Bt Cotton and the Myth of Enhanced Yields

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It is presumed that remarkable increases in cotton productivity in India have come about through bacillus thuringiensis cotton and that this approach therefore must be replicated in other crops. This article explores the myth of rising yields of genetically modified crops and points out that genetic engineering has been at best neutral with respect to yield and in many cotton growing countries the average cotton yields have stagnated since the adoption of Bt cotton.

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There have been several media and industry reports in the past few years talking about how the remarkable increases in cotton productivity in India have come about through bacillus thuringiensis (Bt) cotton, introduced officially in 2002 in the country. People like the Finance Minister P Chidambaram are quoted as saying that the success of Bt cotton must be replicated in other crops to boost farm yield (*Financial Express* 2007). We hear of genetically modified (GM) crop developers like K C Bansal of the Indian Agricultural Research Institute's (IARI) National Research Centre for Crop Biotechnology talking about how cotton production was stagnant before Bt cotton's advent and how production has doubled after GM cotton came in (*The Hindu* 2008). Meanwhile, by December 2008, the hyped projections of a record production of 320 lakh bales in India in that year were pegged down to 270-280 lakh bales (see *Business Line* 2009; Mehta 2008; Iyengar 2008). The latest estimates by American agencies put the production at 230 lakh bales. Untimely rains and plant diseases are reported to be the reasons for the 10% year-on-year reduction in production. Andhra Pradesh, for instance, has admitted to a 40% decrease from projected production figures citing various reasons. Now, this is interesting. When it comes to production increases, it is attributed to Bt cotton but when it comes to decreases, the entire complexity involved in yields of a crop are brought in.

In this context, it would be useful to analyse the performance of transgenic crops like GM soybean and GM cotton in a country like the United States (US) which continues to be the largest cultivator of GM crops after having introduced these crops more than a decade ago, before taking a closer look at Bt cotton in different states of India.

A Friends of the Earth (2008) report points out, after studying the yield figures of crops like cotton, soy and corn in the US starting from the 1930s, that genetic engineering has been at best neutral with respect to yield. At the macro-level, the report points out, average cotton yields have stagnated since the adoption of Bt cotton in the US, as in other countries like Argentina, Australia and Colombia (ibid).

The US Experience

The GM soybean, meant for herbicide tolerance, is planted on the largest areas within GM crop extents in the world (90% of US soybean is estimated to be GM soybean and more than 50% of GM crop land around the world is planted with that crop in just a few countries). The GM crop proponents also argue about yield increases in an indirect fashion – in insect-resistant GM crops through protection from crop losses due to major pests and not yield increases per se. Therefore, looking at the picture of GM soy and GM cotton in the US will give some insights into the reality of yields after the advent of transgenics. Table 1 gives the year-wise picture about the percentage share of transgenics in the total soybean and cotton area (US) from 2000 onwards (data is available from 2000).

Table 1: Transgenic Area Expansion within Cotton and Soybean Extents in the US (in %)

Year	GM Cotton in Total Cotton Area	GM Soybean in Total Soybean Area
2000	61	54
2001	69	68
2002	71	75
2003	73	81
2004	76	85
2005	79	87
2006	83	89
2007	87	91
2008	86	92

Acreage rpts:http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1000

Table 1 shows that the initial five years (1996-2000) saw the largest or most rapid expansion of transgenic area in soybean and cotton cultivation compared to the later period (2001-08). There was a 38% additional shift in soybean and 25%

additional shift in cotton to transgenics in this eight-year period. A minor reduction in transgenic cotton area within total cotton in the US compared to the earlier year was in fact witnessed in 2008.

Table 2 gives the annual average growth rates of these two crops, using three-year moving averages of yields as per the data of the United States Department of Agriculture (USDA). The yield for soybean is recorded in bushels per acre and for cotton in pounds per acre in the US.

Table 2: Annual Average Growth Rates of Yields of Soybean and Cotton, US (1984-2008)

Period	Soybean Yield Growth	Cotton Yield Growth	Remarks
1984-96	2.64	1.27	This is 12 years prior to introduction of transgenics
1996-2008	0.77	2.30	12 years after introduction of transgenics
1996-2000	(-) 0.20	(-) 1.49	The most rapid expansion of transgenics happened during this period – 61% of cotton and 54% of soybean in the US shifted to transgenics
2001-08	1.42	4.30	Subsequent expansion period, at a slower pace
1984-2008	1.63	1.70	

Source: Compiled from three-year moving averages of yields; Yield data obtained from USDA. Available at http://www.nass.usda.gov/QuickStats/index2.jsp, accessed on 9 October 2008.

