Bt Cotton and Farmer Suicides in India: Reviewing the evidence

By G.Gruere, P.Mehta-Bhatt and D.Sengupta[1]

1. Introduction

In July 2007, the Indian governmental authorities announced the approval for commercialization of seventy-three new varieties of Bt cotton, a genetically modified cotton resistant to cotton bollworms, for a total of 135 hybrid Bt cotton varieties available on the Indian market (SABP Newsletter 2007). In 2006, Bt cotton covered 3.8 million ha or over 39% of total cotton area four years after its introduction (The Economic Times, 01/31/2007). For the first time, the area of Bt cotton in India exceeded that of China, one of the leading countries for Bt cotton (The Hindu, 01/19/07) making India the first country in Bt cotton area in Asia. Officials expect a continuous increase in the total area under Bt cotton in the next few years in India (Reuters, 03/16/2007) up to a potential 60% of total cotton area. These different indicators demonstrate the remarkable commercial success of Bt cotton in India.

However, at the same time, Bt cotton is still at the center of a number of controversies, as it has been since its introduction in India in 2002. A number of groups from the civil society contest its effectiveness and report that groups of farmers have lost income using it, needing more pesticides and obtaining lower yields. Other groups report its toxic effects on domestic animal health, despite contradicting evidence. Many producer and activist groups contest the very high cost of seeds of Bt cotton set up by Monsanto Inc., the multinational biotech company. Yet, perhaps the most talked about controversy relates to the alleged resurgence of cotton farmer suicides in certain Indian states and their relationship with the use of Bt cotton.

In recent years, a large number of farmers' suicides have been reported, mostly resulting from the consumption of toxic pesticides by farmers in some cotton growing districts of central and southern India. According to some official statistics, between 2001 and the summer of 2007, more than 4,500 cases of farmer suicides had been reported in the four states of Maharashtra, Andhra Pradesh, Karnataka and Kerala (Mukherjee 2007). Other sources

[1] G. Gruere and D. Sengupta are in the Environment and Production Technology Division, International Food Policy Research Institute. P Mehta-Bhatt was formerly India coordinator, South Asia Biosafety Program, International Food Policy Research Institute.

have reported much higher figuress; in particular, the National Social Watch reports 11,387 cases of farmer suicides in the same period in India, almost all in the four States (The Statesman, 07/01/07) and annual figures published by the National Crime Records Bureau go up to over 16,000 farmer suicide every year. In most cases, male farmers committed suicide after what was qualitatively reported as failed crops and increase indebtedness. The largest number of reported cases was concentrated in districts of North-East Maharashtra (Vidharba district), North-West Andhra Pradesh, and North of Karnataka, where cotton has been increasingly planted in the 1990s to respond to the demand of the large textile industry in Mumbai (Saunders 2007).

Reports initially limited to local newspapers and radios rapidly spread to national and international media, with coverage from some of the most prominent global newspapers and magazines. The main cause of suicide differs across sources, some accusing Bt cotton, some attacking cash crops and industrial agriculture, others multinational companies and developed-country subsidies lowering world prices for cotton (The Economist, 01/18/07). Concurrently with the media hype, the issue progressively caught the attention of the policy sphere to become prominent both in the concerned Indian States and in New Delhi.[2]

Since the beginning of this crisis, many reports have been published by government, national and international non-governmental organizations and other groups of stakeholders involved in agricultural issues in India. Some of these reports focused on Bt cotton and farmer suicides, others on farmers' conditions, and the context in which they committed suicides, or on the socio-economic conditions of farmers in modern India. Still, most studies on Bt cotton tend to reflect the very polarized views on Bt cotton itself, without providing a comprehensive understanding of the actual situation that lead to the observed resurgence of farmer suicides in India, and therefore the potential role (or absence thereof) of Bt cotton in this picture.

The objective of this paper is to provide a critical review of evidence, in a comprehensive way, on the alleged links between Bt cotton and the observed growth in farmer suicides in certain regions of India. We formulate two opposed sets of hypothesis on the presence or absence of a resurgence of farmer suicides and the potential relationship it

[2] For instance, in June 2006, during a meeting at the International Food Policy Research Institute, the Honorable Minister of Agriculture, Government of India, noted that the question of Indian suicides was a top priority issue for Indian agriculture.

may have with the use of Bt cotton. We then use secondary data from multiple sources to evaluate these contradicting hypotheses. In so doing, we provide a comprehensive analysis of the performance of Bt cotton in India, taking into account the competing evidence given by various studies. Alongside, we also delve into a study of the other plausible causes of farmer suicides and whether it has a direct bearing to the commercialization of Bt cotton in the country.

Our method consists of a critical review of available information and existing data. We analyzed information from published official and unofficial reports, peer reviewed journal articles, published studies, media news clips and magazine articles, radio broadcasts, all from India, Asia, and international sources up until December 2007. We also had the opportunity to obtain feedbacks on this specific topic from the Solution Exchange for the Microfinance Community (SEMC); an internet discussion group organized by United Nations Development Program (UNDP) and specialized in issues of microfinance and credit in India. Nineteen group members from as many institutions provided feedbacks, references, and sources of information on the issue of Indian farmer suicides and Bt cotton.

In the next section, we formulate the main hypotheses that will be evaluated in this study. We then present the evidence of suicides, we provide a comprehensive analysis of the effect of Bt cotton in India, and we evaluate the potential role of this technology among other general causes, particularly in the two States of Maharashtra and Andhra Pradesh, who both cultivate Bt cotton and have a high number of suicides.

2. Linking Bt cotton to farmer suicides: formulating hypothesis

As a basis of analysis, we proposed two opposed set of hypothesis to explain the situation. The first one supported at least partially by media reports and by a number of civil society organizations, is based on the following two major assertions:

1.a. There has been a significant resurgence of farmer suicides in recent years (2002-2007), particularly in Central and Southern India.

1.b. The main reason for suicides is indebtedness due to negative farm income from failing cash crop cultivation; Bt cotton, as a costly and ineffective technology, is a main contributor to this resurgence of farmer suicides in these regions of India.

The second set stands in opposition with the first one, and is based on three assertions:

2.a. Farmer suicide is a long term phenomenon, there is no clear evidence of a "resurgence" of farmer suicides in the last five years (2002-2007).

2.b. Bt cotton is neither a necessary nor a sufficient cause of farmer suicides. In contrast, many other factors (not all related to agriculture) likely played a prominent role.

2.c. In specific cases (regions and years) where Bt cotton may have indirectly contributed to farmer indebtedness (via crop failure) leading to suicides, its failure was mainly due to the context or environment in which it was introduced or planted; Bt cotton as a technology is not to blame.

Our review of evidence will provide argument to support the second set and reject the first one. Assumptions 1a and 2a are directly opposed and will be examined in section 3, which reviews the empirical evidence on farmer suicides in India. Assumptions 1b, 2b, and 2c will be mainly supported by our argumentation in sections 4 and 5, which provide a comprehensive review of the effects of Bt cotton and an evaluation of its potential contribution, among other factors, to cases of farmer suicides. We then provide a synthesis of our analysis, reconstructing the evidence, in section 6, and close the paper with some concluding remarks on the policy implication of our results.

3. Farmer suicides in India: reviewing the data

As noted in the introduction, there has been contradicting evidence on reported cases of farmer suicides. Yet, after sorting out across reports, it appears that two sources of official data have been primarily used. On the one hand, the official data reported in IndiaStat (www.indiastat.com), the webportal for data on the Indian Economy, reports relatively low estimates of farmer suicides, as shown on Table 1. Its importance can be reflected in the fact that it has been used by government officials in Parliament during the question-answer sessions in the summer of 2006. These data have been used by journalists and several researchers in their papers on Bt cotton or farmer suicides in India. For instance, Mitra and Shroff (2007) use this table as the basis of their recent analysis on the causes for farmers' suicides in Maharashtra. Still, we find that these data are inconsistent across States and years, that there are missing data, and that several points are reported by crop year others by calendar year. Apparently these data were obtained by State government in 2006.

Table 1. The first official version: Number of farmers' suicides in selected Indian States

State	2000/01	2001/02	2002/03	2003/04	2004/05	2005/06	2006[1]
Andhra Pradesh	191	267	313	393	1126	300	11
Maharashtra		50*	122*	170*	620*	572*	746
Karnataka[2]	2630	2505	2340	708	271	152	
Punjab[3]			13	11	6		
Kerala		56*	69*	74*	135*	120*	52
Orissa		2	1	0			
Gujarat		13*	6*	3*	7*	7*	

Source: Rajya Sabha Unstarred Question No. 2878, June 12, 2006 and Rajya Sabha Unstarred Question No. 1809, dated August 11, 2006.
Notes: * these numbers refer to the whole calendar year listed first, e.g., 2001 rather than 2001/02 etc.
1. Figures for 2006 are counted until June.
2. For Karnataka, the figures for 2000-01 to 2002-03 are based on records with the State Crime Records Bureau and for the subsequent years on the basis of records maintained by State Agriculture Department.
3. Punjab State Government has recently indicated that between 1997 to September 2005 the total number of farmer suicides are 179, without year-wise breakup.

Table 2. The second official version: Farmer suicides in selected states and all India (1997-06)

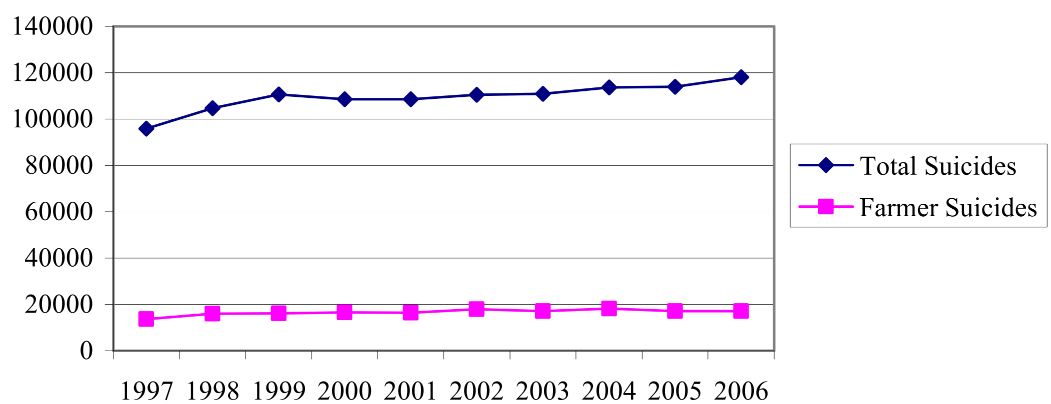
Farmer suicides	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Maharashtra	1917	2409	2423	3022	3536	3695	3836	4147	3926	4453
Andhra Pradesh	1097	1813	1974	1525	1509	1896	1800	2666	2490	2607
Karnataka	1832	1883	2379	2630	2505	2340	2678	1963	1883	1720
Madhya Pradesh	2390	2278	2654	2660	2824	2578	2511	3033	2660	1375
Gujarat	565	653	500	661	594	570	581	523	615	487
Other States	5821	6979	6152	6105	5447	6892	5758	5909	5557	6418
All India	**13622**	**16015**	**16082**	**16603**	**16415**	**17971**	**17164**	**18241**	**17131**	**17060**

Source: various issues of "Accidental Deaths and Suicides in India", National Crime Records Bureau, Ministry of Home Affairs, Government of India.

The second main source of data is the National Crime Records Bureau (NCRB), Ministry of Home Affairs, Government of India, which publishes annual reports on accidental and suicidal deaths in India. One of the main tables provided in the reports published in the last ten years is the State distribution of suicides by profession, which includes a category for self-employed persons in agriculture. As shown in Table 2, the numbers of farmer suicides reported are much larger (e.g. around 17,000 annual suicides in recent years compared to 1,000-2,000 for all reported major suicide States in Table 1) and much more consistent across States and years than the ones of Table 1. Several authors writing reports on farmer suicides have used this source, including Nagaraj (2008), and journalists such as Sainath (2007a and 2007b) in *The Hindu*, and Sengupta (2006) in the *New York Times*. Even though the accuracy of these figures, like the others, is put into question by some, these much larger estimates are considered underestimate of the real farmer suicide figures (e.g., Nagaraj 2008). This implies that the first source of data is likely even more unreliable and negatively biased. The other advantage of these figures is that they are not isolated; they are presented with overall estimates of the numbers of suicides in India and by State in a consistent manner.

While acknowledging the existence of two contradictory official sources of data, we have decided to use NCRB data as the main basis of our analysis, not only because we (and others) believe such data is much more reliable, likely to be closer to actual figures, but also because it is more exploitable for cross State and longer time dependent analysis.

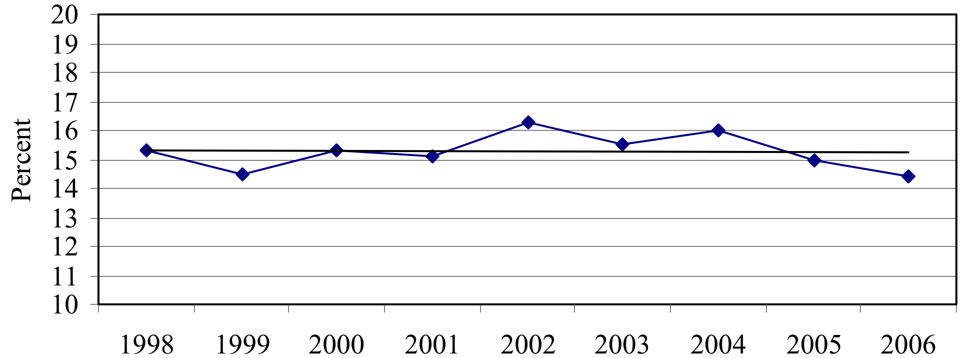
Figure 1. Farmer and total suicides in India (1997-2006)



Source: Various issues of "Accidental Deaths and Suicides in India", National Crime Records Bureau, Ministry of Home Affairs, Government of India.

Using data from this second source, Figure 1 provides the trend in farmer suicides and total suicides in India between 1997 and 2006. Figure 1 first shows that farmer suicides only represent a relatively minor and stable share of total suicides in India. Annual national suicide numbers range between 95,800 and 118,200, while farmer suicides lie between 13,600 and 18,300 in the same time span. There is slight rising trend in total suicides with accelerated growth during 1997-99 and again during 2003-06. The overall trend is still rather flat and there is no obvious interior peak. The rate of farmer suicides is also relatively stable but slowly increasing overtime. There was a visible accelerated increase in farmer suicides in 1997-1999 and later in 2004 but in 2005 the number fell back to the level of 2003. Generally, these national aggregate figures provide a very simple but powerful piece of evidence against the reported rise in farmer suicides. There has not been any recent acceleration in suicides or farmer suicides at the national level.

Figure 2. Share of farmer suicides in total Indian suicides (1997-2006)



Source: Various issues of "Accidental Deaths and Suicides in India", National Crime Records Bureau, Ministry of Home Affairs, Government of India

Table 3. Rates of farmer and total suicides in recent years

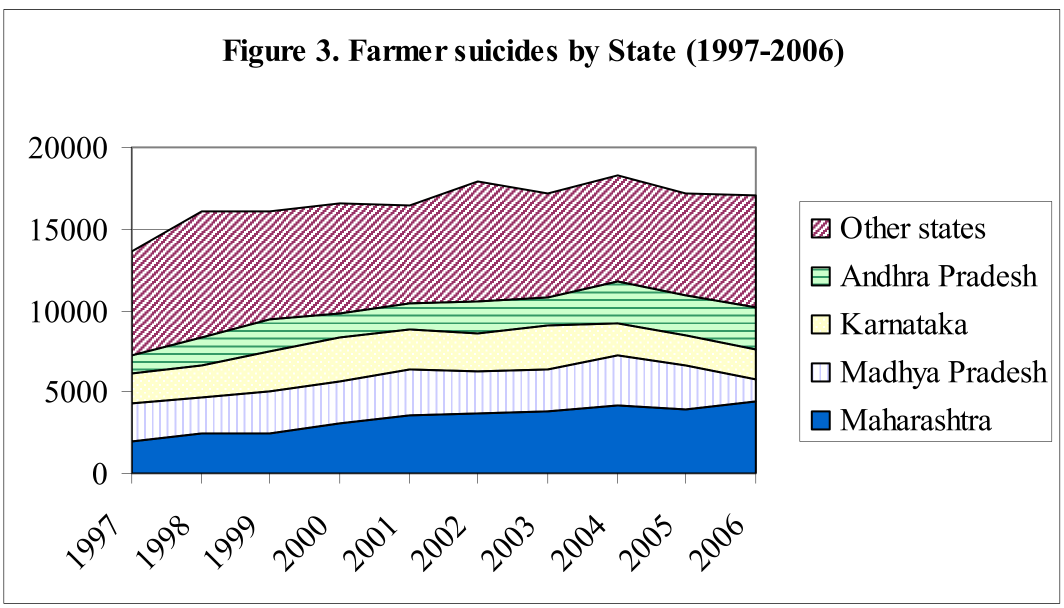
	Suicide rate (per 100,000 pop.)	Farmer suicide rate (per 100,000 pop.)
1997	10.0	1.42
1998	10.8	1.65
1999	11.2	1.62
2000	10.6	1.62
2001	10.6	1.60
2002	10.5	1.71
2003	10.4	1.61
2004	10.5	1.68
2005	10.3	1.55

Source: Sainath (2007a).

More specifically, Figure 2 provides a time series of the share of farmers' suicides in total suicides in the same period. This share fluctuates between 14.5% and just above 16% of total suicides. The series reaches a maximum rate in 2002 and a secondary peak in 2004. The last two years in the series show a very significant decline in the share of farmer suicides, which again hardly supports a resurgence of farmer suicide.

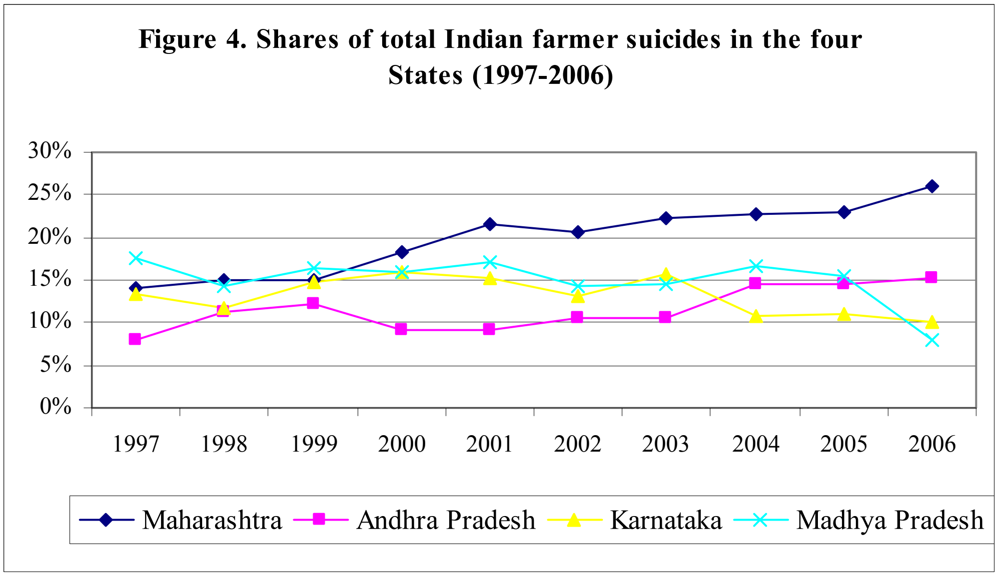
Several authors have also tried to compile suicide rates (per 100,000 population) for different years, generally using population number extrapolations from the 2001 census data (deriving rates that are therefore not completely accurate). For instance, Table 3 provides suicide rates as reported by Sainath (2007a) and derived farmer rates using the farmer suicide shares shown in Figure 2. Despite their limitations, these numbers show first that total suicide rates have not increased rapidly, but also that the farmer suicide rate in total population has not increased significantly between 2000 and 2005 -even if it reached a higher level in 2002 and 2004- which again goes against the hypothesis of the alleged sustained resurgence in farmer suicides.

