tried to capture in terms of expected yield and realised yield. As the survey was done in three phases, we could gather variety-specific information regarding the expected yield in the first round of the survey which was later compared by collecting the realised yield during the third round of the survey.

Interestingly, in both the states, farmers have reported wider differences between the expected and realised yield outcomes. As evident from Table 4, the average expected yield reported in Maharashtra was 4.43 quintals per acre while the farmers were able to realise only 2.69 quintals per acre. Thus, there was a clear shortage of 39%

39% between the expected and realised yield of Bt cotton in Maharashtra.

Similarly, in Gujarat, the farmer expectations regarding yield of Bt cotton varieties was 12.25 quintals per acre while they received 32% less of the expected yield, that is 8.37 quintals per acre. The performance of Non-Bt varieties has been much better in Gujarat where the farmers could realise more than what they expected.

In order to understand whether the farmers are influenced by the seed markets/ seed dealers in their varietal preferences, we have tried to look at the different sources of seed purchase resorted to by the farmers. The results indicate interesting contrast between Gujarat and Maharashtra. Consultation with local farmers (and observations in nearby fields) has been the most important source for Gujarat farmers who apparently used more of unapproved seeds. In contrast, they rely heavily on dealers' advice for the approved varieties. Local learning (from neighbouring farmers and observing the variety in other fields) is most important for Maharashtra farmers, although seed dealers also play an important role. Advertisements and demonstration plots hold comparatively little sway although their influence is much more in Maharashtra than in Gujarat. It would seem that dealers' direct advice is the primary channel for companies to influence seed choices.

## Bt Technology and pesticide treadmill

Arguably, most of the GM crops have been engineered to check or resist pests and diseases. In the case of Bt cotton seeds, there takes place production of high doses of BT toxin. Similarly, planting of non-Bt (refugia) crops either on borders or in several rows of Bt cotton fields is recommended so as to control the Bt toxin resistant insects. Moreover, proponents of Bt technology claim that Bt hybrids have inbuilt resistance to bollworms. It has been further claimed that the toxin produced in Bt hybrid plant is effective against all the three species of bollworms, viz., spotted bollworms, American bollworms (*Helicoverpa* spp.) and pink bollworm (*Pectinophora gossypiella*).

But, it has been proven beyond doubt that cotton is affected by more than 160 pests. This raises the resurgence of secondary pests as well as newly introduced pests and diseases (due to spraying of mixtures of insecticides). In the process, farmers end up spraying the same quantity of insecticides as they have been using before the introduction of Bt cotton. In the literature, this phenomenon has been rightly identified as the 'pesticide treadmill'. It has been reported that in Andhra Pradesh, the number of attacks by number of 'sucking pests', such as aphids, thrips, jassids, etc has risen since the introduction of Bt cotton in 2002. Tobacco leaf streak virus, tobacco caterpillars etc have emerged as new diseases and pests of Bt cotton in the state. Of late, the emergence of new pest, called mealy bug (*Phenacoccus* spp.) has been widely reported from the Punjab, Gujarat and Maharashtra, which is a distinct case of secondary pest resurgence. According to the Punjab State Agriculture Department, over 2000 acres of cotton were destroyed by the mealy bug during the kharif 2007.

While a vast empirical literature suggests that there has been considerable reduction in the number of sprays against bollworms (Pray et al., 2001; Edge et al., 2001; Qaim and Janvry, 2005; Naik et al., 2005; Bennet et al., 2006), some recent studies negate this argument by indicating that Bt varieties require more insecticide spray compared to non-Bt varieties (Narayanamoorthy and Kalamkar, 2006; Mahendradev and Rao, 2007; Lalitha and Ramaswami, 2007). More importantly, it emerges from the above studies that since the farmers are more concerned about protecting the crop against all odds of attacks by pests and all other whether induced disease occurrences, they tend to spray more pesticides leading to a sizeable increase in their farming expenses.

Given this, we have examined the pesticide use practices of Bt cotton farmers in Maharashtra and Gujarat. It has been reported that in Maharashtra, the farmers have undertaken more number of sprays for Bt cotton (5 sprays/ha) as against close to 4 sprays per ha for non-Bt cotton. Similarly, in Gujarat, the average sprays for Bt cotton was close to 8 sprays per ha compared to 5 - 6 sprays per ha for non-Bt cotton. Based on the number of sprayings undertaken for the Bt cotton plots in Gujarat, it was observed that about 57% of the Bt cotton plots were sprayed 6 - 10 times and about 14% of the Bt cotton plots were sprayed more than 10 times. Thus, it emerges from the analysis that adoption of Bt cotton did not have a positive impact on farmers' pesticide use behaviour. In turn, farmers in both the states reports an increase in the number of pesticide sprays due to their adoption of Bt cotton.