GM Soybean: As can be seen from Table 2, no claims of dramatic yield increases can be made about the largest cultivated GM crop, the GM soybean. It is very clear that yield growth has come down in the years after GM soybean was introduced. In fact, the initial five years after the introduction of transgenic soy, which also witnessed the most rapid expansion of GM soy, saw a negative yield growth. In the subsequent years, yields seem to have recovered slightly but are still lower than the pre-GM years. The 2008 yields of US soybean (at 40 bushels per acre, as per the National Agricultural Statistics Service of the USDA), with 92% of such soybean being genetically modified, are lower than the 1994 yields of 41.4 bushels (before GM soybean was introduced). This is just to underline the fact that yields are much more complex in reality than a linear function of one technology.

Further, genetic engineering as a technology cannot increase yields per se since yields are a factor of complex, multi-genic traits, not in application with GM crops now. With GM soybean, decreased yields have been recorded even in field trials. A University of Nebraska study found that Roundup Ready (RR) soya varieties (Roundup Ready is the brand of Monsanto's GM trait) yielded 5% less than their closest conventional relatives and 10% less than high-yielding conventional lines (Elmore et al 2001). This corresponds to a loss in production of nearly 200 kg/ha.

This yield drag of RR soy is also apparent in flat overall soybean yields from 1995 to 2003, the years during which GM soy adoption increases to 81% of US soybean-planted land. A 2007 study by Kansas State University, led by Barney Gordon, an agronomist, suggests that RR soy continues to suffer from a "yield drag" (Gordon 2007). Gordon's study finds that glyphosate applied to the GM crop is inhibiting the uptake of nutrients like manganese essential to plant health and performance. The "yield drag" of RR soy has been correlated to the presence of glyphosate in the root zone of the plant.

GM Cotton: When it comes to cotton, a different picture than the one for soybean emerges. In the years prior to the introduction of transgenic cotton, the yield growth was 1.27 while in the post-1996 period, it jumped to 2.30. However, what is important to note is that the 1996-2000 period saw a sharp decline in yield growths in cotton – this is the period when GM cotton spread to 61% of total cotton cultivation in the US. Therefore, it would be misleading to say that GM cotton has contributed to yield increases in cotton here. The subsequent years, which witnessed a slower expansion of GM cotton, saw an impressive increase in yield growth. Steep yield increases in cotton in 2004 and 2005 are in fact attributed to excellent weather conditions (Meyer et al 2007).

Going by the above data, it can be concluded that transgenic soybean or cotton did not result in yield growths and in fact, there is a clear trend of yield growth declines in the case of soybean after the advent of the transgenic, herbicide-tolerant soybean in the US. For both these crops in the US, the period of rapid expansion of transgenic crop cultivation (1996-2000) witnessed a negative yield growth compared to earlier years.

At the micro-level, a study by the USDA that looked at adoption of GM crops and its relation to net returns/yields throws some light on different GM crops (Fernandez-Cornejo et al 2002). The 2002 USDA study report says that the adoption of herbicide-tolerant soybeans did not have a significant impact on net farm returns while the adoption of herbicide-tolerant corn improved farm net returns among specialised farms. The report goes on to add that the positive financial impact may be due to seed companies setting low premiums for herbicide tolerant corn in an attempt to expand market share. On Bt cotton, the report says there was a positive impact on net returns among cotton farms but adoption of Bt corn had a negative impact among specialised corn farms. The study raises a pertinent question to itself: "perhaps the biggest issue raised by these results is how to explain the rapid adoption of GE crops when financial impacts appear to be mixed or even negative", it says suggesting that "other considerations may be motivating farmers" (what is now called the "convenience effect").

The Chinese Picture

Coming to China, Xinjiang province is known for its cotton cultivation and around 30% to 32% of China's cotton production is contributed by this one province. This province is supposed to have touched yields of 2.5 bales per acre of cotton by 2004. Between 1980 and 2004, the cotton yields in this province are reported to have increased by 3.74 times (Xiaoling et al 2006). What is interesting however is that a USDA Global Agriculture Information Network (GAIN) report of 2005 notes that in Xinjiang, Bt cotton varieties are not widely planted ("because bollworms are less of a problem there than in other areas, so farmers prefer seeds of the cheaper conventional varieties") (GAIN 2005). This picture of planting is reinforced by other researchers (Huang et al 2002). When the overall adoption of Bt cotton within China's cotton was 45% by 2001, Xinjiang gets classified within "rest of China" with its low 7% adoption rate here. Xinjiang's high cotton yields are attributed to the planting of conventional varieties with specific traits, such as dwarf plant size and early maturity, as well as to new agronomic practices, including "high density

sowing, plastic sheet covering and drip irrigation" (USDA 1 May 2007). The FOE (2008) report goes on to illustrate that the yields of Xinjiang are far higher than the rest of the country over the years that Bt cotton adoption has spread in China without such an adoption happening in this important cotton-growing province.