Looking at a more disaggregated spatial level, the distribution of suicides and farmer suicides across State is not uniform. By studying trends in suicides for all Indian states Nagaraj (2008) classifies states into four groups based on the importance of the suicides numbers, the farmer suicide rates, the shares of farmer suicides, and the overall growth of farmer suicides during 1997-2006. The first and leading group includes for big states of Central and Southern India: Maharasthra, Madhya Pradesh, Andhra Pradesh and Karnataka, that account for between 52 and 65% of the total reported farmer suicides in recent years (with a ten year average of 60%) and a significant of total suicides (e.g., 40% in 2001-Nagaraj 2008).[3] Figure 3 shows the number of suicides for these states and the others between 1997 and 2006. Figure 4 shows the share of farmer suicides in total for each of these states in the same period, and Figure 5 shows the relative change in farmer suicides from one year to the other between 2002 and 2006.

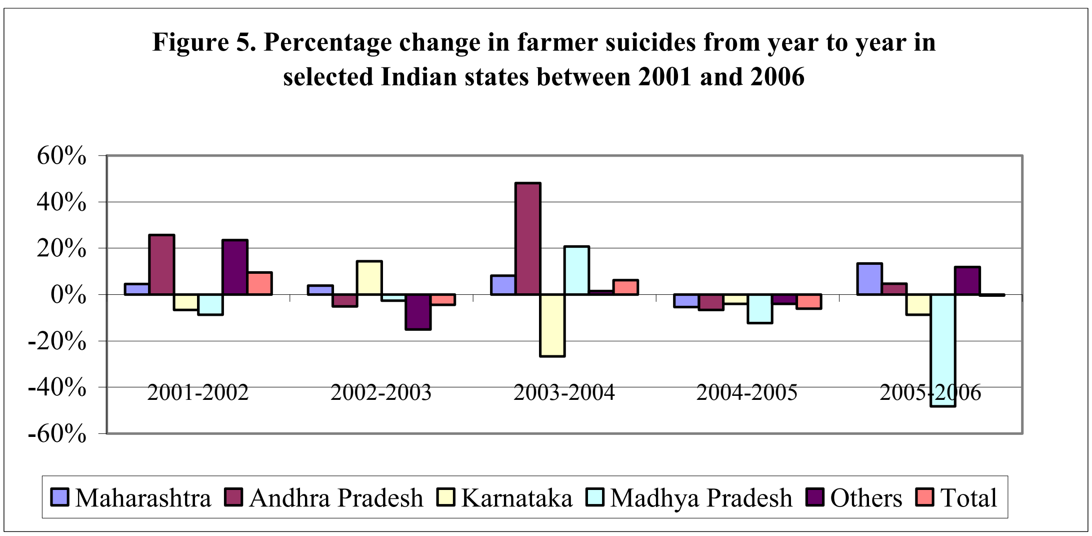


Source: Various issues of "Accidental Deaths and Suicides in India", National Crime Records Bureau, Ministry of Home Affairs, Government of India

[3] The Group also includes the State of Chhattisgarh, because of higher suicide rates in 2001, but its contribution to farmer suicides is not as significant as the three other cotton producing states.



Source: Various issues of "Accidental Deaths and Suicides in India", National Crime Records Bureau, Ministry of Home Affairs, Government of India



Source: Various issues of "Accidental Deaths and Suicides in India", National Crime Records Bureau, Ministry of Home Affairs, Government of India

Maharashtra has both higher numbers of suicides compared to other states (Figure 3) and also presents a steadier annual rate of increase in farmer suicides (Figure 4). Its growth in suicides rate was unsteady with peaks in 2003-2004 and 2005-2006 (Figure 5). Madhya Pradesh and Karnataka had initially almost as many farmer suicides as Maharashtra (Figure 3) but farmer suicides in both states have been decreasing steadily these last few years (Figure 3 and 5). The share of farmer suicides represented by these two States has also decreased considerably (Figure 4). In contrast, Andhra Pradesh started with lower farmer suicides numbers but its suicide numbers rose significantly, to reach what looks like a plateau in 2005-06. Figure 5 shows that the largest increase in farmer suicides across the four states during the period 2001-06 occurred in Andhra Pradesh between 2003 and 2004 and between 2001 and 2002. These two periods also represent the only years when the total farmer suicides number in India showed a relative increase between 2001 and 2006.

We can draw several simple conclusions from this rapid review of the evidence. First, there are contradicting data sources on farmer suicides in India, which provide very different ranges of estimates. The more comprehensive and more consistent source of data estimates that farmer suicides number range between about 14,000-18,000 per year, or between 14-16% of total suicides every year in India since 1997.

Second, the phenomenon of farmer suicides is not new, nor recent. Based on observed trend from 1997-2006 at the national level, one can clearly reject the assertion that there has been an accelerated growth in suicides in the last 5 years or so. The numbers of farmer suicides are significant and tend to be growing overtime, but so are the total numbers of suicides in the population.

Third, these national numbers mask a heterogeneous distribution of cases at the State level. Several central and Southern States, in particular Maharashtra, Andhra Pradesh, Madhya Pradesh and Karnataka, have reported very significant numbers of farmer deaths compared to other states and India as a whole. In this group of States, Maharashtra and Andhra Pradesh have known a significant increase in farmer suicides in the last few years (a consistent fact across otherwise conflicting data sources).

Lastly, although the total numbers of farmer suicides seem to have leveled-off, several of the figures we obtained show that there may have been two relative peaks in suicide numbers in 2002 and 2004 both at the national level and in the two sensitive states (a consistent fact across data sources).

Keeping these facts in consideration, we will turn to a section explaining the story of Bt cotton in India, and its economic effects, to later see if and how it could have related to the discrete increases in the number of suicides particularly in these two States.

4. The effects of Bt cotton in India

4.a. *The approval of Bt cotton in India*

Cotton is a very important commodity crop for India, growing on most agro-climatic zones and providing livelihood to more than 60 million people (James 2002) by way of support in agriculture, processing and textiles. Cotton is grown on nearly nine million hectares in India, making it the global leader in cotton production area (International Cotton Advisory Committee 2007).

At the same time, until recently, the productivity of cotton in India was among the lowest in the world. Table 4 provides comparative ten year average of cotton production, area and yields in the ten largest producing countries between 1997 and 2006. As shown in this table, during this period, India was the third producer overall, with the largest area of cotton (representing about a quarter of the global cotton area), but its yield was below the international average, and only ranked 70th among all producing countries. Table 4 shows the evolution of yield levels over time; according to these official data, the productivity growth in cotton has been rather slow in India during the last fifty years, and the yield level remained far below the global average in 2003.

This significant yield gap is due to various factors, including the lack of irrigation facilities, pest problems, and factors characterized by small-scale and resource-poor farming systems. In India, most of the cotton is cultivated under rain-fed condition (Sundaram et. all, 1999). Thus the variability in yields is largely dependent on monsoon. Another major factor is the infestations of pests, especially the American Bollworm, suffered by the cotton plants at various stages of their life cycle. This implies that farmers have to incur large expenditure on pesticides every year. Figure 6 gives the pesticide consumption by different crops. Cotton consumes about 45% of pesticides and 58% of all insecticides used in Indian agriculture (Choudhary and Laroia, 2001). Rice is a distant second consuming 22% pesticide while pulses, vegetables and other plantation crops consume a miniscule 4%, 9% and 7% respectively.

Table 4. Average cotton lint production, area and yields from 1997 to 2006 in the ten leading producing countries during this period

Country	Production		Area		Average yield	
	Million mt	Share	Million ha	Share	kg/ha	Rank
China	5.12	24.8%	4.70	14.1%	1087	6th
USA	4.15	20.0%	5.24	15.7%	789	14th
India	2.27	11.0%	8.65	25.9%	263	70th
Pakistan	1.89	9.1%	3.00	9.0%	626	23rd
Uzbekistan	1.08	5.2%	1.47	4.4%	735	17th
Turkey	0.89	4.3%	0.66	2.0%	1354	3rd
Brazil	0.72	3.5%	0.90	2.7%	832	13th
Australia	0.62	3.0%	0.39	1.2%	1655	1st
Greece	0.39	1.9%	0.39	1.2%	1002	8th
Syria	0.32	1.5%	0.24	0.7%	1332	4th
World	**24.84**	**100%**	**35.0**	**100%**	**501**	**n.a.**

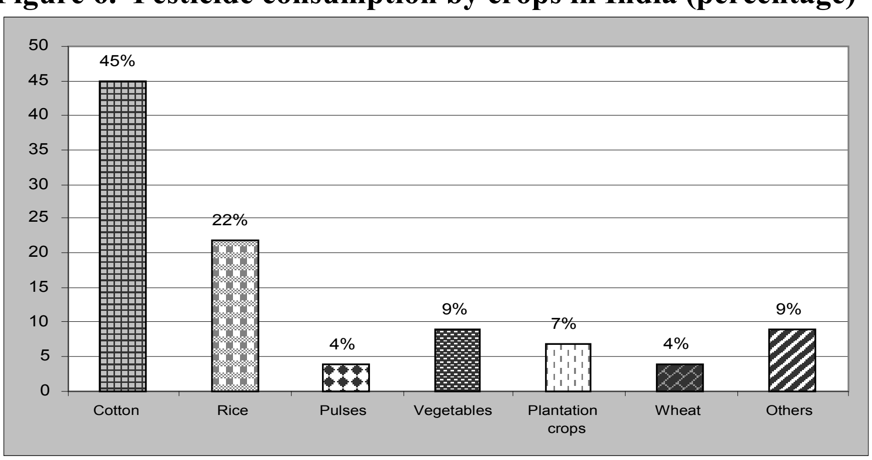
Source: FAOSTAT- ProdSTAT database consulted in August 2007.

Table 5. All-India Area, Production and Yield of Cotton

Year	Area (M.ha)	Production (M.Bales)	Yield (kg/ha)	% Irrigated area
1950-51	5.88	3.04	88	8.2
1960-61	7.61	5.6	125	12.7
1970-71	7.61	4.76	106	17.3
1980-81	7.82	7.01	152	27.3
1990-91	7.44	9.84	225	32.9
2000-01	8.53	9.52	190	N/A
2001-02	9.10	10.09	189	N/A
2002-03	7.48	9.31	212	N/A
2003-04	7.64	13.79	307	N/A

Source: Agricultural Statistics at a Glance, 2004. Ministry of Agriculture,Government of India.
Note: each bale weighs 170kg.

Figure 6. Pesticide consumption by crops in India (percentage)



Source: Choudhary and Laroia, 2001.

Higher dosages of pesticides are also used frequently as a numbers of insects have developed a resistance to the commonly used chemicals. This has mandated repeated applications of pesticides leading to increased costs in cotton production (Govt. of India, 2002).

At the end of the 1990s, Bt cotton, a genetically engineered insect resistant cotton, with a potential to provide protection against bollworm *(Helicoverpa armigera*), one of the major cotton pest, was considered a possible solution to the high costs of pesticide use in the country. In view of the importance of this commodity crop, upon satisfying review of biosafety data and successful field trials by the regulatory authorities, and partly prompted by the intrusion of unofficial Bt cotton seeds in India in 2001, the Government of India gave permission for Bt cotton to be commercially cultivated in the country in 2002.

Table 6. Rapid chronology of Bt Cotton in India

Year	Activity
2000	Mahyco is given permission to conduct large scale field trials of Bt cotton including seed production in six states.
2001	The GEAC extends field trials of Bt cotton by another year. Mahyco conducts large scale field trials on 100 hectares in seven states. Illegal Bt cotton plantations are discovered over several thousand hectares in Gujarat. Source of seeds are traced back to Navbharat Seeds, a company that has used a Monsanto Bt cotton event (MON 531) illegally imported from the United States.
2002	DBT declares that the field trials of Bt cotton were satisfactory and GEAC and MoEF can decide on a date for commercial release. GEAC approves the use of MON 531(Bollgard I) in three Mahyco Bt cotton hybrids after taking into account their performances in field trials.
2004	GEAC approved a fourth hybrid transformed with MON 531
2005	GEAC approves 16 more hybrids transformed with MON 531
2006	GEAC approves three events: MON 15985 (Bollgard II) from Monsanto, Event 1 from the Indian company JK Seeds, and GFM event using a Chinese gene from Nath Seeds. 42 additional hybrids are approved.
2007	GEAC approves 73 more hybrids transformed with one of the four events.

Notes : DBT: Department of Biotechnology, GEAC : Genetic Engineering Approval Committee, MoEF: Ministry of Environment and Forests.
Sources: India Resource Centre (2002); FICCI (2005); APCoAB (2006).

Table 6 provides a rapid summary of the history of the approval of Bt cotton, the only transgenic crop approved for commercial release up to date in India. Table A1 in the appendix provides the locations and number of varieties approved by region between 2002 and 2007. The Bt cotton introduced in India is genetically modified to contain a gene (cry1Ac for the first event) of Bacillus thuringiensis (Bt) which is a naturally occurring soil bacterium and is toxic to the cotton bollworms, the most active cotton pests, largely responsible for widespread damages in the fields.

The first approved genetic event (crop/trait combination) MON531, also called Bollgard-I, developed by the private U.S. company Monsanto, was originally infused into three local hybrids to get the insect resistant property (APCoAB, 2006). The first Bt cotton varieties approved for cultivation in India were MECH-12 Bt, MECH-162 Bt and MECH-184 Bt, all produced by Mahyco (Maharashtra Hybrid Seed Company), a company partially owned by Monsanto. In 2004 and 2005, a total of 17 additional hybrids were released based on the same event. In 2006, 62 varieties of hybrid Bt cotton were approved by the Genetic Engineering Approval Committee (GEAC), in charge of approval decisions. Most of these varieties have been developed by local seed companies with the Bollgard I gene and the newly approved Bollgard II (MON 15985) with stacked genes Cry1Ac and Cry2Ab with improved resistance to bollworm and a few other pests. Two additional events were approved, the first indigenous Indian Bt gene (developed in collaboration with a public research institution) and using Cry1Ac was by the firm JK Agri-Genetics, Ltd and a second event (GFM event) based on a Chinese gene, with a fusion Cry1Ab-Cry1Ac introduced by Nath Seeds. In 2007, 135 varieties of Bt cotton were available based on four events, the two Bollgard, the one of Agri-Genetic and a second Bt gene.

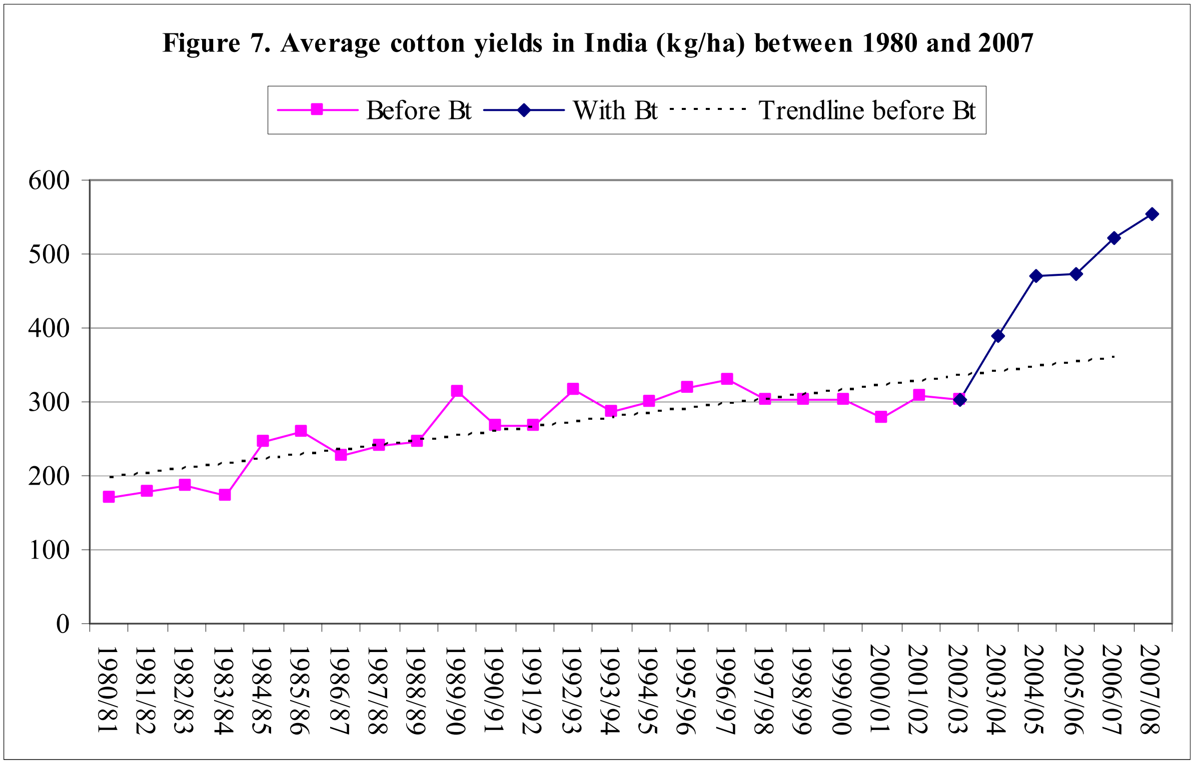
4.b. *Bt cotton at the national level: observed effects*

Currently, Bt cotton is cultivated in more than ten states of India, the major ones being Maharashtra, Andhra Pradesh and Gujarat. Table A1 (appendix) shows that the first varieties were approved in the Central and Southern regions, and that the Northern zone only had Bt cotton a few years later. Table 7 gives the estimated state-wise adoption area of Bt cotton in India between 2002 and 2006.

Table 7. State-wise Adoption of Bt Cotton in India

State/Region	2002	2003	2004	2005	2006
Maharashtra	12,424	21,854	161,475	508,692	1,840,000
Gujarat	9,137	41,684	125,925	149,258	470,000
Madhya Pradesh	1,488	13,355	86,119	136,221	310,000
Andhra Pradesh	3,806	5,463	71,227	90,419	830,000
Karnataka	2,186	3,035	34,304	29,345	85,000
Tamil Nadu	374	7,689	11,995	17,017	45,000
Northern Zone	-	-	-	83,503	215,000
Other	-	-	-	-	5,000
Total			500,000	1,310,000	3,800,000

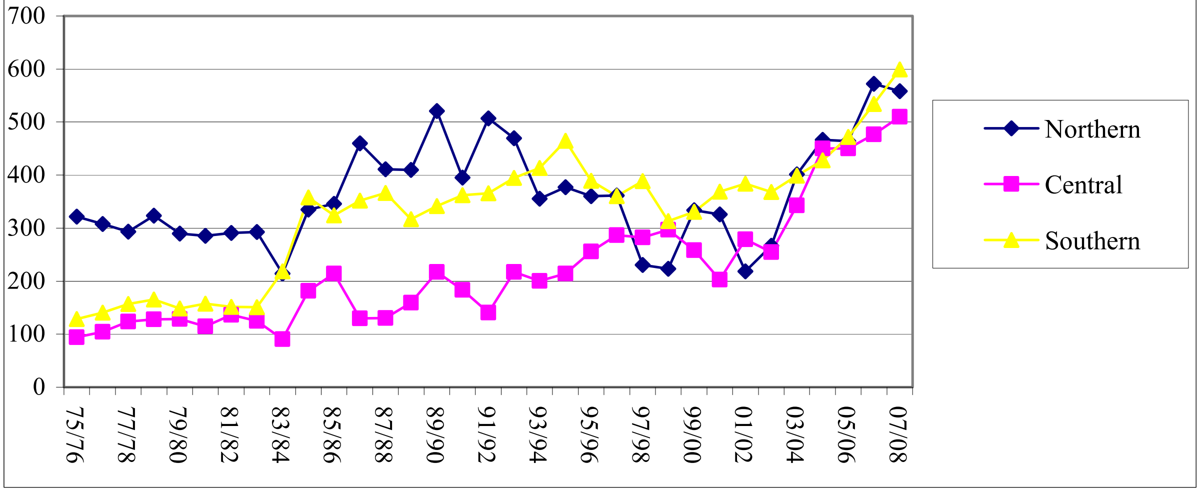
Source: www.indiastat.com for 2002-2005, ISAAA (2006) for 2006.