The opinions of cotton farmers about the use of insecticides bring out an interesting point. Most farmers believe that the technology has lowered the use of insecticides for bollworm control. But, in turn, there has been a significant rise in insecticide use for other pests, like sucking pests, Mealybug, and other diseases as a result of adoption of Bt cotton (Lalitha and Viswanathan, 2009).

## BT TECHNOLOGY AND SUSTAINABLE AGRICULTURE: POTENTIAL CHALLENGES

In this section, we try to contemplate some of the critical challenges confronting the sustainable development of cotton sector in India especially in the context of emergence and wide-scale adoption of Bt technology by a major segment of the small and marginal cotton farmers. Broadly, these challenges encompass an array of operational level issues and constraints affecting the feasibility of the technology, profitability of the crop and the sustainability of the Bt cotton production. For analytical brevity, these issues and challenges may be broadly categorized into two, viz., a) Institutional and regulatory regimes; and b) Farm level structural and operational impediments. In what follows, we briefly discuss on each of these issues.

## Institutional and regulatory regimes

In the first instance, it may be noted that the Bt technology has been introduced in India as a panacea for the ills of low productivity which has been haunting the country since past several decades. While the technology has achieved certain amount of success in making a dent on the low productivity syndrome, there are serious concerns about the efficiency and consistency in the performance of the technology in diverse agro-ecological and hydrological environments. In fact, the proponents of the technology have made several claims about its performance, which mainly include: a) resistance to bollworms and the resultant decline in insecticide sprays and thereby a significant reduction in cost of cotton production; and b) a positive impact on yield arising from effective control of insecticides. Having said that, the question remains to be further clarified 'whether Bt cotton contributes directly to enhancing yield irrespective of varietal diversity and the complexities arising from insect attacks'.

However, as emerge from the foregoing analysis as well as the voluminous empirical literature within and outside India, the Bt technology has had only limited success in realising the claims. Apparently, the Bt technology, which is otherwise considered as the second green revolution (GM revolution), has been introduced in India without adequate thought on creating a conducive institutional and regulatory environment for legitimising the technology adoption on a wider scale. In other words, the technology has been externally imposed (by the corporate seed combine, like the Mahyco-Monsanto) without a strong institutional or legal backing from the regulatory regimes at the national level. This is in sharp contrast to the historic context when the Green Revolution was launched in India during early 1960s. Notably, Green revolution had made tremendous strides in Indian agriculture as it was backed up by a strong network of R&D as well as regulatory institutions and governance structures. The GM technology, including Bt cotton has been introduced in India in a vacuum created by the virtual absence of such institutional and regulatory systems to facilitate the technology adoption and its scaling up with proper R&D and extension facilitations. Even after almost seven years of its introduction, the national as well as the respective state governments have not taken any serious attempts to understand the rationale behind the development and spread of the technology, its potential and scope for scaling up in the Indian context and legitimize it based on proper investigations on the ground level performance of the Bt technology.

A serious challenge posed by the apparently haphazard scenario of Bt technology as exist today is that the Agriculture Research and Development Institutions as created in the GR era virtually remain non-functional or redundant in terms of facilitating the adoption of technologies and best management practices (BMPs) for achieving the desirable outcomes of the GM technology in the India. This observation needs to be substantiated with the empirical reality that prevails in most of the states where Bt cotton has made a tremendous breakthrough at least In terms of farmer adoption. The fact is that Bt cotton farmers are left themselves to decide their destiny by the State and Agriculture Research and Development Institutions (like the State Agriculture Universities, Agriculture Departments and other specialized institutions) especially in matters of decision-making as regards choice of seeds, insecticides, and adoption of other disease control measures. In most cases, farmers are left at the mercy of the seed companies or pesticide companies or the local seed and pesticide sellers to seek extension and information support as regards the varietal attributes and crucial management practices to be followed at the farm level.

This points to the imperfections in the existing institutional environments encompassing R&D interventions and extension services as well as apparently exploitative inputs (Bt cotton seed and insecticide) and output markets at the fag end of the cotton production system. The imperfections in the seed and insecticides markets breeds in total anarchy in the production system as the farmers are unable to get proper advice and timely guidance for choosing a seed or Bt variety based on prior understanding about its primary and secondary attributes given the agro-climatic and other resource endowments. Further, the anarchy in the production system is aggravated when the farmers do not find any extension services forthcoming at times when they are faced with problems of increasing infestations by pests like mealy bug, sucking pests and other unknown diseases affecting Bt cotton.