Bt Cotton in India

While this is the picture with China, it is interesting to note that the hype in India about Bt cotton hides important factors that have contributed to cotton yield improvements in the country. The Xinjiang province equivalent here seems to be Gujarat. Before looking at cotton in Gujarat, Table 3 gives the area, production and yield of cotton in India (1997-98 onwards).

Table 3: Cotton Area, Production and Yield in India (1997-98 to 2007-08)

	1997-98	1998-99	1999-2000	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07
Area in lakh hectares	89.04	92.87	87.91	85.76	87.3	76.67	76.3	87.86	86.77	91.58
Production in lakh bales	158	165	156	140	158	136	179	243	244	270
Yield in kgs/ha	302	302	302	278	308	302	399	470	478	501

Source: Cotton Corporation of India, web site http://www.cotcorp.gov.in/national_cotton.asp accessed on 7 February 2009.

Cotton is grown in several states of India like Maharashtra, Gujarat, Andhra Pradesh, Punjab, Haryana, Tamil Nadu, etc, and the cotton cultivation in India is divided into southern, central and northern (cotton-growing) zones.

Gujarat is one of the most important cotton-growing states in India. By 2007, Gujarat's share in total cotton production in India has gone up from around 29% at the time of introduction of Bt cotton to an impressive 39%. In fact, understanding the situation of cotton in Gujarat separately and not allowing it to distort the entire picture of cotton in the country is an important aspect of any analysis of cotton production.

Table 4: Cotton Area, Production and Yield in Gujarat (1997-98 to 2006-07)

Year	Cotton Area: in Lakh Hectares	Production: in Lakh Bales (1 bale=170 kgs)	Yield: in Kg/Ha
1997-98	15.19	42	470
1998-99	16.07	47.5	502
1999-2000	15.39	27.5	304
2000-01	16.15	23.7	250
2001-02	16.87	32.5	328
2002-03	16.34	30.5	317
2003-04	16.47	50.0	516
2004-05	19.06	73	651
2005-06	19.01	89	794
2006-07	23.9	93	718 (662?)

Source: Cotton Corporation of India's web site.

Table 4 enumerates the area, production and yields of cotton in the state of Gujarat, starting from 1997-98 as per the Cotton Corporation of India's data. It has to be noted that these figures vary from the data put out by the Central Institute for Cotton Research (CICR) as well as the state department of agriculture, Gujarat (yield figures put out by state departments are based on "crop cutting experiments" and not on data from ginning factories).

In a letter dated 9 May 2005 (D O No IST/2003/Bt Cotton K-6 (PtII)), the agricultural secretary, government of Gujarat wrote to the chairperson of the Genetic Engineering Approval Committee:

> Yes, the productivity which was 175 kg/ha in 2002-03 is touching 460 kg/ha in 2004-05. But this is not solely due to Bt cotton hybrids as Gujarat recorded 450 in 1998-99 when there was no Bt cotton. In our opinion, all these years were good years with low to medium bollworm activity, hence this increase.

The agricultural secretary (government of Gujarat) is pointing to an important aspect related to yield analysis with insect resistant GM crops here – that if pest incidence itself is low due to climatic and other conditions, there cannot be yield increases due to protection from crop losses through insect-resistant varieties! In India, it is recorded that bollworm incidence across regions has been quite low from 2001 (AICCIP *Annual Reports*).

Through their official monitoring and evaluation report of Bt cotton in 2006-07, the Gujarat state authorities have also revealed that

> the productivity of cotton crop also increased due to increase of irrigation facility by massive water harvesting programmes. On the other hand, rainfall is also very good during past three years. Parameters like irrigation facility, good monsoon, use of drip, low pest pressure, black soil and farmers' experience are contributing in the success of cotton crop in the state.

Reports from the first quarter of 2008 indicate that cotton production in Gujarat declined in the kharif crop of 2007 as well as 2006 (Pandit 2008). Cotton production was estimated to have come down to 90 to 100 lakh bales from the earlier projected 125 lakh bales. Another report stated that cotton productivity in Gujarat, according to the directorate of agriculture, could have gone down by 78 kg/ha in 2006-07, coming down to 650 kg/ha from a record 728 kg in 2005-06 and could have fallen further in the 2007 kharif season (Trivedi 2008).