Source: International Cotton Advisory Committee (ICAC). 2007/08: estimate.

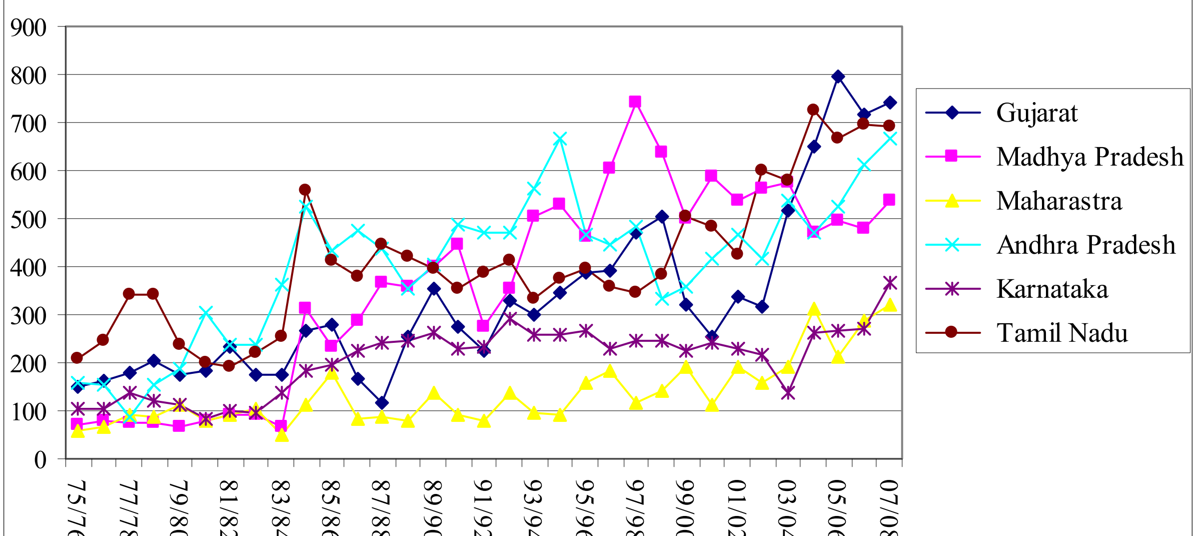
According to the Cotton Advisory Board, in 2005/06, Bt cotton has been the major factor behind increased cotton production in the country, rising from 15.8 million bales in 2001/02 to 24.4 million bales in 2005/06 (ISAAA, 2006). To confirm this conclusion, Figure 7 shows the change in average yields at the national level in India between 1980/81 and 2007/08, separating the evolution before 2001/02 and after 2002/03. The difference between the trend in national average yields before and after Bt cotton does suggest a significant jump in productivity at the exact same time as the introduction of Bt cotton introduction. Perhaps more striking is the fact that average yield level almost reached 400 kg/ha in 2003/04 for the first time in history, and that a yield level of 500kg/ha has been exceeded only three years later in 2006/07. In comparison, it took about fifteen years, from 1982 to 1997, for the national yield level to increase from 200kg/ha to an annual average of 300kg/ha.

Figure 8. Average cotton yields by region in India (kg/ha) (1975-2007)



Source: Director of Cotton Development, Government of India; East India Cotton Association.

Figure 9. Average cotton yield level by state (kg/ha) (1975-2007)



Source: Director of Cotton Development, Government of India; East India Cotton Association.

Interestingly, this evolution does not reflect changes in all regions of India. Figure 8 shows the regional trends between 1975/76 and 2007/08. If the North, South and Central regions[4] all converge at the end of the thirty year period, the North and South regions are closer to their long term trend. The yield evolution in the Central region is much more significant after 2002 and closer to the national average, as expected, given its leading production level. More specifically, Figure 9 provides the same evolution at the state level, for selected states that have adopted Bt cotton, and shows that all States except Madhya Pradesh have reached a record average yield level in recent years. But the southern States of Andhra Pradesh and Karnataka may have done so only not before 2007/08 (estimates for this crop season) while the other States reached record level one or more years earlier. Among the central states, Gujarat shows the most striking upwards trend in yields from under 300kg/ha in 2000/01 to over 800kg/ha five years later. It is likely that seasonal variation played a role, but in the absence of other structural changes in the sector, this state would be expected to reach an average level of just above 500kg/ha by 2007/08. Instead, the level of yields in Gujarat seems to be bound to stay at about 750kg/ha, i.e. 50% higher.

To sum up, although measuring the actual net effects of Bt cotton introduction would require a formal empirical analysis, our simple overview of the yield average levels help us draw two conclusions. First, in the absence of other technical or continuous climate shocks in the last five years, Bt cotton likely played a role in the large jump in productivity observed in yield levels in India these last five years to reach record high levels. Second, regional data shows that Bt cotton may not have had the same marginal effects in each states. In particular, it seems to have had a larger effect in the Central region, and the Central Western states of Maharashtra and especially Gujarat.

Table 8. Pesticide Consumption (million metric tons) (Tech Grade)

States	2001-02	2002-03	2003-04	2004-05
Andhra Pradesh	3850	3706	2034	2133
Maharashtra	3135	3724	3385	3030

Source- Directorate of Plant Protection, Quarantine and Storage, Govt. of India

In terms of input reduction, it is difficult to find precise data on the use of pesticides in cotton in specific regions of India. But there are data on total pesticide use. Table 8 shows total pesticide consumption in Andhra Pradesh and Maharashtra between 2001 and 2005. This

[4] The three cotton regions are defined as follows: Northern: Punjab, Haryana, and Rajhastan; Central: Gujarat, Madhya Pradesh, and Maharashtra; Southern: Andhra Pradesh, Karnataka, and Tamil Nadu.

table shows that pesticide use has been going down from 2002 onwards in both states. Knowing that a large proportion of total pesticides are used in cotton production, it is possible that the growing adoption of Bt cotton played a role in this decrease in pesticide consumption, even if one cannot be sure from such aggregate data. The only certainty is that there was a reduction in pesticide consumption concurrently with the adoption of Bt cotton in these two states, more visibly in Andhra Pradesh (45% reduction).

4.c. *The Bt cotton controversy: the institutional context.*

Even with the yearly increases in adoption, production and yields, Bt cotton has had its share of controversies. Lack of information on growing conditions, pesticide usage as well as importance of proper seeds seems to have developed into a group of factors behind the controversy shrouding Bt cotton's performance and the earnings expectations of farmers from using this technology. More specifically, four factors or issues seem to have dominated the Bt cotton debate particularly in Maharashtra and Andhra Pradesh.

The first issue is the widespread distribution and use of spurious seeds. Inclusive of the technology fee, in the absence of regulations, Bt cotton (hybrid) seeds were initially sold at a price equal to five times that of the local hybrid varieties. Bt cotton seeds initially cost about Rupees 1650 for a 450 grams packet compared to the Rs 300 for 450 grams pack for the local hybrid variety DCH32 (Achrya, 2006). This prompted a booming market for spurious seeds, which were sold at a much lower price. However, these seeds were mostly a mix of Bt and non-Bt cotton as well as those of unapproved varieties. Mostly sold by local traders, the targets were farmers trying to save on seed costs. The germination rate of these seeds was observed to be inconsistent and often resulted in crop loss and disappointed many farmers. Indian legislations like the Seed Act have been of limited effect since there was no provision for legal action on the sale of unpackaged/unlabelled seeds. The New Seed Bill of 2004 tries to remedy this situation by removing the distinction between notified and other varieties. If this bill is passed, all seeds whether packaged or not has to be registered. This would help in reducing the sale of mixed and spurious seeds (Kulkarni, 2006).

Another factor, which has helped the sale of spurious seeds, is the confusion related to the large release of approved Bt cotton varieties by the government of India in recent years. In the summer of 2007, there were 135 varieties of Bt cotton hybrids approved by the GEAC.

This figure is up from 62 approved varieties in 2006 and 20 in 2005. The new varieties are available for sale in one or more of the six originally approved states of Gujarat, Karnataka, Andhra Pradesh, Maharashtra, Madhya Pradesh and Tamil Nadu along with three new states of Punjab, Haryana and Rajasthan (as shown in Table A1).

The lack of agriculture extension and dissemination of knowledge about these new varieties from the government has left farmers solely dependent on the companies for information regarding these varieties (SEMC 2007). The spreading adoption of Bt cotton has been mainly driven by demonstrations from farmers who have had success cultivating it (Ministry of Environment & Forest, India, 2003). Very few agriculture extension services were provided and at very distant places (Rao and Suri, 2006). The seed and fertilizer company agents have been the sole interface between the technology and the farmers (Shridhar, 2006). This coupled with the numerous brands of Bt cotton seeds released between 2004 and 2005, some of the medium or poor farmers were practically gambling on the seed use (Stone 2007).

Third, the high use of pesticides even with Bt cotton seems to have played a role (SEMC 2007). Cotton has been the major pesticide dependent crop in India. It is cultivated in only 5% of the area but receives 45% of the pesticides used in India which accounts for 42-50% of the total cost of cultivation (Shetty, 2004). The advantage of higher price for Bt cotton seeds are justified by the reduction in pesticide use as the plants already guard against cotton's worst pest, the bollworm. But this does not mean a total elimination of pesticide sprays. To have maximum yield results from Bt cotton, pesticide sprays should be optimized and targeted for the other secondary pests which used to be covered by the wide spectrum pesticides used before this new technology.

However, farmers lacked the knowledge about the requirements for Bt cotton and followed their own spraying schedules. In a survey of farmers in Maharashtra and Gujarat, Shetty (2004) found that farmers followed a 20-30 spray pattern for cotton in Guntur and Warrangal, when the optimum required as only 15. This indiscriminate spraying led to development of resistance in the bollworm and hence pest infestation returned back lowering the yield from Bt cotton in these regions. The survey also revealed that farmers changed pesticide types and doses to combat the development of resistance among bollworms (Shetty, 2004). However, the situation shows some improvement according to a more recent report

(ASSOCHAM-IMRB 2007), showing that Bt cotton farmers have largely reduced pesticide consumption compared to conventional hybrids.

Lastly, the controversy has been fueled by the lack of consistent public information on the performance of Bt cotton (SEMC 2007). Many studies have been reported or published by various institutes, and cited one after the other by the media, or selectively by opponents or proponents to Bt cotton, without visible public efforts towards a comprehensive and synthetic assessment of the effects of Bt cotton in the field. This proliferation of reports going in either direction has contributed to the public confusion on the use of genetically modified crops among educated readers. Yet, as shown in the next subsection, a comprehensive review of the literature shows there has been a convergence in the empirical evidence on Bt cotton, which progressively dismissed any controversy on the observed productivity and income effects of the technology.

4.d. *The economic effects of Bt cotton at the farm level: a review of empirical evidence*

Since its introduction, many empirical studies have been published on the economic effects of Bt cotton adoption at the farm level in India (Smale, Zambrano, and Cartel 2006). These ex-post assessment studies use different methods to compare the effect of Bt cotton and non-Bt cotton in terms of pesticide use, yields, cost of seeds, other costs, net revenues. Among them, over fifteen studies have been published in peer-reviewed journals, while other studies have not been published, but have been widely distributed. In this section, we do not provide a detailed review of the literature. Instead, we synthesize the findings from published or available economic studies to draw some general conclusion on the observed effects of Bt cotton and the controversy around the use of this technology.

Smale et al. (2006) provide an analysis of the methods used in all farm level studies of Bt cotton in India up to 2006, and draw several important conclusions. First they note that existing studies show that the reported effects of Bt cotton in India largely vary due to the large heterogeneity of the growing environment, pest pressures, farmer practice and the social context. Second, they show that there is a polarization of views on the effects of Bt cotton, which may be reflected in some of the reported studies from groups that are vocally proponent or opponent to the technology. Third, Smale et al. (2006) emphasize the observed importance of the host germplasm in the literature in determining the effectiveness of Bt cotton.

These three factors, together with the presence of unofficial varieties, the data used and methodology employed, provide a very convincing explanation of the observed findings of existing studies. In particular, the results widely change across studies according to the season and location (Qaim et al. 2006), type of data and type of analysis (Smale, Zambrano, and Cartel 2006), varieties of Bt and non-Bt cotton compared (Morse, Bennett, and Ismael 2007; Naik, Qaim, and Zilberman 2005), and whether the Bt variety is official or not (Bennett, Ismael, and Morse 2005). Even if most published studies show that Bt cotton resulted in significant income gains in average, certain studies report significant losses with Bt cotton varieties in particular regions and seasons. The overall conclusion from the literature is that the gains of Bt cotton cannot be generalized to all farmers, all state and all years. This inconsistency in the results surely played a role to fuel the controversy over the use of Bt cotton and its benefit for Indian farmers.

We summarize the methods, data and results of each distinct study we gathered in Table A2 in the appendix. Because several research teams used the same data in different papers, we differentiate the groups of studies by their source of data rather than papers. Table A2 shows that the location, season, sample, methods and varieties largely varied across studies, and so did the results. But it also shows a clear converging trend from contradictory results to consistent results. The first published studies showed extremely different results. On the one hand, the study of field trials in multiple states (Qaim and Zilberman 2003) obtained very large and positive results. On the other hand, the study led by two non-governmental organizations in certain districts of Andhra Pradesh obtained very large negative results (Qayum and Sakkhari 2003; Sahai and Rahman 2003).

Later, a number of studies (e.g., Bennett et al. 2004) by academic researchers showed relatively more moderate effects with the use of Bt cotton. And a number of more recent studies focus on explaining the original observed discrepancy. Bennett et al (2005) analyze the effect of varietal differences to show that the host germplasm played a very significant role in the contrasting results. They further show the difference in productivity with official versus unofficial varieties, and the better outcome obtained with F1 compared to F2 varieties. Orphal (2005) shows that Bt cotton varieties performed better under irrigated condition that under rainfed conditions. Naik, Qaim and Zilberman (2005) and Qaim et al. (2006) show the role of different varieties in terms of the seedcotton quality and local conditions. If the

Mahyco Bt varieties have the same ginning ratio than non-Bt varieties, their staple has a smaller length than the one of Bunny, one of the most popular cotton varieties in India (not available with the Bt trait until 2006), therefore resulting in lower output prices in some locations. Their results also show that Bt cotton has been very effective in Tamil Nadu, Karnataka and Maharasthra, but that it failed in Andhra Pradesh, in part because a limited yield potential as the growers used relatively more pesticides for cotton combined with a high cost of seeds, and because the available Bt varieties were not suited to the local conditions. Lastly, Morse et al. (2007a) explain the effects of Bt cotton adoption in terms of inequality: they show that adopting Bt cotton resulted in less inequality among growers using it, but that it did increase the inequality with the non-adopters.

In sum, these latter studies use empirical analysis to show that there was no real controversy on the effects of Bt cotton in India, because the variability in results can be explained based on tangible factors. The loss observed in some studies is largely due to the lack of adequate Bt varieties (particularly for rainfed conditions under drought), the lower quality of cotton with some of these varieties, the high price of seeds compensating for the reduction in pesticide costs, and the improper use of the technology associated with the low knowledge of the technology among farmers (e.g., use of wrong variety, pesticide use and perception of Bt as a “silver bullet” by cotton growers). In other words, the technology, represented by the Bt trait, should not be blamed, instead, it is the conditions in which it was introduced, sold, and used that would explain some of the observed losses in specific regions of India.[5] At the same time, taken together, these later studies show that despite all these constraints, in average, a large majority of Indian farmers gained significantly by adopting Bt cotton varieties in most locations and seasons.

To confirm or infirm this last conclusion, we conducted a simplified meta-analysis of Bt cotton effects in India. Using all the studies described in Table A2 all from 2002/03 to 2004/05,[6] we collected the estimated average effects with Bt cotton and obtained a pool of

[5] Pemsl et al. (2004) report that there has been some inconsistency in the expression of the Bt toxins by Bt varieties, meaning that the technology could be improved. But their results do not as such discredit the ones of larger empirical surveys on the reported positive and significant effects of Bt cotton in damage control in most locations.

[6] By restricting our analysis to 2002/03-2004/05, we excluded the results of studies from field trials before 2002, that tend to be overestimating the effects of Bt cotton, and those from ASSOCHAM-IMRB International (2007), who report results from a survey conducted in 2006/07, notably because it has a much larger sample of varieties

estimate of the relative technology effects by state and season. Because all studies were not subject to the same quality checking, we first compared the average effects from all studies with the average effects only based on published peer reviewed studies (using more rigorous sampling and analytical methods). Table 9 and Figure 10 show the average effects of Bt cotton and the weighted average effects of Bt cotton accounting for the number of plots for these two groups of studies. We find that the differences across average estimates do not

Figure 10. Results of the meta- analysis: Average economic effects of Bt cotton compared to non-Bt cotton in India (2002/03-2004/05)

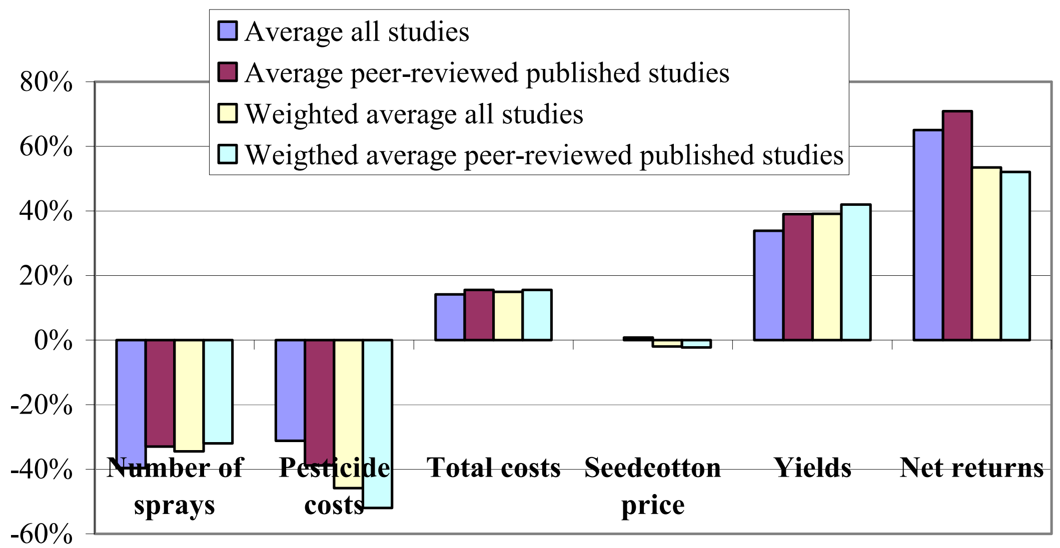


Table 9. Average effects of Bt cotton compared to non-Bt cotton in India based on all farm level studies and only on peer-reviewed published studies.