On the question of access to extension facilities, it may be further observed that the farmers in Maharashtra were mostly expressing their lack of access to better extension services especially when new pests like mealy bug or diseases like reddening of leaves occur. The farmers widely feel that they are really in problems on such occasions to get a trained extension agent to help them resolve their Bt cotton pest related problems. Ultimately, in most cases, their search for access to extension desperately takes them to the footsteps of the pesticide dealers who further complicate the matter by prescribing insecticides, which are new in the market, but may be quite obsolete to serve the purpose.

At the national level, public awareness about the potential benefits of the Bt technology as well as the probable risks involved in the use of GM crops including cotton is rather low. Though commercial release of a Bt variety needs prior approval and authentication by the Genetic Engineering Approval Committee (GEAC), often the approvals are not based on scientific investigations based on larger trials laid out in diverse agro-ecological and hydrological settings of the cotton growing regions in the country. Moreover, there has not been greater appreciation of the fact that the commercial release of Bt varieties is to be preceded by proper dissemination of information about the varieties to the farmers.

A yet another challenge faced by the Bt cotton farmers especially in Maharashtra has been that despite a significant switch over to Bt varieties, cotton prices were stagnant in the state for most part of the decade beginning 1997 - 1998. Farmers are never equipped to improve their skills to upgrade the quality of raw-cotton so that they could strive for a better price for the produce. In fact, this is going to be a major challenge affecting the sustainability of Bt cotton in India. Though it may seem quite untenable, a major chunk of the farmer suicides as reported from one of the study districts, that is Yavatmal, may have some corollary with the mental state of affairs that the Bt cotton farmers have been underway in terms of: a) Lack of access to the institutional support, R&D and extension services; b) Heavy dependence on the seed and insecticide dealers; and c) The unattractive cotton prices over the entire decade of Bt adoption. Thus, it is important to streamline policies for institutional restructuring so as to make the input and output markets more responsive to the dynamic changes in the production sector as brought out by the introduction of Bt cotton.

It may also be observed that the country has not yet evolved a fool proof legal or regulatory framework to monitor the spread of legally approved Bt cotton varieties on the one side as well as the wide-scale use of illegal or unapproved Bt varieties on the other side. For instance, an overwhelming majority of cotton farmers in Gujarat still use unapproved Bt varieties, which have been sourced from the same retail outlets who also sell approved Bt varieties. This underlies the dilemma that the State faces in matters of legitimizing the Bt technology through exercising the regulatory power for devising proper monitoring mechanisms. Since a vast majority of the farmers have been planting these varieties ever since the official release of Bt varieties, any legal or regulatory measure to be adopted by the state government for banning such illegal Bt varieties would have serious repercussions on the political future of the government.

In India, both public sector institutions (universities, autonomous research bodies, Central Institute of Cotton Research, etc) as well as private sector agencies [Maharashtra Hybrids Seed Company- Mahyco, Monsanto; M/s Proagro PGS (India) Ltd, etc] are engaged in developing cotton varieties with high levels of resistance. However, it is pertinent to note that these agencies are primarily focusing on developing plants that are resistant to biotic stresses, that is resistant to pests and insects, and not to abiotic stresses, that is making plants more adaptable or tolerant to adverse climatic conditions, such as drought. This is an important challenge in the country where a major chunk of Bt cotton is grown under rainfed or drought conditions, like Maharashtra. More importantly, with the emergence and spread of Bt varieties, the rich genetic diversity is being replaced by the new varieties. For instance, in Maharashtra, the emergence of Bt varieties has significantly replaced the traditional (desi) cotton varieties and currently almost the entire cotton growing area in the traditional cotton growing districts are distributed between Bt cotton and hybrid cotton varieties. Of late, the Central Institute of Cotton Research (CICR) based at Nagpur has been trying to develop insect resistant and high yielding desi cotton varieties as an alternative to the Bt cotton. However, it has been reported that the GEAC has been successful in getting Government accord in directing the CICR to discontinue with the R & D experimentations in this regard.

**Structural issues and operational impediments**

The structural as well as operational impediments affecting the upscaling of Bt technology in India is certainly unrelated to the resource endowments of the small and marginal farmers, as the technology is scale-neutral. In fact, there are no significant differences between small and larger farmers in terms of adoption of Bt technology. Thus, the issues are more related to the structure and functioning of the input and output markets which exert greater influence on the non-viability of Bt cotton production system in India.