Incidentally, from 2002 onwards, the increase in irrigated cotton area in Gujarat has been steady. Table 5 is based on data obtained from the Directorate of Agriculture on the year-wise extents of irrigated and unirrigated cotton in Gujarat, in hundreds of hectares.

While the percentage area of irrigated cotton within total cotton cultivation in Gujarat has been steadily increasing, between 2000-01 and 2005-06, there has been a 43.3% increase in the total area under irrigated cotton. Any analysis of cotton yield increases at the state level in Gujarat has to note this increase. In addition, the watershed programmes of the government would also have contributed their share to yields in the rainfed cotton plots too.

Table 5: Changes in Irrigated and Unirrigated Cotton in Gujarat (2000-01 to 2005-06)

	Irrigated Cotton Area in '00 Ha	Unirrigated Cotton Area in '00 Ha	Percentage Irrigated Area
2000-01	6,619	10,131	39.5
2001-02	7,146	10,226	41.1
2002-03	7,377	9,357	44.1
2003-04	7,570	9,379	44.7
2004-05	8,434	10,629	44.2
2005-06	9,485	10,623	47.2

Source: Right to Information obtained from the Department of Agriculture, Government of Gujarat, 2008.

Seed Sources: Another factor that is often neglected in most analyses on cotton yields is the shift in seed source – from varieties to hybrids and from F2 seed sources to F1. Table 6, based on data estimates provided by the department of

Table 6: Estimates of Cotton Area (in hectares under varieties and hybrids in Gujarat)

	Varieties	Hybrids	Total	Percentage under Varieties
2003-04	7,19,822	9,27,257	16,47,079	43.7
2004-05	7,61,245	11,45,055	19,06,300	39.9
2005-06	7,74,314	13,03,492	20,77,806	37.3
2006-07	8,30,140	15,64,865	23,95,005	34.7
2007-08	6,66,200	18,49,800	25,16000	26.5

Source: Information obtained from the Department of Agriculture, Government of Gujarat, 2008.

agriculture, Gujarat, gives a picture of the large-scale shift in seed from cotton varieties to hybrids in the state.

While cotton varieties occupy around 26.5% of cotton area now, they used to be on 43.7% of cotton area just a few years ago (2003-04) as per the estimates of the department. Further, there is a doubling of absolute area under cotton hybrids during this period.

A report by the CICR in 2007 points out that one clear impact of Bt cotton on Indian agriculture appears to be the replacement of large tracts of varietal areas with Bt hybrids since the (transgenic) technology is available in India only in the form of hybrids (Khadi 2007).

To take an example of another state, in Andhra Pradesh, cotton varieties were estimated to be on 28% of cotton land in the state in 2002-03, the year of introduction of Bt cotton. Data obtained from the department of agriculture shows that the land under cotton varieties has come down to 1.3% by 2007-08.

Table 7: Cotton Area under Varieties, Non-Bt Cotton Hybrids and Bt Cotton Hybrids, Andhra Pradesh (2001-02 to 2007-08, area in lakh hectares)

	Varieties	(Non-Bt) Hybrids	Bt Cotton	Total	Varieties Percentage
2001-02	3.32	7.76		11.08	30.0
2002-03	2.25	5.74	0.04	8.03	28.0
2003-04	2.34	5.98	0.05	8.37	28.0
2004-05	1.63	9.43	0.73	11.79	13.8
2005-06	0.16	6.93	3.24	10.33	1.5
2006-07	0.1	3.05	6.57	9.72	1.0
2007-08	0.15	1.17	10.01	11.33	1.3

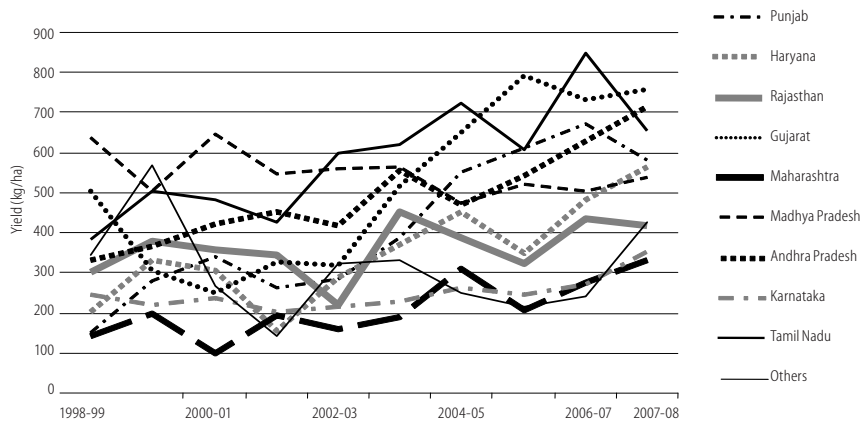
Source: RTI data from Department of Agriculture, Government of Andhra Pradesh.