		Pesticide use	Pesticide costs	Total costs	Seedcotton price	Yields	Net returns
All studies	Number of points	22	27	31	27	36	31
	Average	-39.6%*	-31.2%*	14.2%*	0.0%	33.8%*	65.1%*
	Number of plots	11136	12699	12931	12179	13686	12931
	Weighted average	-34.4%	-45.8%	15.0%	-2.0%	39.1%	53.5%
Peer reviewed studies	Number of points	14	18	20	18	20	20
	Average	-33.0%*	-38.8%*	15.5%*	0.8%	39.1%*	70.9%*
	Number of plots	9731	10357	10589	10357	10589	10589
	Weighted average	-32.0%	-52.0%	15.5%	-2.3%	42.0%	52.1%

* Significantly different from zero at the 5% level.

than all previous studies, and that it includes the first results with Bt II (Bollgard II), a recently introduced more efficient Bt cotton in some of the states.

differ that much. As shown in the table and in the figure, according to these empirical studies, in average, Bt cotton reduces the number of pesticide sprays by 32-40%, it reduces pesticide costs by 30-50%, it increases the total costs of production by about 15%, it has no clear effect on seedcotton price, increases yields by 33-42%, and raises net returns by 52-71%. By deriving standard deviations among studies, we also compared our average results to zero, and find that all the point average effects except seedcotton price are significantly different from zero. Because the results obtained with only the peer-reviewed studies do not seem to stand out significantly from the more inclusive general average, and in an effort of inclusiveness, we decided to use the latter for the rest of this section.

It is important to note that a significant caveat of these results, is that not only do studies not share their methodology (e.g., only a few provide regression estimates of effects), but that virtually all studies, whether peer-reviewed or not, do not make any effort to correct for the potential presence of self-selection bias (Crost et al. 2007, Morse et al. 2007b). Because adoption is a non-randomized process, Bt cotton adopters may be more productive farmers than non-adopters, and neglecting this fact could result in overestimating the actual net effect of Bt cotton compared to non-Bt cotton. Indeed, Crost et al. (2007) and Morse et al. (2007b) show that this bias may be serious in certain cases. Crost et al. (2007) use a fixed effect model on survey data collected in Maharashtra (and analyzed in Morse et al. (2007a)), and find that, by accounting for the endogenous choice in varieties, the net yield effect of Bt cotton, although still positive, is divided by three (from +92% to +31%) with the proper correction. This suggests that the results presented here may be higher than what the real net effects of Bt cotton may be. Yet, at the same time, ASSOCHAM (2007) used a large sample of Bt and non-Bt farmers (9361) in 460 villages located in eight Indian states and selected using a multi-criteria matching process based on 2001 census data (i.e., before adoption of Bt cotton), and show that in 2006, Bt and non-Bt farmers shared many similar socio-economic characteristics (including their plot size and use of irrigation, among others). This suggests that these biases may not be that significant in all parts of India.

With this and other potential limitations in mind, we believe that these general results based on field observations are important and unlikely to be qualitatively reversed even with the proper correction. Bt cotton appears to be an expensive technology, raising the overall production costs, that is still successful overall in increasing returns to farmers. On the one hand, it confirms what has been observed at the macro level: since the introduction of Bt cotton, average national yields in India have reached a record high level, exceeding 400kg/ha and probably 500kg/ha for the first time in history, and national cotton acreage has remained very high despite relatively low prices. On the other hand, these numbers are estimated averages of averages; they do not provide a valid description of the overall variance across states. In particular, more studies have been conducted in Maharashtra than in other states of India. Moreover, the first studies looked at field trials, and limited areas of adoption.

As a step further, we separated the average results by state and season. The average effects of Bt cotton by state computed across studies are shown in Table 10, the weighted average statewide effects by plots are shown in Table 11, and the average effects by season

Table 10. Average effects of Bt cotton relative to non-Bt cotton based on all farm level studies by State

State	Number of estimates	Pesticide use	Pesticide costs	Total costs	Seedcotton price	Yields	Net returns
Andhra Pradesh	10	-41.7%	-14.7%*	12.4%*	-3.3%	12.0%	27.1%
Gujarat	6	-39.5%*	-34.7%*	7.1%*	2.9%*	32.6%*	72.8%*
Madhya Pradesh	2	-72.0%	n.a.	n.a	n.a	78.0%	n.a.
Maharashtra	14	-33.2%	-35.5%*	17.8%*	-1.9%	45.8%*	62.2%*
Karnataka	4	-40.5%*	-40.7%	20.0%*	1.8%	38.5%	56.0%
Tamil Nadu	2	-54.0%	-64.0%	9.5%	6.5%	36.0%	196.5%
Average- all samples		-39.6%*	-31.2%*	14.2%*	0.0%	33.8%*	65.1%*

* Significantly different from zero at the 5% level.

Table 11.Weighted average of the effects of Bt cotton relative to non-Bt cotton by state using numbers of plots

State	Number of plots	Pesticide use	Pesticide costs	Total costs	Seedcotton price	Yields	Net returns
Andhra Pradesh	2141	-43.5%	-14.9%	13.2%	-1.7%	17.6%	40.4%
Gujarat	984	-39.8%	-41.9%	6.9%	2.1%	48.2%	85.3%
Madhya Pradesh	178	-72.0%	n.a.	n.a	n.a	72.0%	n.a.
Maharashtra	9925	-32.5%	-51.9%	15.6%	-2.8%	42.7%	49.3%
Karnataka	472	-44.3%	-46.9%	17.7%	-2.4%	45.0%	59.0%
Tamil Nadu	221	-40.8%	-58.3%	12.3%	9.3%	31.6%	176.1%
Average- all samples		-34.4%	-45.8%	15.0%	-2.0%	39.1%	53.5%

Table 12. Average studies' effects of Bt cotton compared to non-Bt cotton by season

Season	Number of estimates	Pesticide use	Pesticide costs	Total costs	Seedcotton price	Yields	Net returns
2002/03	16	-44.1%*	-42.4%*	16.6%*	-1.1%	36.6%*	53.1%
2003/04	12	-27.6%	-27.7%*	13.9%*	1.1%	35.1%*	56.8%*
2004/05	8	-38.7%*	-22.0%*	11.2%*	0.2%	26.5%*	94.0%
Average all samples		-39.6%*	-31.2%*	14.2%*	0.0%	33.8%*	65.1%*

* Significantly different from zero at the 5% level.

are shown in Table 12.

The results in these three tables show that surveyed states may be divided into three groups. In the first group of states, including Gujarat, Madhya Pradesh (with limited results) and Tamil Nadu (with limited points, the results being insignificant), Bt cotton seems to be very successful, with relatively high cost reduction effects, high yields, positive relative prices of Bt seedcotton, resulting in a large rise in gross margins. In the second group, including Maharastra and Karnataka (although for the latter, yield and returns effects are insignificant), Bt cotton is associated with relatively higher costs of production, potentially lower cotton prices but still a very large yield increase resulting in significant net income gains. The third group is represented by Andhra Pradesh, where Bt cotton did not reduce pesticide costs much, and had negative but insignificant effect on price, insignificant positive effect on yields and net returns.

The results separated by growing season are less variable. Table 12 shows that with increased adoption, the reported average effects of Bt cotton have been decreasing in absolute value overtime, even as the average net returns from the technology increased. Bt cotton has resulted lower pesticide cost reduction effect overtime, but the total cost of Bt cotton also decreased. The average yield effect was reduced from 36% to 26%, yet the net return from Bt increased from +53% to 94%. However it is important to note that if the pesticide cost, total cost and yield effects were significantly different from zero ever year, the net return effect was only significantly positive in 2003/04, which implies that there was a large variance in net income effects with Bt cotton across studies in 2002/03 and 2004/05, 2002 and 2004 being two years that correspond to peaks in suicides in Andhra Pradesh and Maharashtra.

Because the largest variances across results are reported in Andhra Pradesh, Maharashtra and Karnataka, three suicide-prone states, we separated the results obtained for these three states in Table 13. We show the different results by season of studies and the minimum, median and maximum effects observed in these three states. The case of Andhra Pradesh shows a relative increase in net returns overtime, from negative to positive, apparently due to better average yield effects in 2004/05 than in the previous two years. Sahai and Rahman (2004) argued that cotton growers progressively replaced the use of MECH varieties (the official Bt varieties of Monsanto-Mahyco) by Navbharat unofficial varieties, who may have performed better with the local condition, but also whose seeds cost relatively less than official varieties. It may also be due to an abandonment of the technology; the largest losers probably did not purchase the same Bt seeds a second season in a row. If it is the case, only the ones who did not incur losses and potentially gained from it would purchase Bt varieties again.

Table 13. Detailed analysis of average effects of Bt cotton relative to non-Bt cotton in Andhra Pradesh, Maharashtra, and Karnataka

	Pesticide use	Pesticide costs	Total costs	Price cotton	Yields	Net returns
Andhra Pradesh						
2002/03	-39.0%	-10.5%	12.0%	-2.2%	1.3%	-58.0%
2003/04	n.a.	-14.5%	14.5%	-10.0%	-5.6%	-38.0%
2004/05	-41.7%	-14.7%*	12.4%*	-3.3%	12.0%	27.1%
Minimum	-57.0%	-28.0%	5.0%	-10.0%	-35.0%	-142.0%
Median	-47.0%	-17.0%	13.0%	-3.0%	4.2%	-9.0%
Maximum	-21.0%	-2.0%	21.0%	2.3%	46.0%	380.0%
Average studies	-41.7%	-14.7%*	12.4%*	-3.3%	12.0%	27.1%
Weighted average	-43.5%	-14.9%	13.2%	-1.7%	17.6%	40.4%
Maharashtra						
2002/03	-38.2%*	-52.0%*	18.8%*	-3.6%	44.8%*	60.6%*
2003/04	-27.6%	-26.8%	19.3%*	-0.7%	50.2%*	61.1%*
2004/05	-36.0%	-21.0%	3.0%	-3.0%	21.0%	78.0%
Minimum	-64.0%	-61.0%	-4.0%	-11.0%	18.0%	14.0%
Median	-38.5%	-48.0%	16.0%	-0.1%	48.5%	78.0%
Maximum	31.0%	17.0%	49.0%	3.0%	84.0%	112.0%
Average studies	-33.2%	-35.5%*	17.8%*	-1.9%	45.8%*	62.2%*
Weighted average	-34.4%	-45.8%	15.0%	-2.0%	39.1%	53.5%
Karnataka						
2002/03	-40.5%*	-40.7%	20.0%*	1.8%	38.5%	56.0%
Minimum	-61.0%	-55.0%	13.0%	-7.5%	-3.0%	-30.0%
Median	-37.0%	-49.0%	19.0%	-4.0%	42.0%	26.0%
Maximum	-27.0%	-18.0%	28.0%	17.0%	73.0%	172.0%
Average studies	-40.5%*	-40.7%	20.0%*	1.8%	38.5%	56.0%
Weighted average	-44.3%	-46.9%	17.7%	-2.4%	45.0%	59.0%

* Significantly different from zero at the 5% level.

The results in Andhra Pradesh also show a large variance in the estimated effects of Bt cotton across studies. First, total cost of production effects range from 5 to 21% while seedcotton price decrease by up to 10%, but both remain within a reasonable range. In contrast, yield effects with Bt cotton range from –35% to +46% and net returns effects present enormous differences across studies from –142% to +380%. The negative estimates were particularly large in non-government organization studies conducted in study areas known to have had difficulties with Bt cotton. In any case, this observed variance explains why neither average yields, nor average net returns effects are significant.

Results obtained in the state of Maharashtra, the second suicide prone area, are more consistent across studies. It is the state with the largest number of studies and the largest number of plots surveyed. Average effects in the three seasons reported are qualitatively similar, even if 2004/05 shows lower yield effects which is compensated by much lower total cost effects. Yields and net return effects appear to be positive in all studies, but there is more variance on cost effects. Overall, the general tendency observed for Maharashtra seems to be similar to the one observed for all India.

In the case of Karnataka, only one year was covered by our set of studies. The range of estimates vary less than for Andhra Pradesh but we still find changes of signs for the effects of Bt cotton in terms of seedcotton price (from –7.5% to +17%), yields (from –3% to 73%) and net returns (from –30% to 172%). In average, these latter two are positive (even with weighted averages), but it is clear that the discrepancy across results during the same season shows that the Bt cotton varieties adopted in theses states had various effects on cotton productivity and farm income.

4.e. *The Indian Government's assessment of Bt cotton in India*

The conclusions from our literature review are largely consistent with the Government of India's own assessment of Bt cotton in the country. The overall status report on the performance of Bt cotton by the Central Institute for Cotton Research credited the technology for the observed increase in yields of cotton in India. The report enumerated that Bt cotton cultivation increased yields in most areas in India and at the same time reduced pesticide sprays (Mayee, 2003). The combined cost savings from reduced pesticide use and increased yields has thus increased profits for farmers. It also explains that Bt cotton worked well in irrigated areas (Gujarat) and that the problem of wilting found in many Central Indian states like Madhya Pradesh, Maharashtra and Andhra Pradesh was the result of physiological stress on the plant due to less moisture during dry spells. The incidence of bollworms were low across both Bt and non-Bt varieties, hence distinction could not be made. Bt cotton had more number of balls per tree but the size of the balls was often smaller than the traditional variety.

The report did argue that the farmers in most states were not educated regarding the Bt technology, which was the main factor explaining crop losses (Mayee, 2003).

State government reports, on the other hand, are often more critical of the technology and the surveys in 2002 both in Andhra Pradesh and Maharashtra show that the Bt cotton hybrids performed rather poorly compared to the non-Bt popular hybrids. In Andhra Pradesh, especially in Warangal district, the performance of Bt cotton was particularly poor, consistent with the conclusion of the economic literature. According to the Bt cotton farmers surveyed there, yields were less than the traditional hybrids and the incidence of bollworm was also higher. The quality of produce was relatively low, which resulted in lower market value for the crop (Govt. of Andhra Pradesh, 2002).

The situations improved later, according to a 2006 report by the Government of India, on Bt cotton and related issues, based on a season with no sale of Mahyco seeds in the state.[7] The new varieties sold were RCH-2Bt and RCH-20 Bt from Rassi Seeds, Pro Agro 368 Bt Pro Agro and NCS-145 and NCS- 207 by Nuziveedu Seeds. The incidence of spurious seeds was a significant concern as that had resulted in crop loss for many farmers in the state in previous years. Among other things, the recent report noted: a) the higher yield for Bt varieties (10-15 Quintals compared to 8-10 Quintals) depending on soil type and climatic conditions, b) the lower cost of cultivation with Bt, c) the better quality of Kapas (size of balls) in Bt cotton compared to non-Bt, e) the maximum retail price decrease to Rs 600-700.

In Maharashtra the state reports followed a similar trend between 2002-03 and 2005-06. In this state almost 97% of cotton is grown under rainfed conditions. In 2002-03, the Bt cotton hybrids could not match up in performance with the popular local hybrids NCS-145 (Bunny), Ankur 651, Brahma and Paras. There were complaints of wilting which is a characteristic of a particular hybrid and is not a pathogenic condition. Pest infestation was similar across Bt and non-Bt varieties though incidence of bollworm was marginally less in Bt cotton plants. Yield increases of Bt over non-Bt was between 16-60%.

In 2004-05, Bt cotton performed quite well in most districts in Maharashtra. No significant difference between plant heights was observed. There was moderate to heavy infestation of sucking pests in both Bt and non-Bt cotton plants. This required an average of

[7] In 2005/06, in response to farmer complains, the sale of Mahyco Bt cotton hybrid seeds was prohibited in Andhra Pradesh.

5-6 sprayings in non-Bt hybrids and 2-3 sprayings in Bt hybrids. The yield of Bt cotton, too, was higher than that of non-Bt hybrids. Bt cotton yields varied between 1510 – 2498 kg/ha (as shown in Table 14) while that of non-Bt hybrid ranged between 962.16 – 1979 kg/ha. As the table shows, Bt cotton yields were also higher in all divisions compared to the non-Bt hybrids.

Table 14. Yield comparison between Bt and non-Bt Cotton in Maharashtra, 2004-05

Name of Division	Total Yield in 4 Pickings: Bt Cotton (% change from 2002-03)	Total Yield in 4 Pickings: Non-Bt Cotton
Nasik	1510 (-30.9%)	1375
Aurangabad	1686 (-2.9%)	962.16
Latur	1853 ((108%)	1606
Amravati	2449 (187%)	1814
Nagpur	2498 (106%)	1587
Total	9996 (45.4%)	7344.16

Source: Commission of Agriculture, Maharashtra

The performance report in Madhya Pradesh in 2005 also presents a positive effect of Bt cotton in the state. The cost of cultivation for Bt cotton is higher (Rs 22-25,000/ha) to the one obtained with non-Bt hybrid cotton (Rs 18-20,000/ha). At the same time, Bt cotton resulted in higher productivity (20-25 quintals/ha) compared to non-Bt (18-20 quintals/ha). There were much fewer bollworm attacks on Bt cotton, therefore lowering the cost of pesticides. In the end, the Bt cotton farmers earned an additional profit of about Rs 5,000/ha compared to the non-Bt cotton under normal circumstances.

Apart from that, there was widespread news of wilting among Bt cotton in Dhar and Barwani districts in Madhya Pradesh. Bt cotton was susceptible to the phenomenon called “New Wilt”, a physiological disorder likely due to the change in agro-climatic conditions. It was particularly evident in Bt crops sown before the onset of the monsoons. The affected fields had light and shallow soils. This caused low moisture retention in the soil and thus the plants underwent moisture stress. Moreover, Bt plants are more prone to this stress because they have greater number of open balls at the time of the “Wilt” compared to the non-Bt plants. This increased moisture requirements for the Bt cotton plants.

5. Farmer Suicides: the elusive role of Bt cotton in the confluence of other factors

Many reports and studies have been written on the cause of farmer suicides in India. Although some focus on purely agricultural matters, others have taken a broader view relating the suicides as an indicator of a more systemic problem in agriculture and society, especially in the central and Southern states we focus on.

In the conclusion of his report on farmer suicides in India, Nagaraj (2008) explains that “mono-causal explanation for farmer suicides would be totally inadequate”. Instead Nagaraj argues that a complex set of socio-economic factors likely play a role. Our own review of the literature confirms this conclusion; there is no single explanation, or even consistent explanations across reported cases. However, one leading factor seems to connect several other causes particularly related to agriculture: the heavy indebtedness of farm households particularly in the suicide prone states.

Analyzing the social roots of suicides, Durkheim distinguished between egoistic, anomic, altruistic, and fatalistic suicides. These broad classifications reflect the then-prevailing theories of human behavior. Dismissing altruistic and fatalistic suicide as unimportant, he viewed egoistic suicide as a consequence of the deterioration of social and familial bonds and linked anomic suicide to disillusionment and disappointment (Durkheim, 1951). A modern perspective views the “*phenomenon of suicides as a result of an individual’s inability to cope with sudden and cataclysmic change in socio-economic conditions”* (Sridhar, 2006). Both views draw attention to the fact that suicides are not just an act of insanity, but is often caused and conditioned by social factors. Social facts, which are external to, yet constraining on the individual, regulate human social actions and acts as a constraint over human behavior. In the case of the Indian farmer, indebtedness from repeated crop loss, fall in social status due to loss of income and the inability to maintain the same level of expenditure were characteristic signs of anomic suicide. This coupled with hopelessness of any possible improvements in the situation played a role in encouraging suicide as the only possibly solution to redeem oneself from social disgrace.

Causes of indebtedness include changes in cropping patterns, resistance to pesticides, and hence increased spending on pesticides, involving a shift from low-cost food crops to high-cost cash crops, lack of access to institutional credit and also a shift of government policy focus away from agriculture.

Indebtedness among rural households in India is not a new phenomenon. What is new, however, is the nature of the debts and the pattern of high cost agriculture which farmers engage in, with the hopes of making it debt-free if the harvest is sufficient. This phenomenon of “going for broke and losing out” is likely related to the increased instances of suicides among farm households. Table 15 shows the level of indebtedness by households in four states of India.