As stated above, the input markets comprising the seed, pesticide and fertiliser sectors are highly imperfect in terms of creating dilemmas among the farmers in matters right from the choice of Bt cotton varieties to the choice of proper insecticides and fertiliser use. As newer and newer Bt varieties are introduced into the market year after year, farmers hardly get sufficient time to make a careful scrutiny about the varieties and build up their knowledge base based on experience. The proliferation of varieties makes the scenario further complex as majority of these varieties do not seem to be unique in terms of farm level performance and other varietal attributes as already observed. Thus, there are limited chances for the farmers to strengthen or enrich their experience with Bt cotton based on either environmental or social learning.

Since the performance (of what ever magnitude) of Bt varieties is certainly specific to the single year of adoption, farmers become highly dependent on the seed market to replace seeds every year. To make the matters further worse, newer varieties are introduced into the market which persuades the farmers to try the new seeds/ varieties every year, thus adversely affecting their economic status. Thus, with the entry of Bt cotton, the practice of the use of 'farm saved seeds' come to permanent halt.

## Imperfections in input and output markets

With the emergence of Bt cotton in particular, the local input markets became highly integrated with the seed, pesticide as well as fertiliser companies. A survey conducted among 80 seed dealers in the Vidarbha region as part of the study revealed that almost 95% of the seed dealers are also sellers of insecticides and fertilisers. As a result, the farmers are mostly compelled to buy the seed, insecticides and fertilisers from the same shop. This enables the local seed-pesticide-fertiliser sellers to strengthen their hold over the farmers, which always puts the farmers at a disadvantage. Though sales of seeds are not on credit, the sales of insecticides and fertilisers are on credit and very often, the interest rates charged by the seed/pesticide sellers are exorbitant.

Coming to the complexities in the output market, it is important to note that the development of Bt technology did not have any considerable impact on revamping the otherwise ineffective and imperfect cotton marketing systems. Though the existing system of marketing of raw-cotton also allows for differential pricing of the product based on quality of the lint, in reality, farmers do not get higher prices for better grades of cotton sold by them. Hence, the farmers are compelled to sell cotton as ungraded and there are no proper systems or legal or institutional mechanisms to distinguish between cotton outputs produced from Bt planted plots and non-Bt or conventional cotton planted plots. Even the existing lower prices of such ungraded cotton are further discounted in the pretext of poor quality of cotton (containing seed, wastes, particles of leaf and cotton stem) as sold by the farmers. This is an important challenge which has greater implications for the viability of Bt technology and sustainability of Bt production system.

## CONCLUSION: IS THERE A WAY FORWARD?

To conclude, it may be observed that there is no clear way forward to sustain the initial dynamism cast by the introduction of Bt technology in India. A bright future for Indian agriculture with the presence of GM technology in general and Bt technology in particular, would essentially call for many reforms, development strategies and institutional and policy interventions covering a wide spectrum of activities ranging from restructuring the input markets to the output markets. Though it is true to believe that Bt cotton contributes to yield increases, the most important objective of the technology was to lower the use of insecticides. The study reveals that Bt technology has been a total failure on that score and the impact of the technology has been less evident. While the effect of Bt technology becomes somewhat clear in reducing (but not eliminating) bollworm attack, it proves to be highly ineffective in terms of control of sucking pests, including the latest emergence of mealy bugs as widely reported from almost all the cotton growing regions in the country.

The paper highlights the importance of evolving new institutions and regulatory systems for proper grounding and spread of the Bt technology in India. Areas of immediate concern includes *inter alia*: a) Development or strengthening of existing R&D systems in the cotton sector to make the technology work efficiently for the benefit of about 4 - 5 million cotton farmers in the country; b) Regulation of input markets with proper legislations and administrative systems; c) Developing financial support systems, like crop insurance against crop loss caused by germination failure (seed companies to be implicated for this), pest infestations, drought or floods; d) Creating efficient extension systems by revamping the state level agriculture extension services to facilitate better adoption of Bt technology among the farmers with proper skill formation through imparting training on farm level benefits arising from the practice of IPM and IRM; and e) Creating efficient marketing system for Bt cotton by which output quality is improved through grading with higher premiums paid for better quality output.

In sum, it may be observed that India has to evolve carefully devised strategies and action plans to learn from the experiences of other countries with respect to the performance of GM technology in general and Bt technology in particular. These strategies and action plans presupposes creation of new institutional or regulatory regimes or reinventing the existing ones so as to make a sustainable impact of the technology on the livelihoods of millions of cotton farmers as well as the century old cotton production sector in India.

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