Apart from the picture related to "irrigated vs unirrigated" cotton and "varieties vs hybrids" in terms of seed source, the report from the CICR director also states that

> Bt cotton seems to have reduced the overall quantity of insecticide substantially only in some parts of the country coupled with spectacular yield increases reported from Gujarat, while the rest of the states have been showing mixed results despite increase in area under Bt cotton.

The figure gives a picture of the cotton yields in different states of India. Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra and Tamil Nadu have been cultivating Bt cotton from 2002 officially. The figure illustrates what Khadi says about the spectacular yield increases in Gujarat and mixed results in other states.

Figure: Cotton Yields – States



Source: Cotton Corporation of India's web site accessed on 12 October 2008: http://www.cotcorp.gov.in/state_operations.asp

Interestingly, in the very first year of Bt cotton's commercial cultivation in India (2002-03), the largest survey on performance was done in the state of Andhra Pradesh, by the department of agriculture. While there were 6,949 farmers who went in for Bt cotton in 2002-03 in Andhra Pradesh as per the sales figures of Monsanto-Mahyco, the department's survey covered 3,709 of these farmers. This continues to be the largest percentage sample of Bt cotton performance in the country to this day. A whopping majority of the respondents in this survey (71%) reported low yields with Bt cotton.

Another factor worth analysing with regard to current cotton cultivation in India is the use of chemical fertilisers. Increased use of fertilisers on Bt cotton is observed from various informal and media reports in addition to agriculture university recommendations as in the case of the recommendation by the Acharya N G Ranga Agriculture University, Hyderabad (2007). There are no indications of yield analysis of cotton factoring in this increased use of chemical fertilisers on cotton.

Moving to another state, Madhya Pradesh posted impressive yields of 612.7 kg/ha per hectare on an average, for six years between 1996 and 2002 (six years prior to introduction of Bt cotton in the country), as per the Cotton Corporation of India's records and such impressive results were without the help of GM technology. In 1997-98, Madhya Pradesh's yields were a record 740 kg/ha – there was of course no Bt cotton then. However, in the six years after the introduction of Bt cotton, cotton yields in Madhya Pradesh have gone down to 518.3 kg/ha on a six-year-average.

In Conclusion

Most farmers as well as good agricultural scientists understand that crop yields are a complex phenomenon and depend on a variety of factors. However, the hype around Bt cotton and the cause-effect relationship being attributed to Bt cotton and cotton yields in India required an article of this sort. This article was written only to explore the myth of yields behind GM crops like Bt cotton and not because the author believes that yields can be a simplistic linear function of one technology.

A matter of great concern is the lack of analysis of the current agrarian crisis in India (and using that understanding to predict the implications from risky technologies like GE), where farmers who have been relentlessly pushed towards treadmill technologies find that their costs of cultivation are ever-increasing, the productivity of their resources is constantly being eroded and despite increased yields, are left with dismal incomes of Rs 2,115 on an average! Going by various parameters to study the agrarian crisis, it is clear that yield increases from intensive agriculture models have not translated into livelihood improvements for farmers. This is something that the Kisan Policy of the National Commission of Farmers (NCT) ("Serving Farmers, Saving Farming") headed by M S Swaminathan notes expressly. The NCF document states that the Kisan Policy attempts to "get the focus of our agricultural

policies shifted to the women and men who feed the nation, thus moving away from an attitude which measures progress only in millions of tonnes of foodgrains and other farm commodities". However, it is again with the promise of yield-increases that farmers are being lured towards one more treadmill technology in the form of GM seeds.

It is surprising that the current dominant discourse about GM crops in India is willing to accept blindly that Bt cotton is the reason for yield increases in cotton in India. This article is a small attempt to point out that there has not been a deeper analysis including by policymakers about the real reasons behind yield improvements, that too in certain states. This alternative analysis will show that large-scale shift in seed sources, shift from unirrigated to irrigated cotton, good monsoons, low pest incidence, etc, have all contributed to cotton yield increases in some years in some states of the country, coupled with increased use of chemical fertilisers.

Incidentally, while the biotech industry supported by un-analytical media hypes up Bt cotton for everything good with cotton in the country, the official data and reports tucked away here and there are much more pragmatic and realistic with their analysis. For the media and the policymakers however, it is ironical that all good years are attributed to Bt cotton's magic and in years when production or yields fall, the full complexity of various factors influencing yields are acknowledged!

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