Table 15. Indebtedness of farmer households

Indicators	**Maharashtra**	**Andhra Pradesh**	**Kerala**	**Punjab**	**All India**
Percent of farmers HHs among rural HHs.	55.7	42.3	43.9	61.8	60.4
Percent of farmers HHs Indebted.	54.8	82.0	64.4	65.4	48.6
Percent of farmers HHs with cultivation as main income.	57.9	53.7	16.8	45.6	57.2
Percent of indebted farmers HHs with cultivation as main income.	62.6	54.4	14.4	52.7	56.9
Percent of indebted farmers HHs, land less <1 hector.	36.0	55.7	87.7	53.3	61.0
Percent of indebted farmers HHs, land 1-2 hectors.	26.2	21.8	9.1	15.8	18.9
Percent of indebted farmers HHs, land > 2 hectors.	37.9	22.4	3.2	31.0	20.1
Percent of farmers HHs taken loan for farming activities.	75.4	61.5	21.4	62.4	58.4
Percent of farmers HHs taken loan form Government.	1.2	1.0	4.9	1.9	2.5
Percent of farmers HHs taken loan form cooperative societies.	48.5	10.4	28.3	17.6	19.6
Percent of farmers HHs taken loan form bank.	34.1	20.0	49.1	28.4	35.6
Percent of farmers HHs taken loan form moneylenders.	6.8	53.4	7.4	36.3	25.7
Percent of farmers HHs taken loan form other sources.	9.4	15.1	10.2	15.8	16.7

Note: - HHs indicates Households.
Source: - *Situation Assessment Survey of Farmers: Indebtedness of Farmers Households: NSS 59th round (January- December 2003)* National Sample Survey Organization, Report No. 498 (59/33/1), May 2005.

According to these data, the percentage of farm households in Maharashtra who are indebted is higher in the class which owns less than one hectare of land and also among those that own greater than two hectares (36% and 37.9% respectively). Comparatively, in Andhra Pradesh indebtedness is definitely higher among the small and marginal farmers who own less than one hectare of land (55.7%). It is also clear from the table that in Andhra Pradesh, the main source of loans was private money lenders (53.4%) while cooperative societies (48.5%) were the main source for Maharashtra. Until recently government contributed a minimal amount towards farming loans in both states. The increasing dependence on local moneylenders and other private sources for crop loans meant that the rate of interest was high thus resulting in greater indebtedness with crop failures.

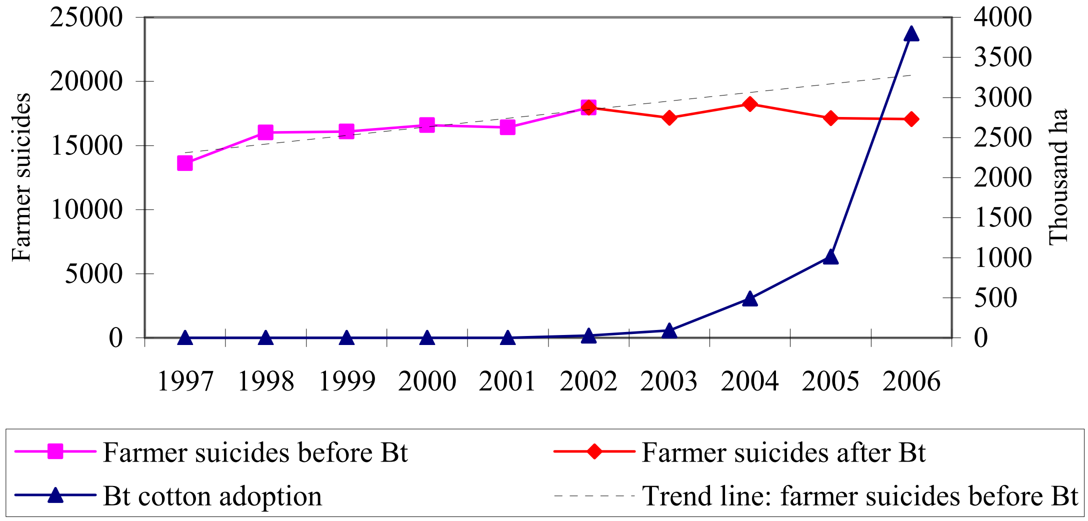
The alleged potential link between farmer suicides and Bt cotton is based on the assertion that it may have contributed to higher costs of production and to crop failures, both increasing the chance of increased indebtedness and therefore likelihood of suicides. In the next subsection we specifically look at the evidence on the possible relationship between Bt cotton and farmer suicides. In the subsequent subsections we then enumerate more general factors that have been reported to be causal factors of indebtedness and/or farmer suicides.

5.a Empirical evidence on the possible direct role of Bt cotton

First and foremost, it should be noted that none of the reported data sources on farmer suicide provides the concerned farmers' characteristics. In particular, there are no numbers on the actual shares of farmers committing suicides that had been cultivating cotton, let alone the proportion of them that were cultivating Bt cotton and among them, those that would have committed suicide because of a potential failure of their Bt cotton crop. In particular districts, some qualitative evidence has been presented, based on reported stories of farmers including some cultivating cotton, but the core of the support to the argumentations have been based on hypothetical links, not quantitative evidence.

In the absence of such data, we can only provide a second best assessment of the evidence. With assembled empirical evidence on farmer suicides on the one hand and the effects of Bt cotton on the other, we can try and evaluate the possible (and hypothetical) role Bt cotton may have had in this process. We start by looking at a potential relationship at the aggregate level. In Figure 11, we combined data on the adoption of Bt cotton with the numbers of farmer suicides at the national level between 1997 and 2006. We use this figure to compare the trend in farmer suicides with the spread of Bt cotton in the country.

Figure 11. Farmer suicides and Bt cotton area in India (1997-2006)

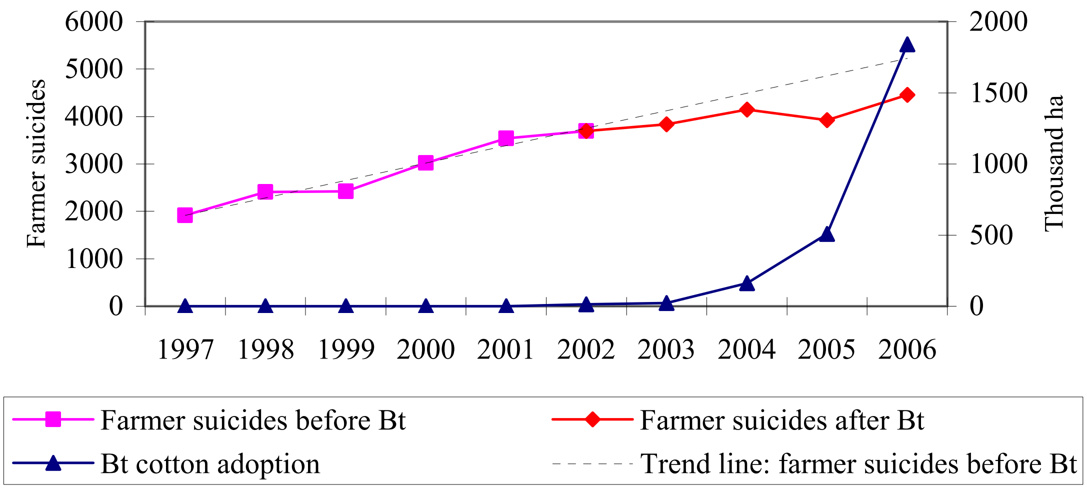


Source: Combined from Table 2 and Table 7.

Figure 11 provides three very clear conclusions: a) there is no observed correspondence (or causality) between the national Bt cotton adoption rate and the farmer suicides, b) the annual growth in suicides actually diminishes after the introduction of Bt cotton, c) the two relative recent peaks in farmer suicides in 2002 and 2004 happened during years with very limited adoption of Bt cotton, while the largest increase in adoption happened during years with reduced suicides.

However, as in the case of suicide numbers, these aggregate results may not stand at a lower spatial level. We provide similar figures for Maharashtra (Figure 12), Andhra Pradesh (Figure 13), and in the appendix Madhya Pradesh (Figure A1), Karnataka (Figure A2) and other states (Figure A3).

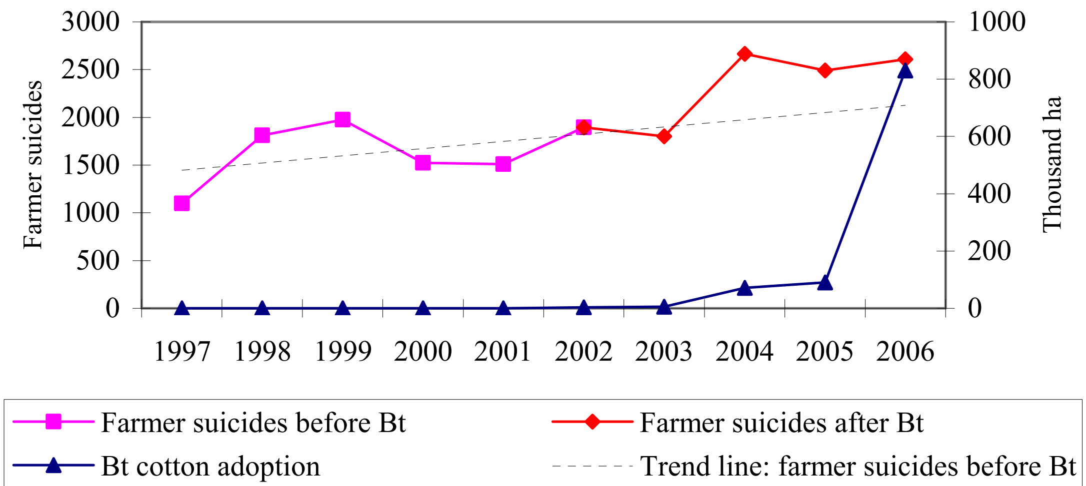
Figure 12. Farmer suicides and Bt cotton area in Maharashtra (1997-2006)



Source: Combined from Table 2 and Table 7.

In the case of Maharashtra (Figure 12), the combination of suicide and adoption rates leads to very similar conclusions. As observed in the case of cotton and Bt cotton data, Maharashtra tends to be a good proxy for what happened at the aggregate national level, notably because of its important cotton sector. Figure 12 clearly shows that the growth in farm suicides in this state started much before Bt cotton, and actually slowed down in the years after the introduction of Bt cotton. Even the relative peaks in suicides observed in 2004 and then in 2006 lie under the projected trend line from1997-2002. Overall, at this level of analysis, all other things being equal, it is clear that the overall adoption of this technology was not a driver of suicide growth; in fact it may even have contributed to slowing the process.

Figure 13. Farmer suicides and Bt cotton area in Andhra Pradesh (1997-2006)



Source: Combined from Table 2 and Table 7.

The case of Andhra Pradesh (Figure 13) is more ambiguous, because the farmer suicide numbers seem to have followed a much less regular (and less linear) pattern during the whole period. The linear trend of suicides before Bt shows that there might have been a faster rate of suicides during the seasons after the introduction of Bt cotton compared to before Bt cotton. Based on this sole evidence, we cannot reject a possible partial correlation between Bt cotton adoption on suicide growth, even if overall, there was many farmer suicides and a clear increasing pattern much before Bt cotton was introduced (so the effect would be marginal). The last three years of data are quite high. The year 2004 stands out as a peak in the suicides as noted before. Of course, that year, Bt cotton had only been partially adopted. The much larger acceleration in adoption rate of Bt cotton the following two years corresponded only to limited negative and positive relative changes in suicide rates in Andhra Pradesh.

A rapid overview of the same figures for the other states (presented in appendix Figures A1 to A4) show that Bt cotton adoption happened simultaneously with a clear decrease (Karnataka and Madhya Pradesh) or stagnation (Gujarat and other states aggregated) in farmer suicides. The case of Gujarat (shown in Figure A3) is particularly interesting as it provides another piece of evidence on the lack of clear general relationship between Bt cotton and farmer suicides. Gujarat shares a number of similarities with the bordering state of Maharashtra including climatic and socio-economic factors. Gujarat happens to be the initial state where Bt cotton was adopted and the third adopter of Bt cotton (behind Maharashtra and Andhra Pradesh) with an area reaching an estimated 470,000 ha (or about 25% of its cotton area) in 2006. Yet at the same time, it also has one of the fewest totals of reported farmer suicides, with a total around 500 per year, or less than 3% of total farmer suicides in the country for an important agricultural state with over 50 millions inhabitants (Census 2001). Nagaraj (2008) classed this state in Group 3, i.e. a Group in which farmer and overall suicides are not prominent or growing.

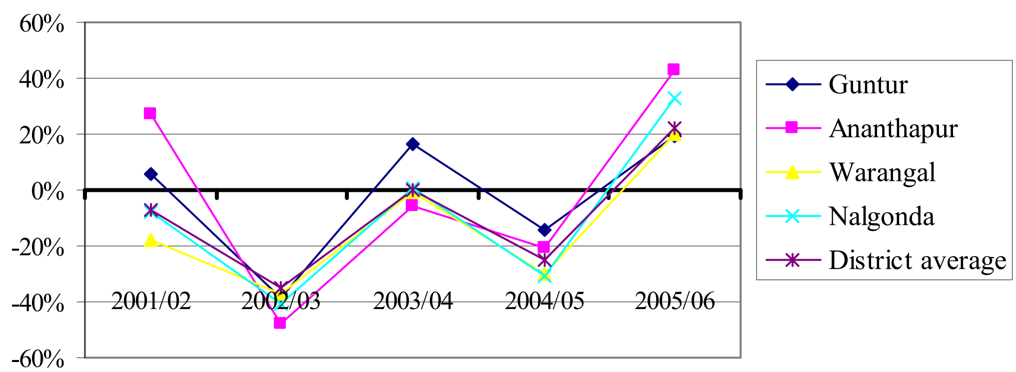
To sum up, with these simple insights, we can already dismiss the possibility of Bt cotton being a necessary or sufficient condition for farmer suicides (confirming hypothesis 2b). It is evident that very high numbers of farmer suicides occurred much before Bt cotton was introduced, and that the introduction of Bt cotton did not result in a clear leap in farmer suicides in India. [8] What we cannot reject, however, is the potential role of Bt cotton varieties in the observed discrete increases of farmer suicides in certain States and years, especially during the peak of 2004 in Andhra Pradesh and Maharashtra.

5.b. Bt cotton and discrete suicide growth in Andhra Pradesh and Maharashtra

In effect, the evidence has shown that Bt cotton was not always effective in theses two states, particularly during the first few years, due to a number of factors, including the use of inadequate varieties and the high prices of seeds. Institutional factors may have played a role, but it is difficult to conceive that they would have been particularly different in a particular season compared to other seasons. In contrast, climatic and economic factors, which are naturally more seasonal, could have contributed to lower yields and/or crop failure and therefore negative net revenues in these particular years.

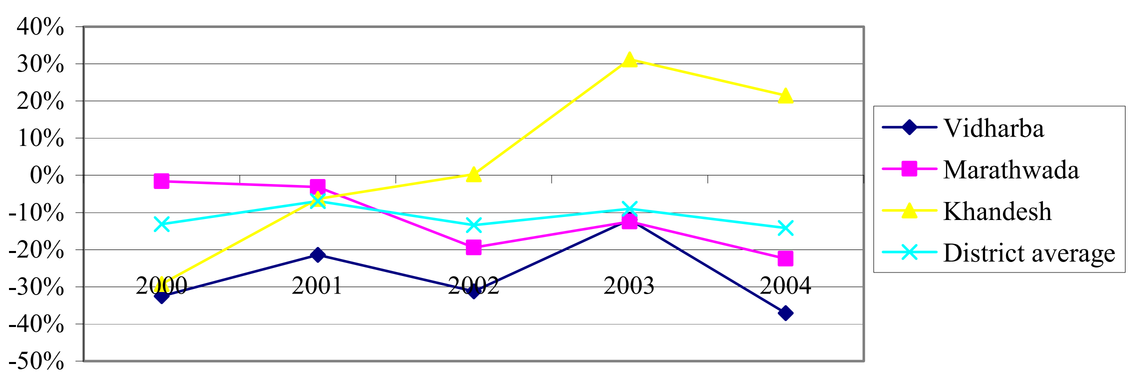
[8] The largest difference in total farmer suicides between 2001 (before Bt) and after 2002 (after Bt) is only 1800, which represents about 11% of the total farmer suicides in 2001. In other words, a minimum 89% share of the total annual cases of farmer suicides was already reported before Bt cotton was even introduced.

Figure 14. Precipitation deviation from norm in four districts and district average for Andhra Pradesh (2001-06)



Source: www.indiastat.com

Figure 15. Average deviation from normal precipitations in three suicide prone regions of Maharasthra, compared to district average (2000-2004)

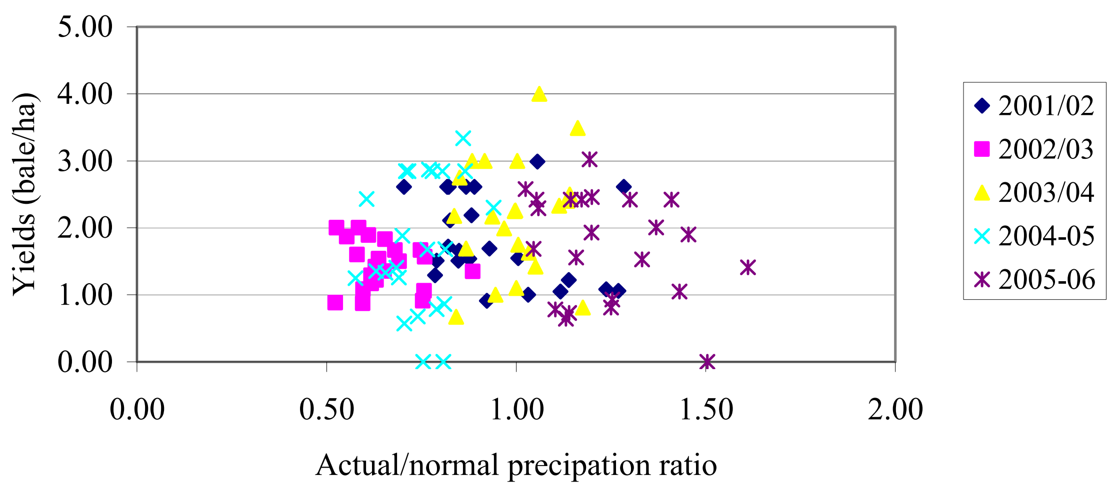


Source: www.indiastat.com

- Dry seasons, low cotton yields

To investigate the possible role of drought we gathered data on precipitation in recent years in Andhra Pradesh and Maharashtra. Figure 14 provides precipitation deviation from normal rainfalls in several suicide prone districts of Andhra Pradesh between 2001 and 2006. It also shows the average across State districts. This figure clearly shows a drop in rainfall in 2002/03 and 2004/05 in these districts and the state as a whole. Figure 15 does the same for three regions that are known to have a high concentration of suicides in Maharashtra from 2000 to 2004 and the State district average. The pattern is less clear, although both the district average and the Vidharba and Marathwada districts reached minimum rainfall compared to the norm in 2002 and 2004.

Figure 16. Precipitation and cotton yields levels in 23 districts of Andhra Pradesh (2001-2004)

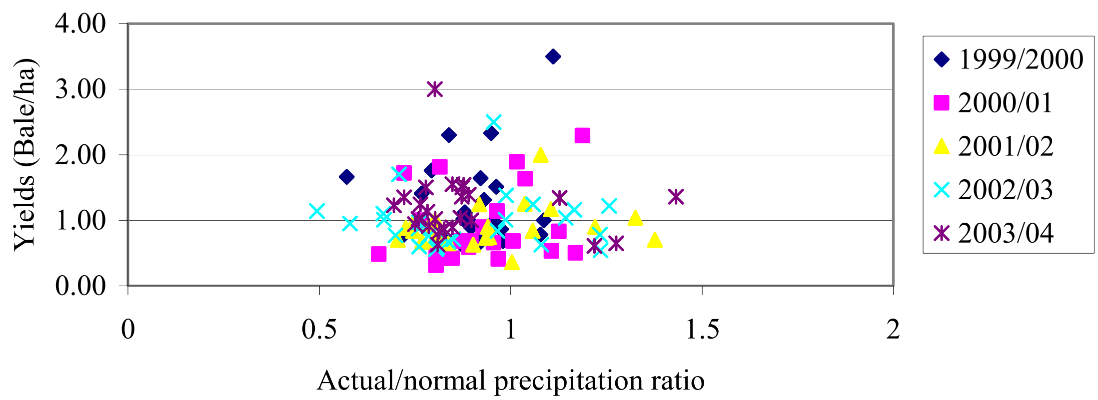


Source: www.indiastat.com, and Agricultural Statistics at a Glance, Government of India 2004.

However these figures only present data derived from annual precipitation which is a poor proxy of drought. Perhaps more importantly, the lack of precipitation does not provide information on the actual crop productivity these particular years. To remedy this latter problem, we gathered district level cotton yield data for the two states in recent years and analyzed their relationship with rainfall data. Figures 16 and 17 plot the possible correspondence between yield levels and actual to normal rainfall ratio per year based on district level data.

Figure 16, depicting the case of Andhra Pradesh, is particularly interesting, because each year seems to follow a different pattern. First, 2001/02 seemed to be an average year, both in terms of yields and rainfalls with some dry districts, other receiving more rain, and a rather even and medium distribution of yield levels across districts, as depicted by a relatively spread cloud of points around the average. In contrast, 2002/03 shows a very homogenous set of points, concentrated in an area in the left of the Figure; this means that all districts were facing low annual precipitations and therefore dry conditions. At the same time, the yield distribution is much more condensed towards relatively low level; 2002/03 was a bad year for cotton in most districts. 2003/04 is more centered toward normal precipitation. But compared to the two earlier years, it presents a very wide range of yield levels across dry or less dry districts (including a record level in one district). This variation cannot be completely explained by precipitations- technology differences may have contributed to this increased variance (e.g., Bt cotton increased inequality between adopters and non-adopters as shown by Morse et al. 2007a). 2004/05 also presents a large variance of yield levels, although it is smaller than the previous year, but it is also located in an area of precipitation clearly lower than the average. It was a rather dry year for many districts, and the highest yields were therefore lower, but it was still a much more productive year than 2002. Lastly 2005/06 present a much higher than normal precipitation rate. The monsoon was particularly strong that year, which may have contributed to the moderate low and high yields observed in different districts.

Figure 17. Cotton yields and precipitation ratio (2000-2004) in 25 districts of Maharashtra



Source: www.indiastat.com, and Agricultural Statistics at a Glance, Government of India 2004.

Unfortunately, the case of Maharashtra is much more obscure. It is very difficult to distinguish any pattern across years on Figure 17. Most points are located to the left of a ratio of 1, meaning that most districts had less than average rainfalls these years, and at relatively low level of yields. Perhaps the only visible feature for seasons before and after 2002 is the widespread rainfall estimates across districts: some having large excesses of rainfalls, other large deficits. Both factors could have contributed to relatively low yields. Unfortunately we did not obtain data for 2004/05 or 2006/07, therefore we cannot conclude on the role of rainfall those particular years.

- Low cotton prices and additional economic issues

There is also evidence that cotton was sold at a low price during these seasons, but the data trend tend to be aggregate and unfortunately incomplete. At the macro level, the Cotlook A index, which provides an index of international cotton prices, did decrease significantly at the end of the 1990s, and reached a minimum in 2001/02 and a second relative minimum in 2004/05 as shown in Table 16. The four listed Indian varieties also did reach a minimum price in 2001/02 and a second relative minimum in 2004/05 (except DCH-32 whose price almost did not change between 2002 and 2005). So if 2002/03 was a particularly dry season in Andhra Pradesh and Maharashtra with low cotton yields in the former, it also followed a record low price year. Combined together, these two successive "bad" seasons bringing low or even negative revenues may have increased farmers' indebtedness significantly. In contrast, 2004/05 was both a low price year and a relatively dry year (at least in Andhra Pradesh) therefore potentially resulting in low or even revenues by cotton farmers in certain districts.

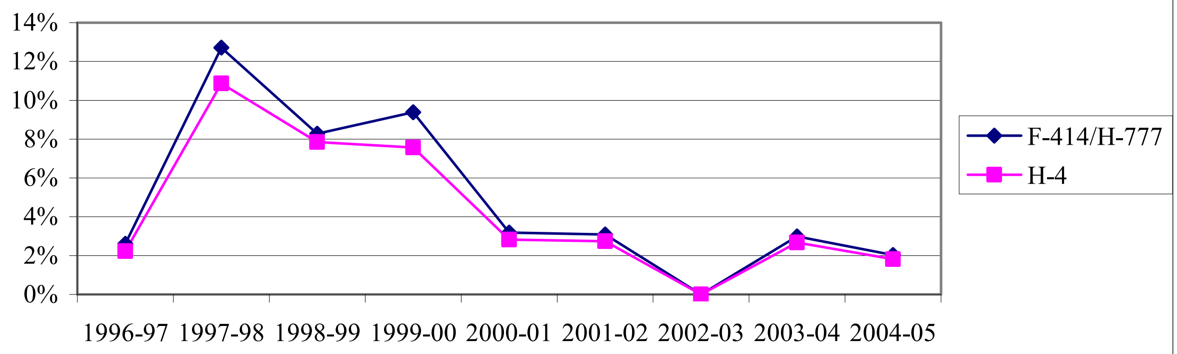
Table 16. International and Indian prices for cotton in recent years

	Cotlook A index	Average annual prices of important cotton varieties in India			
		H-4	**S-6**	**MCU-5**	**DCH-32**
2000-01	57.2	19676	20863	24592	33550
2001-02	41.8	15559	16659	19379	26443
2002-03	55.7	19980	20791	23038	30561
2003-04	69.1	22193	23307	25035	30767
2004-05	53.5	15942	16736	20055	30599
2005-06	57.0	17002	18308	21330	40252

Note: shaded years represent peak suicide years in Andhra Pradesh and Maharashtra.
Source: Cotlook and the Cotton Corporation as cited by Mitra and Shroff (2007).

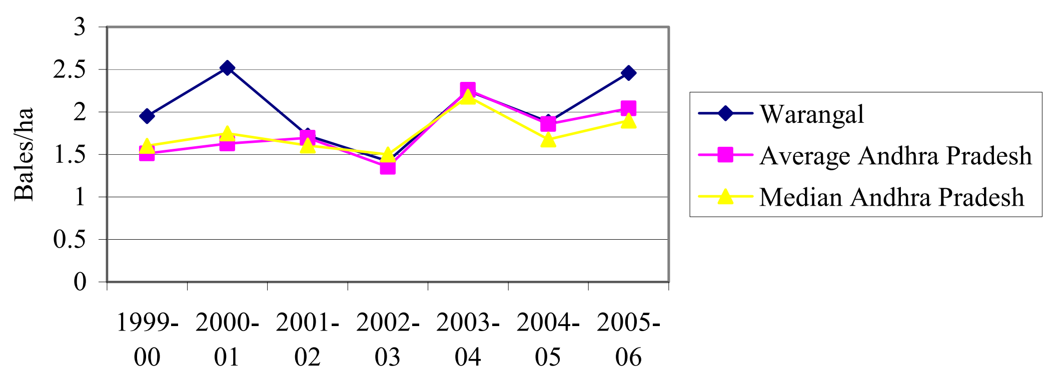
Minimum support prices, which are designed as default prices for farmers unable to sell at the market also did not respond proportionally to these relative lows. Figure 18 shows that the increase in support prices was minimum in 2002/03 and 2004/05. Yet, figures (Indiastat.com) on the cotton volume purchased under the MSP program between 1982 and 2005 reached a clear maximum in the year 2004-05 (with 279000 bales, twice as much as in the former record level in 1985/86).

Figure 18. Annual changes in minimum support price for two popular varieties of cotton (1996-2005)



Source: www.indiastat.com

Figure 19. Yields in Warangal district compared to all district average and median

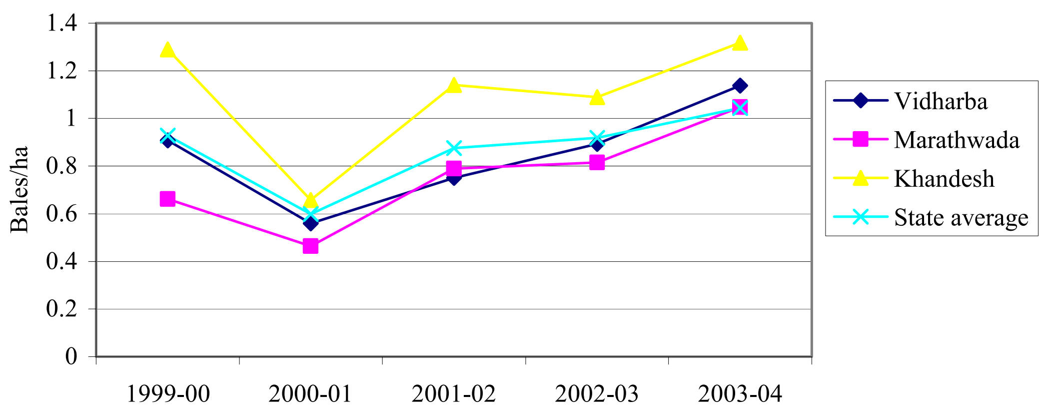


Source: www.indiastat.com

To complete this outlook of economic factors, we use insights from our review of studies conducted on Bt cotton. Once again, the case of Andhra Pradesh seems to stand out. The main talked about suicide area in Andhra Pradesh was the Warangal district, where Bt cotton did not perform well in 2002 (Govt of Andhra Pradesh, 2003), and Figure 19 shows that this district effectively knew a minimum yield level in 2002/03 and a secondary minimum in 2004/05. There have been highly contradicting reports on Bt cotton effects in the Warrangal district the kharif season 2004/05 (Gandhi and Namboodiri 2006, Quayum and

Sakkhari 2005).[9] Still, two recent reports (Ramgopal 2006, Dev and Chandrasekhara, 2007) based on surveys conducted in various cotton districts of Andhra Pradesh during the kharif season 2004/05 found that found average negative returns for cotton during that season. In both cases Bt cotton lead to better yields and net returns than non-Bt cotton, but in one case (Dev and Chandrasekhara, 2007) both Bt and non-Bt lead to average negative net income, while in the other (Ramgopal, 2006) Bt farmers obtained positive net income but non-Bt had negative net income. The main reported reasons for these negative outcomes was said to be the drought and the low average output price that year in the region. These two elements and the conclusions of these reports do collaborate with our data on yields, rainfall, and prices.

Figure 20. Average cotton yields in three suicide prone regions of Maharasthra



Source: Agriculture at a glance, Government of India 2004.

In the case of Maharashtra, economic studies tend to follow the national trend. Despite a large variance across seasons and datasets, all available studies found an advantage for Bt compared to non-Bt, and if there was a multiyear deficit in rainfall, no year seemed to stand out in terms of precipitation. In fact 2004/05 was a peak year for cotton yields according to official data (see Figure 9). The district level yield data we obtained stops in 2003/04, but still showed that despite the lack of precipitation, yield levels increase significantly in the regions said to be suicide prone between 2000/01 and 2003/04 in Maharashtra (see Figure 20). Vidharba, which is arguably the most talked about suicide prone area, actually almost doubled

[9] These contradictions may be explained by the fact that the second cited study only considered the outcome of the inadequate Mahyco varieties of Bt cotton and reported negative results with Bt, while the first included all varieties and obtained high positive results with Bt compared to non-Bt.

its yields during these years. According to the two reports covering that season, Bt cotton performed well in Maharashtra in 2004/05 (Gandhi and Namboodiri, 2006, Govt. of Maharashtra, 2005).

Although we can confer some of these results to our observations on prices, we were not able to find State level or district level price data. Mitra and Shroff (2007) points out to a variety of factors around cotton cultivation, including trade liberalization, leading to low prices, and only the high cost of cultivation is reported to be related to Bt cotton. But as they do not provide any specific data on Bt versus non-Bt, we cannot confirm or infirm any of their conclusions on the possible effect of Bt cotton. The case of 2006/07 is even more difficult to relate to Bt as our only piece of evidence reported record high profits with Bt cotton (ASSOCHAM-IMRB 2007).

To sum up, we have assembled evidence to show that, even if there is no robust quantitative evidence that links Bt cotton adoption to farmer suicides in Maharashtra and Andhra Pradesh, available evidence shows that, in combination with low rainfall, low output prices, inadequate institutional context and inadequate information, cotton in general and Bt cotton in particular could have partially contributed to lower farm revenues, increasing indebtedness and therefore indirectly lead to some possible cases of farmer suicides during the peak suicide years of 2002 and 2004. However, our findings are much more consistent for Andhra Pradesh than for Maharashtra.

We will complete this section by listing a few more significant key factors and trends, that put together, likely contributed to indebtedness leading to farmer suicides in recent years, particularly in the two States we focus on.

5.c. More general factors and trends linked to increased indebtedness

- General changes in cropping pattern towards risky non-food crops

Agriculture in Andhra Pradesh and Maharashtra used to be dominated by rain-fed, low cost food crops and has gradually moved towards cultivation of cash crops. The area under food crops has declined in both states (Mishra, 2006 and Shridhar, 2006). In Maharashtra, cash crops like oilseeds have significantly increased (Mohanty and Shroff, 2004). The comparison of cropping patterns in1958 and 1998 in Andhra Pradesh shows a rising trend towards cash crops like groundnuts and oilseeds. Changes in cropping pattern towards cash crops would not be a concern if the crops had not failed in certain seasons, sinking farmers' investments. With dry conditions and inadequate water irrigation systems in some part of these states, farmers have been pushed towards financial distress.

- Increased dependence on monsoons

Increased area under cash crops was not accompanied by increased irrigation, despite the important water requirements of most of these crops. Crops like sugarcane require a lot of water at the right time to obtain reasonable yields. There is evidence that Bt cotton has performed better under irrigated conditions (Naik et al. 2005). Yet, Bt and non-Bt cotton were reported to have similar irrigation facilities (ASSOCHAM, 2007), and nationally, 66 percent of the area under cotton was cultivated under rain-fed conditions in 2000/01 (Narayanmoorthy and Kalamkar, 2006).

Inadequate water supply has been a problem faced by farmers in Andhra Pradesh for a long time (Govt. of Andhra Pradesh, 2004). Public investment for irrigation has declined in the 1990s and so has the sources for surface irrigation (Shridhar, 2006). Ongoing irrigation projects have stalled due to lack of funding (Govt. of Andhra Pradesh, 2004). Currently, in the state most of the irrigation uses groundwater which greatly decreases the water table (Sridhar, 2006, Narayanmoorthy and Kalamkar, 2006). Surveys conducted on reasons for farmer suicides finds failure of the wells as a major cause of indebtedness among farmers in Andhra Pradesh (Sridhar, 2006). Failure of the wells not only sunk costs in digging it, but also led to loss of the cotton crop, adding to their woes (Govt. of Andhra Pradesh, 2004). In 2004, crop losses in parts of the state were not only confined to cotton, but also to food crops following the delayed release of water from the nearby Nagarjuna Sagar dam (Rao and Suri, 2006).

In Maharashtra, cotton growers are still dependent on the monsoons, as only 6-8 percent of the net sown area is irrigated (Mohanty and Shroff, 2004). In 2004, rainfall was deficient in Amravati, Wardha, Washim and Yavatmal districts but it does not seem to have influenced the production of cotton in the state as a whole (Mishra, 2006).

- Access to Rural Credit

Another factor leading to indebtedness is the lack of access to institutional credit. Most of the farmers who committed suicides in both states have had high unpaid loans. In Maharashtra, the share of total credit utilization going towards agriculture declined from 20.2 to 11.2% from 1991 to 2004 (Mishra, 2006). In Andhra Pradesh, the share of money lenders and other sources as credit agencies going towards agriculture is much higher, reaching around 68% (Mishra, 2006). A survey conducted by the government of Andhra Pradesh showed that 80% of all agricultural loans come from non-institutional sources. The interest rate from these sources is high at 24-36%.[10] In both states, many of the families directly affected by a farmer suicide, whose story was reported in studies or the press, seemed to have accessed local money lenders for credit (Govt. of Andhra Pradesh, 2004). The advent of new technologies, including Bt cotton, or other hybrid crop varieties with high priced inputs like seeds, but also fertilizers and/or pesticides, made seed and pesticide sellers as the new age money lenders (Rao and Suri, 2006). Their high interest rates on loans became a major burden on farmers, particularly when the cash crops failed to give them sufficient returns on the investment.

- Rising cost of cultivation coupled without increased Minimum Support Price (MSP)

Mitra and Shroff (2007) provide evidence of a general increase in cultivation costs particularly in Maharashtra, which was not compensated by low or stagnating prices for cotton, therefore leading to negative net revenues. A survey conducted amongst the household of deceased farmers in Andhra Pradesh in 2003 found the same trend of unrecovered costs incurred in cotton but also in HYV chili cultivation (Rao and Suri, 2006).

Most small and medium farmers sell to the local government procurement centre where the prices have been very low (Dandekar et. al., 2005). However, as shown in Figure 17 in the case of cotton, the Minimum Support Prices (MSP) did not increase as fast as cultivation costs. The Dandekar Report of 2005 claims that crops cultivated in the region were done so at a loss to the farmers. According to this report, between 1996 and 2004, farmers' net loss was around 38% for paddy, around 38% of cotton, 32% for groundnut, 37% for soybeans and 12% for sugarcane.

- Loss of Social Status

While dealing with crop loss, farmers did not have any respite from repayment of the heavy debts they had accumulated. Farmers who committed suicides have consistently been harassed for immediate repayment of loans even after a crop failure (Mishra, 2006). In some cases it led to the selling of land and other assets to repay back some of the amount. This

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[10] Some reports even mention rates of 50-60% from moneylenders in the district of Vidarbha (Hindustan Times, 07/02/2007).

factor is seen as more significant in the feeling of loss of economic standing among farmers, along with the fact that they are continually relying on credit to get out of debt (Mishra, 2006). According to the various communications with the families of deceased farmers by P. Sainath and reported in *The Hindu* in June 2004, the farmers had often taken loans for expenses other than agriculture including health related expenses and expenses for marriage. Their income, however, was largely dependent on farm revenues, as they rarely rely on any type of non-farm revenue sources. In such cases, a loss of crops, whether with cotton, high yielding varieties of chilies, or oilseeds, pushed the farmers over the brink into committing suicides.

This loss of social position was more prominent among small and marginal farmers who owned some land and hence some social standing. According to P.Sainath, most deceased farmers had loans for marriages and other social events. Others had daughters who had to be married and hence could be thought of as an obligatory duty of the father. Farmers who lost crops and were in huge debts often concealed this fact from their families (Hardikar, 2006). These observations show that the loss of social position was a concern which distressed the farmers. The necessity of these farmers to maintain the appearance of well-being can be understood from the disgrace associated with the loss of social standing and the inability to perform the required social duties due to their already heavy debt burden. The only solution for farmers then appeared to be committing suicide to absolve one of their obligations, both to the money lender and also towards their family.

- Availability of toxic pesticide

Although not noted in our section on suicide above, the NCBR annual estimates attribute about 20% of every suicide to the absorption of toxic pesticides. This factor is even more important in rural areas. It has long been known that toxic pesticides, present in all farms or household in India, represent a large source of death in rural Asia. It is estimated that 300,000 people living in rural areas of Asia commit suicides every year by ingesting toxic pesticides- which may represent up to 60% of all suicides in Asia (Gunnell and Eddleston 2003, Konradsen et al. 2007).

- Government policies: for better or worse?

Suicides also seem to be associated with a demonstration effect and a hope that the sacrifice of one family member would get the family back on track. This has become a distinct concern as in 2007, the Indian government announced a major rehabilitation package for the families of farmers who had committed suicides (Kennedy, 2007). While the scheme would only give 30% of the compensation directly to the family while keeping 70% in the bank to disburse over five years, it has definitely raised questions on the possible perverse incentive it could have created by encouraging farmers into committing even more suicides.

In March 2008, the Government of India also initiated a large loan waiver scheme (of Rs 600 billion equivalent to $15 billion) to allow for the clearance of debts for small and marginal farmers. Although designed to provide a strong response to the issue, this plan has been largely criticized for different reasons. Swaminathan (2008) opposed two major criticisms to the plan. First, he criticized the unified definition of small and marginal farmers to whom the plan is targeted. Under the present definition, the plan would provide waivers to farmers that own 1 to 2 ha, which would exclude many small and marginal farmers in rainfed areas that tend to own up to four or five hectares, notably because their land is much less productive. Second, targeted loans eligible for repayment are defined as those provided by scheduled commercial banks, rural banks and cooperative credit institutions. Yet in fact money lenders and traders represent a major share of the source of loans used by distressed farmers. By keeping these inadequate conditions, Swaminathan argued, it is clear that the plan is bound to be largely ineffective. Many others have criticized the method of this plan. Indeed, a month after the implementation of the plan, the press was keen to report additional cases of suicides in Vidarbha as an evidence of the failure of the plan (Menon, 2008).

4. Discussion

By reviewing existing evidence on the relationship between the adoption of Bt cotton and the increased occurrence of farmer suicides in India, we do not claim to have a sufficient understanding to provide a full picture of the reality behind these tragic events. Instead, we believe that we have gathered sufficient evidence from various sources of information to propose a menu of possible reasons behind the occurrence of suicides in cotton growing regions**.**

Still, our analysis is sufficiently well documented to discredit the possibility of a naïve direct causal or reciprocal relationship between Bt cotton and farmer suicides. First, adopting Bt cotton is *not a sufficient condition* for the occurrence of farmer suicides in India. It is estimated that about one million farmers have planted Bt cotton, when a cumulated total of ninety thousands farmers are reported to have committed suicides between 2002 (year of the commercialization of Bt cotton) and 2007. More importantly, the trend in farmer suicides in India appears to have slowed down since the year of Bt cotton introduction, which would certainly not happen if Bt cotton was responsible for increasing farmer suicides. Secondly, the adoption of Bt cotton *is not*, nor as it ever been, *a necessary condition* for farmer suicides in India. Farmer suicides occurred in various states of India long before the introduction of Bt cotton. Historical reports from the 1980s observed the increase in suicides in certain districts of Northern India with the increase use of chemicals associated with the transition to post green revolution input based agricultural systems for other crops like wheat or rice. More recent data, compiled in this report, show that the marginal difference in annual farmer suicides in years after Bt cotton represents under 11% of the total number of farmer suicides before Bt. More generally, farmer suicides have happened in many other countries, with a diversity of crops and most of which did not have Bt cotton (Benkimoun 2007, The Economist, 06/23/07).

Therefore it is not only inaccurate but simply wrong to blame the use of Bt cotton as the primary cause of farmer suicides in India. In fact, our overview of the evidence suggest that Bt cotton has been very successful in most States and years in India, contributing to an impressive leap in average cotton yields, as well as decrease pesticide use and increase farmer revenues. So, as noted in several studies, the reality is much more complex, both on the conditions surrounding the use and resulting effects of Bt cotton, and on the socio-economic constraints that have likely pushed farmers in particular regions of India to commit suicides during some of these last few years.

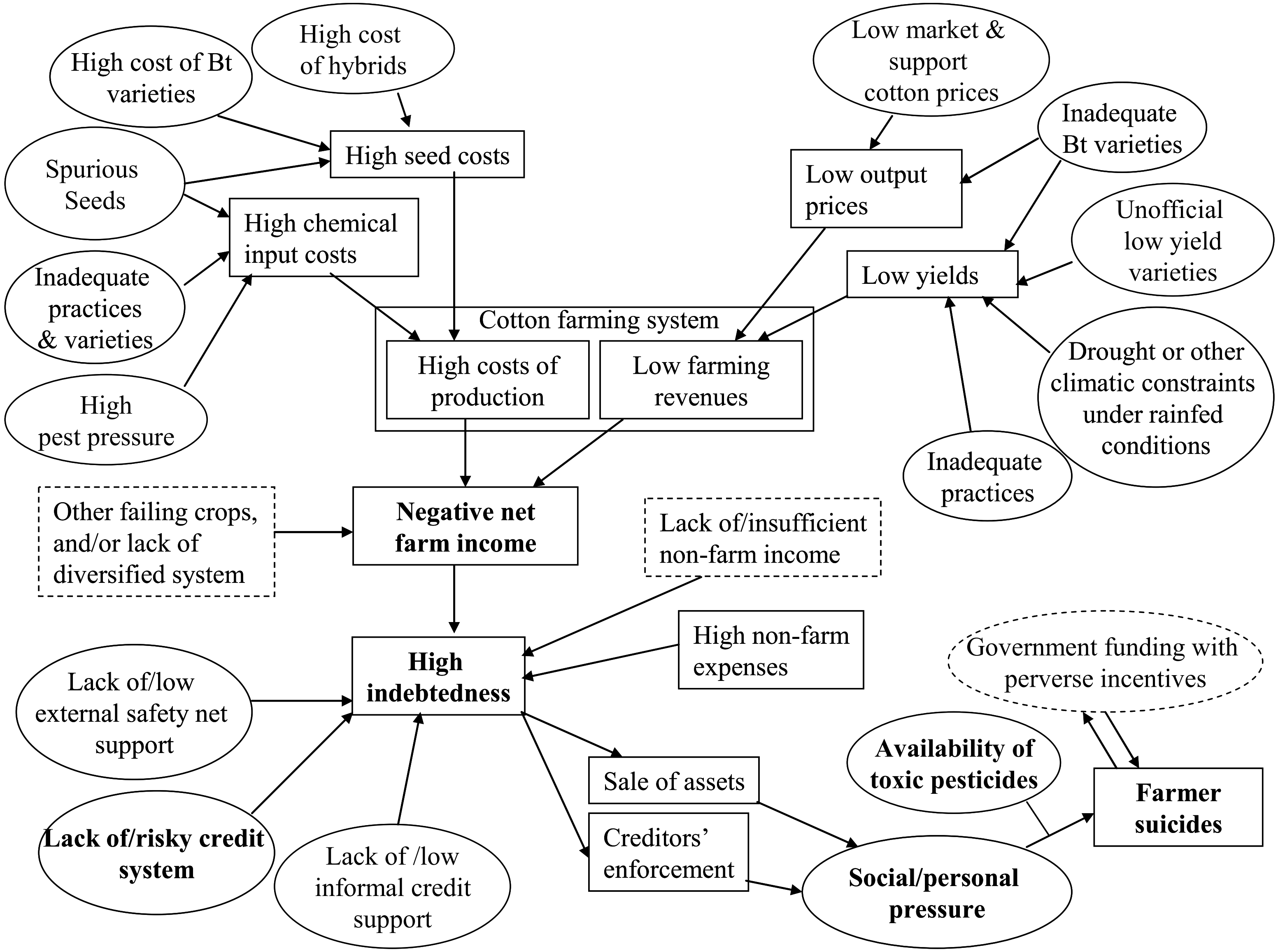
Using more disaggregated data, we explored some of the complexity on the hypothetical link between Bt cotton and farmer suicides in the cases of two States (Andrha Pradesh and Maharasthra) and specific suicide peak years: 2002, 2004 and 2006.

We find that in Andhra Pradesh, low rainfall, leading to low yields and following a season with minimum prices could have played a role in the observed relative peak in suicides in 2002. Bt cotton, which had only been introduced, likely did not play any significant role that year. In 2004, low rainfall and low prices, with another drought, seemed to have resulted in low or negative revenue for cotton, including in some cases Bt cotton, whose seeds were sold at a high prices, and whose main official varieties were still mostly inadequate. But available evidence suggests that, in average, Bt cotton still performed significantly better than non-Bt that year, even in suicide prone districts.

In Maharashtra, the two peaks of 2004 and 2006 are more difficult to apprehend, notably because of our lack of complete or consistent data. 2004 was clearly a season of low prices, and was very dry especially in the suicide-stricken regions of Vidharba and Marathwada. Bt cotton seeds were sold at a high price, and even if the technology was reportedly quite successful, there is insufficient evidence of its performance that year. Average yields of cotton did reach a historic record level in 2004/05, which suggest that cotton productivity increased in the State, weakening any link between cotton and suicides at the state level. Still, the few varieties of Bt cotton being sold that year, that were still not suitable for dry conditions, could have been adopted by groups of rainfed farmers in arid or semi-arid districts of the State. In 2006, however, with the availability of many more varieties, this factor likely did not play a role. Average yields in the state in 2005/06 and 2006/07 were lower than in 2004/05 suggesting that cotton did not perform well. Yet, the only survey we found on 2006/07 found extremely positive results with Bt cotton, so our investigation was inconclusive.

More generally, a complete analysis of the causes would require an elicitation of each story behind each farmer committing suicide, from the constraints within the household to the personal story of the individuals, and the community and farming issues they may have faced. In the absence of such comprehensive data, at this stage, we can only formulate general hypotheses on the possible socio-economic considerations that likely played a role in the resurgence of farmer suicides in central India. Throughout our review of reports and data, we identified a number of elements that may have played a role in the critical distress situations leading to farmer suicides in India. We gathered all these individual elements into a synthetic framework that links the possible initial factors to the main causes of suicides, as shown in Figure 21. In this figure, the initial presumed factors are circled; the observed factors and effects are framed. A few uncertain factors are circled or framed with dash lines, while the consistent and more robust factors and effects are shown in boldface. Each of the arrows in the figure represents a possible causal relationship that would need to be confirmed empirically on a case by case basis.

Figure 21. Bt cotton and farmer suicides in Central India: A conceptual framework of *hypothetical* links



To explain this framework, we start from the lower end of the path, analyzing what we assume to be the primary causes of suicides: social, personal, or individual pressure. The wide availability of toxic pesticides made suicide a relatively feasible option for highly distressed individuals. In fact, epidemiologists consider it a major factor to explain suicides in developing countries, as it is estimated to cause about 60% of all suicides in most of Asia (Gunnel and Eddleston 2003, Konradsen et al. 2007). Some reports have also mentioned financial support from the government as an incentive for suicides but these programs only came later (Kennedy 2007, The Economist 06/21/2007). Social or other pressures may be the results of threat from within (social pressure due to the lost of earnings and belonging to a social class or caste) or from outside the community (individual creditors coming after a farmer), but we find consistently across reports that it is likely to be the result of heavy indebtedness.

Debts are based on high expenses and insufficient or sometimes inexistent revenues, but also critically depend on the formal credit constraint they faced, which mostly combined the absence or low number of creditors, with high interest rate, low turnover period, with the lack of outside informal creditors (family members) or formal public support. In addition, farmers may have incurred multiple significant expenses outside of the farm; according to some reports, non-farm expenses, such as wedding or medical expenses, or even household consumer goods, likely played a significant role in some of the distressed families (Saunders 2007). Still, farm expenses probably contributed significantly in the budget of many of these individuals, and we focus on these particular costs in our framework. Similarly, without field data, we cannot reject the presence of non-farm revenues, but we presume that farming revenues likely represent a higher share of total income.

Under these assumptions, high farm expenditures and insufficient revenues likely played a role in the level of indebtedness of farmers, potentially leading some of these farmers to commit suicides. We still do not know the proportion of cotton growers among farmers committing suicides, but reports consistently talk about farmers planting cotton and other cash crops. In this context, it is important to note that the lack of diversification in the farming system is probably at least as much a problem as the particular choice of crop. Some experts have even encouraged farmers to switch to oilseeds such as soybeans because of high market prices fueled by a seemingly stable demand (The Press Trust of India, 06/19/2007). This may not necessarily be a successful strategy if these crops remain costly and if they still put non irrigated farmers at risk in case of drought. In any case, for the purpose of our framework we assume that cotton has remained the main crop, to analyze in detail the potential sources of high expenses and unexpected low revenues.

High farm expenditures are common for cotton, because of their requested level of chemical inputs. As explained above, cotton is heavily subject to insect attacks that largely determine the yields. At the same time, it is important to note that cotton growers in some of the target states, particularly Maharashtra have overwhelmingly embraced the use of hybrid seeds (The Economic Times 01/15/2007), which means that they spend part of their budget on new seeds almost every season (whether for Bt or non-Bt cotton). In this context, we find that despite reducing pesticides in most fields and thereby lowering associated costs, on the balance, Bt cotton is a costly technology compared to non-Bt cotton because of the highly priced seeds. At the same time, certain farmers seems to have spent significant amounts on other inputs (fertilizers etc) with the planting of Bt cotton based on the belief that this new technology would result in an extraordinary level of yields in all conditions (even with drought) or on the false perception that it still required high pesticide use. Other farmers seem to have purchased high cost spurious seeds of what they thought were Bt seeds, but that did not produce the Bt toxins. Lastly, and more generally, a number of farmers bought the Bt seeds without considering the type of Bt varieties they were purchasing and therefore ended up blaming Bt for what were actually inadequate varieties.

Low levels of farm revenues can be explained by low prices and/or low quantities of agricultural outputs. International cotton prices have been quite low since 1999, which could play a role in the low cotton revenues. But this trend has started long before the period we focused on. In fact, many farmers in these regions were only able to sell to the government for a minimum price, which was lower than commercial price. Our review of economic empirical studies has shown that in average seedcotton price from Bt fields is not statistically different from seedcotton price of non-Bt seeds, but that there was a difference in certain locations during the first few seasons, such as in Andhra Pradesh, partially because of the lower quality of the cotton lint from available Bt varieties compared to non-Bt varieties. Regarding production, the first Bt cotton varieties did increase yields compared to conventional cotton in most places and seasons in India. Still, their performance largely varied across locations, and in extreme cases they apparently did not perform well, for a number of reasons, including climatic conditions (drought or bad monsoon), inadequate varieties, improper agronomic practices, all combined with rainfed conditions. The use of unofficial varieties may also have resulted in underperformance, particularly with the use of hybrid F_2 lines from Bt cotton hybrids.

At the same time, production constraints in suicide prone areas likely did not only concern Bt cotton. Conventional cotton is also relatively high cost, more because of the price of pesticides than the price of seeds, and it is vulnerable to drought in rain-fed conditions. Other cash crops are expensive and likely have underperformed too. Because the link between recent suicides and the use of cotton (and in particular Bt cotton) has not been formally proven, it is important to keep in mind that it is only *one of the possible crops* in the vulnerable farming systems that could have contributed to the high indebtedness of farmers, some of who decided to commit suicides.

More generally, one has to read this framework as a series of possible sources of explanations, which put together (and not individually) increased the likelihood of suicides. Some of the factors have appeared consistently across all sources and therefore could be considered robust; namely, the degree of indebtedness, the inappropriate credit system, the presence of toxic pesticides, and in many cases crop failures. Yet all the other links need empirical confirmations, if not of causal relationships, at least of a correspondence between the resurgence of suicides and the various factors we identified.

5. Conclusions

In the last five years, India has rapidly increased its production of cotton, becoming a major exporter of cotton, and is likely to exceed the production of the United States in 2008 to become the second largest producer of cotton. Among other factors, the introduction and rapid adoption of Bt cotton likely played a significant role in the increase in production in India thanks to its observed contribution to a period of high cotton productivity growth. Yet, despite its visible commercial success, Bt cotton remains largely controversial in India. Among the many allegations against it, some groups accuse it to be the main reason for a resurgence of farmer suicides in cotton producing districts of Central and Southern India, particularly in certain dry districts of Maharashtra and Andhra Pradesh.

In this paper, we review the evidence on the alleged resurgence of farmer suicides in India and the potential relationship between the adoption of Bt cotton and suicides among Indian farmers. Using secondary data from multiple sources, we evaluate two sets of contradicting hypothesis on the phenomenon of farmer suicides and Bt cotton in India. The first supports the existence of a visible increase in farmer suicides concurrent with the adoption of Bt cotton, and affirms that this technology contributed to this rise in farmer suicides. The second set rejects both the presence of a surge in farmer suicides in recent years and any direct or reciprocal role of Bt cotton introduction in farmer suicides, while noting that in specific cases and seasons where Bt cotton may have played a role, among many other factors, it was mainly because of institutional, climatic and economic constraints. By compiling and synthesizing available data from official sources, research reports and economic and policy analysis we are able to clearly reject the first set and support the second.

We first showed that despite the recent media hype around farmer suicides, fueled by civil society organizations, and that has reached the highest political spheres in India and elsewhere, there is no evidence in available data of a "resurgence" of farmer suicide in India in the last five years. Yes, farmer suicide is an important phenomenon, but it still only represent three quarters of the total number of suicides due to pesticide ingestion in India, and less than a fifth of total suicides in India. Moreover, even if there has been an increasing trend in total suicides, the reported share of farmer suicides has in fact been decreasing. Of course, all these conclusions are based on available estimates, that may be underestimated, but with no better data, one cannot deny that claim.

Secondly, we provided a comprehensive review of available evidence on the effects of Bt cotton in India, and find that Bt cotton technology has been very effective overall, but the context in which Bt cotton was introduced has generated disappointing results in some particular and limited cases. Using macro data on productivity and a synthetic review of results from micro level studies, we show that in average Bt cotton has had a very significant positive effect on cotton productivity in India, raising farmers' income via an increase in yields and a reduction in pesticide use, despite rising the overall production costs. But we also find that Bt cotton's results during the first three seasons varied across studies and locations.

In particular, it did not always perform well in some particular limited areas and seasons, mainly because of the climatic conditions, low cotton prices, inadequate farming practices fueled by misinformation around the new technology, and the widespread use of initial varieties with the Bt gene that were not adequate for all locations and farming practices. We also find that the institutional context played a significant role in the cases of non positive outcome with Bt cotton, including the lack of or weak extension system, the lack of information on the multiple types of seeds, the presence of unofficial and spurious seeds sometimes being sold as official Bt.

Third, we reviewed reports and evidence on a possible relationship between suicides and the observed effects of Bt cotton. Overall, our analysis shows that, without a doubt, Bt cotton is not a necessary nor a sufficient condition for the occurrence of farmer suicides. Therefore, it should not be blamed for the resurgence of farmer' suicides in the field. In contrast, other factors have almost certainly played an indispensable role in these cases; namely the insufficient or risky credit system with no formal or informal support, and the wide availability of toxic pesticides. Still, by using more disaggregate data on suicides and on the reported effects of Bt cotton in Andhra Pradesh and Maharasthra, two States with farmer suicide hotspots especially in certain seasons, we showed that if Bt cotton may have been linked to specific cases of suicides (as reported), its marginal contribution among other factors is likely due to the general context in which it was introduced.

At the same time, we identify hypothetical links between indebtedness and net negative returns from agriculture, particularly related to highly costly agriculture in risky rain fed conditions in the States of Andhra Pradesh and Maharashtra. The absence of irrigation system in drought prone areas (especially in Maharashtra) combined with the specialization in high cost crops, low market and support prices, and the absence or failure of the credit system is a clear recipe for expected failures. In particular, it is possible that in the conditions in which it was introduced, Bt cotton, an expensive technology, that was poorly explained, often misused and only initially available with a few varieties, played a role in the overall indebtedness of certain farmers in some of the suicide prone areas of these two states particularly in its initial years. But none of these possible links has been explicitly demonstrated with a sufficiently robust analysis. At this stage, with qualitative and/or anecdotal evidence, we can only identify multiple hypothetical sources of indebtedness that may have contributed to farmer distress and ultimately farmer suicide, but we can't prove their relationship in a robust manner.

One implication of our study is the critical need to distinguish the effect of Bt cotton as a technology with the context in which it was introduced. Revealed preference based on farmer adoption rates and official or unofficial data all point out towards the overall success it had in controlling pest damage and therefore raising observable yields in India. In fact, some have argued that farmers' demand played a role in the approval of the technology; when the government requested to burn all fields of unapproved Bt cotton, some farmers demonstrated against this decision asking for a clear access to the pest resisting technology. In addition, the increasing adoption rate in two suicide proven states, Andhra Pradesh and Maharashtra indicate that farmers overall are seeing this technology as one of the solutions to their problem and not a cause of the problem.

In contrast, marketing constraints and institutional issues may have played a significant role. The initial high price of Bt cotton seeds and the limited number of initial varieties available due to the lack of competition are becoming less problematic with more varieties approved and a second, non-Monsanto trait commercially available since 2006. At the same time, our analysis suggests the need for better extension system, more controlled seed marketing system, anti fraud enforcement, and better information dissemination among farmers in all regions before the introduction of any new costly technologies like Bt cotton. Information should not come from seed dealers whose job is to promote and sell their technologies without explaining their proper use. At the same time, farmers should be encouraged to diversify their farming and non farming activities to spread the risk they may incur instead of spending everything on one single risky crop.

The second implication is that, as farmer suicides are not new or specific to recent cases or to the introduction of Bt cotton, they point towards the failure of the socio economic environment and institutional settings in rural dry areas of India. The absence of safety net or any other insurance support, the ineffective irrigation systems, the presence of abusive banking systems, the wide availability of highly toxic pesticides, and the potential rewards for suicides likely all contributed to farmer suicides. This has nothing to do with cotton or the use of new technology and would suggest as many potential policy changes. Some policy changes have already been proposed in several states such as Karnataka or Andhra Pradesh (Indo-

Asian News 2007). Others have been implemented by the Government of India, with significant budgets, but arguably inappropriately designed programs that either rewarded farmer suicides or offered loan waivers to only a minor portion of the distressed farming population. Rather than spending more on large programs directed towards farmer suicides, because of hype in the media, a rational approach would suggest to use better targeted State or district programs for distressed farmers, and much more federal and State investment on preventing the 80% or more other cases of suicides.

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Appendix: additional tables.

Table A1. Approved Bt Cotton hybrids in India up until August 2007

Region and GM event	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
North Zone (Haryana, Punjab, Rajasthan)						
Bollgard-I (Mahyco)				6	12	25
Bollgard-II (Mahyco)					1	5
Event 1 (JK Seeds)					1	2
GFM Event (Nath seeds)					1	1
Total				6	15	33
Central Zone (Gujarat, Madhya Pradesh, Maharashtra)						
Bollgard-I (Mahyco)	3	3	4	12	22	59
Bollgard-II (Mahyco)					6	12
Event 1(JK Seeds)					3	5
GFM Event (Nath seeds)					1	3
Total	3	3	4	12	32	79
South Zone (Andhra Pradesh, Karnataka, Tamil Nadu)						
Bollgard-I (Mahyco)	3	3	4	9	21	46
Bollgard-II (Mahyco)					2	10
Event 1 (JK Seeds)					2	3
GFM Event (Nath seeds)					1	2
Total	3	3	4	9	26	61
All India						
Bollgard-I (Mahyco)	3	3	4	20	44	97
Bollgard-II (Mahyco)					8	21
Event 1(JK Seeds)					7	11
GFM Event (Nath seeds)					3	6
Total	**3**	**3**	**4**	**20**	**62**	**135**

Source: ISAAA (2006), SABP Newsletter (2007), GEAC website: http://www.envfor.nic.in/divisions/csurv/geac/status.html

Table A2. Summary of published studies on the economic effects of Bt cotton at the farm level in India

Study	Type and data	Location	Season	Varieties	Results
ASSOCHAM – IMRB International (2007)	5950 farmers (60% Bt users) surveyed by IMRB	Andhra Pradesh, Karnataka, Tamil Nadu, Madhya Pradesh, Maharashtra, Gujarat, Punjab, Haryana, Rajasthan	2006/07 kharif*	Not detailed. Includes Bt and Bt II varieties.	For India as a whole, Bt increases yield by 50%, reduces pesticide costs by 32% and increase profits by 162%. All States gain from Bt cotton, the biggest relative profit increases occur in Maharashtra (+375%), Andhra Pradesh (+217%), and Gujarat (+198%), and Madhya Pradesh (+156%).The benefit-cost ratios of Bt I and Bt II are 11.6 and 10.8 for 2006, up from 5.8 in 2005.
Barwale et al. (2004)	1069 farmers surveyed by Mahyco.	Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Tamil Nadu	2002/03 kharif*	Bt : MECH 12, MECH 162, MECH 184. Non-Bt : non specified.	Observation show yield gains with Bt of 61% in average, 42% in AP, 43% in Gujarat, 70% in Karnataka, 72% in Madhya Pradesh and 44% in Maharashtra. Pesticide sprays are reduced by 57% in AP, 39% in Gujarat, 61% in Karnataka, 72% in MP, 64% in Maharashtra for an average reduction of 62%.
Bennett et al. (2004)	Farm statistical survey, 7751 plots in 2002, 1580 in 2003	Maharashtra	2002 and 2003	Bt: MECH-162, MECH-184, MECH 12, Non-Bt: Bunny, Tulsi, NHH-44, JK-666	In average, Bt reduces bollworm pesticide use by 70-80% but has ambiguous effect on sucking pesticides, cost of Bt seed is 200% higher than non-BT, but yields with Bt increased by 45-63% and gross margins increased by 49 and 73%.
Bennett et al. (2006)					Production function analysis finds average yield effect of 33 and 48%.
Morse et al. (2005a)	7793 plots in 2002, 1577 plots in 2003	Maharashtra sub-regions: Vidharba, Marathwada, Khandesh			Average results: higher cost with Bt (15% and 5%), but also higher yields (39% and 63%) and revenues (43 and 73%). In Vidharba, Marathwada, Khandesh: costs (31 and 13%,18 and 1%,-4 and 5%), yields (35 and 41%, 18 and 60%, 75 and 84%), revenues (37 and 45%,14 and 68%, 92 and 101%).
Bennett et al. (2005)	Farm statistical survey, 622 farmers, 306 plots with official Bt, 169 with unofficial, and 151 with non-Bt	Gujarat	2003/04	Bt: MECH 12 and MECH 162, unofficial F1, unofficial F2 Non-Bt: Bunny, Tulsi, NHH-44, JK-666	Average yield benefits: +37% for MECH 12, +20% for MECH 162, +14% for unofficial F1, -5% for unofficial F2. Gross margins also follow the same order (+132%, +73%, +37%, +20%). Econometric stepwise regression concurs with the results.
Morse et al. (2005b)					Same results, but also provide a table on cost of seed as percentage of gross margins, and find : MECH 12:18%, MECH 162: 25%, F1 18%, F2: 28%, non-BT 14%. As of total costs: 126%, 169%, 209%, 218%, 260%. So replanting Bt is still better than replanting others in terms of needed funds.

Morse et al. (2007a)	Farm statistical survey, 137 Bt plots, 95 non-Bt plots	Jaelgon, Maharashtra	2002 and 2003 kharif seasons*	Bt:MECH-162, MECH-184, MECH 12, Non-Bt: Bunny, Tulsi, NHH-44, JK-666	Revenues with Bt for adopters are 2.5 times higher than non-Bt adopters; revenues for Bt plots are 1.6 times higher than non-Bt for adopters. Bt cotton reduced the inequality among adopters but increased inequality with non-adopters.
Dev and Rao (2007)	Stratified statistical survey, 437 Bt and 186 non-Bt farmers	Warangal, Nalgonda, Guntur and Kurnool districts of Andhra Pradesh	2004/05 kharif*	Bt: MECH-12, RCS-2, Banni-12, unofficial Non-Bt: Bunny, Tulsi, NHH-44, others.	Based on simple differences, they find that overall Bt cotton decreased pesticide cost by 18%, increased total costs by 17%, and increased net income by 83%. Regression with production function finds a 36% advantage of Bt over non-Bt. Also find that Bt has a positive effect on farm employment. However total net income for cotton was negative for both Bt and non-Bt. 2004/05 was a bad year for Andhra Pradesh, with a drought and low cotton prices.
Gandhi and Namboodiri (2006)	Farm statistical survey: 694 farms	Gujarat (Vadodara, Rajkot), Maharashtra (Budhana, Jalgaon), Andhra Pradesh (Guatur, Warangal), Tamil Nadu (Salem, Peranbalur)	2004	Bt: Maha: MECH-162, MECH-184, MECH 12, Rashi AP: Rashi. MECH, other G: RCH, Mahyco, other TN: Rashi, MECH, other Non-Bt: various	In average, using regression analysis, Bt provides yield gains of 31% but at a cost 7% higher, for a higher profit by 88%. In Gujarat, Yield:35%, Cost:13.5%, Profit:74%. Maharashtra: Yield:43%, Cost: 5%, Profit: 120% Andhra Pradesh: Yield: 21%, Cost:3.3%, Profit :78% Tamil Nadu not indicated. Also provide results of a farm survey in Maha, AP and TN. Almost all farmers want to plant Bt in the future.
Naik, Qaim, and Zilberman (2005)	Farm statistical survey, 341 farmers, 133 Bt plots, 301 non-Bt plots	Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu	2002/03	Bt:MECH-162, MECH-184, MECH 12, Non-Bt: Bunny, others	Show the same results as below, also show the ginning percentage is similar between MECH and Bunny but staple length is smaller for MECH 12 and 162 than Bunny. Karnataka and TN growers realize much larger gains than Maharashtra, and AP growers lose. Econometric regressions suggest yield gains of 37% on average and increases to 47% if capture Bunny effect.
Qaim et al. (2006)					In average, with Bt cotton: less spraying (2.6 times less), higher costs, higher yields (mean difference 34%), higher profits. However, Andhra Pradesh suffered losses, as there Bt has less effect because of high pesticide use, and there was a severe drought with inadequate Bt varieties. Also, Bt varieties provided lower quality fibers.
Narayamamoorthy	Statistical	Vidarbha region of	2003/04	Bt: MECH-162,	Early adopters are mainly irrigated farmers. Show that Bt

and Kalamar (2006)	survey, 150 farms, including 50 non-Bt	Maharashtra: Budhana and Yuvamatal	kharif*	MECH-184, Non-Bt: Bunny 145 and Ankur 161.	resulted in 31% more sprays in Budhana, -44% in Yavatmal (-14% overall) , more fertilizer use for Bt, higher cost of pesticides in both districts (8.4%, 16.8%, 4.7% overall), higher total costs (29%, 49%, 35% overall), higher productivity (Yield:53% and 65%, 52% overall), higher profit (78%, 91%,79% overall).
Orphal (2005)	Statistical survey of 100 farms mostly under rainfed conditions	Karnataka (Dharwad and Belgaum districts)	2002/03	Bt: MECH-162 Non-Bt: Bunny, Brahma, DHH 11, Kashinath, RCH 2, Sanju, others	Bt cotton lower use of pesticide (-27 to -30%), higher seed costs (+300%), lower output prices (MECH 162 medium staple), lower yield for rainfed (-3%), higher yield for irrigated (14%), lower profits for rainfed (-20 to -40%), higher for irrigated farmers (20 to 32%, but non significant). Noted the lack of knowledge of farmers about the technology. In 2002, pest pressure (bollworm) was low, so there was not much pesticide needed.
Pemsl et. al (2004)					Stochastic simulations based on the survey data to account for the uncertainty in pest pressure and effectiveness of BT cotton, show that pesticide use has first order stochastic dominance compared to Bt, but that without a price decrease for Bt cotton output, there is no first order stochastic dominance between pesticide and Bt cotton.
Qaim and Zilberman (2003)	Statistical survey of 157 farms under trials	Maharashtra, Madhya Pradesh, Tamil Nadu	2001 trials	Bt: MECH not specified. Non-Bt: not indicated	Bt versus non-Bt plots: yields higher by 80%(same hybrid) to 87% (popular hybrid), 82-83% less spray.
Qayum and Sakkhari (2003)	225 farms in 2002, 164 farms in 2003 and 220 farms in 2004 (random in chosen villages)	Andhra Pradesh: Warangal	2002/03 kharif*	Bt: MECH-162 Non-Bt: not indicated	Bt results in increase seed by 155%, loss of yields by 35%, higher cost of cultivation by 11%, lower output price by 4% and net returns reduced by 76%- (no statistical comparison).
Qayum and Sakkhari (2005)		Andhra Pradesh: 2002/03: see above 2003/04: Warangal, Adilabad, Kurnool, 2004/05: Warangal, Adilabad , Nalgonda	2002/03, 2003/04, 2004/05 kharif*	Bt: MECH-162, MECH-184, MECH-12, Non-BT: not indicated	Total with Bt Mahyco varieties: Seed cost +234%, pest management -7%, total costs +12%, yields -8.3%, net returns-57%. In 2003/04, good weather: Seed costs (SC) +130%, Pest management (PM) -12%, Total costs (TC) +8%, yields (Y) 3.4%, Net returns (NR) -9%. In 2004/05: SC +117%, PM -2%, TC +17%, Y 5%, NR -142%. No statistical comparison.
Ramgopal (2007)	180 farmers, 90 Bt, 90 non-Bt.	Andhra Pradesh: Warrangal, Guntur districts	2004/05	Bt: Rasi, MECH, unofficial. Non-Bt: Bunny, Super Bunny,	Comparing total costs and benefits: seed costs: +171%, Insecticide costs: -28%, total costs +5%, yields:+46%, price cotton: -0.8%, net income: +380%. In Guntur, both Bt and non-Bt had positive net income, in Warrangal only Bt lead to

				Brahma, JK, Satya others.	positive net income.
Sahai and Rahman (2003)	100 Bt/non-Bt farms surveyed (random sample among growers)	Andhra Pradesh (75), Maharashtra (25)	2002/03 kharif*	Bt: MECH-162 and MECH-184 Non-Bt: Banny and Bhrama	Premature falling of bolls in Bt cotton, cotton quality of Bt of lower grade. Bt seeds four times more costly. Bt results in loss of yields, higher cost, lower price, and lower quality of cotton (no statistical difference computed). 98% of surveyed farmers against replanting Bt cotton. Failure attributed to bad varieties, high cost of seeds, modest pesticide savings, refuge requirements, vulnerability to the pink bollworm, no extension service.
Sahai and Rahman (2004)	136 Bt/non-Bt farmers surveyed (random sample among growers)	Andhra Pradesh: Warangal, Guntur, Mahboobnagar, Rangareddy	2003/04 kharif*	Bt: official MECH 12, rarely MECH 162, and unofficial Navbharat 151. Non-Bt:	Better yields because of good monsoon. Bt and non-Bt same yields, same output price, higher cost of seed and pesticide costs with Bt, and lower profit for Bt (no statistical difference computed). This season more unofficial seeds distributed and MECH 162 rarely used given its poor results in previous season.

* Kharif means that the crop was harvested in winter during the first calendar year of the crop season.

Figure A1. Farmer suicides and Bt cotton area in Karnataka (1997-2006)

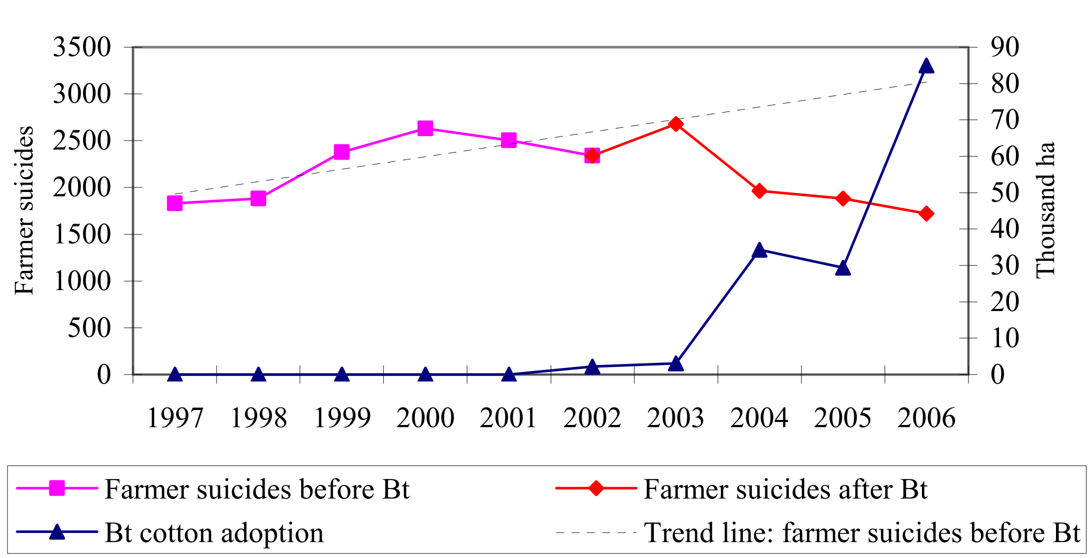

Figure A2. Farmer suicides and Bt cotton area in Madhya Pradesh (1997-2006)

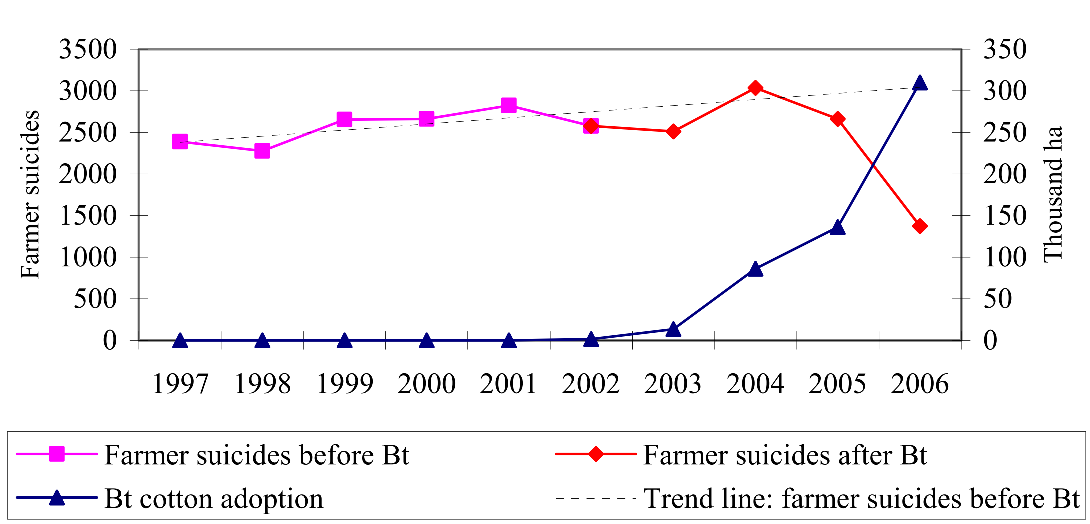

Figure A3. Farmer suicides and Bt cotton area in Gujarat (1997-2006)

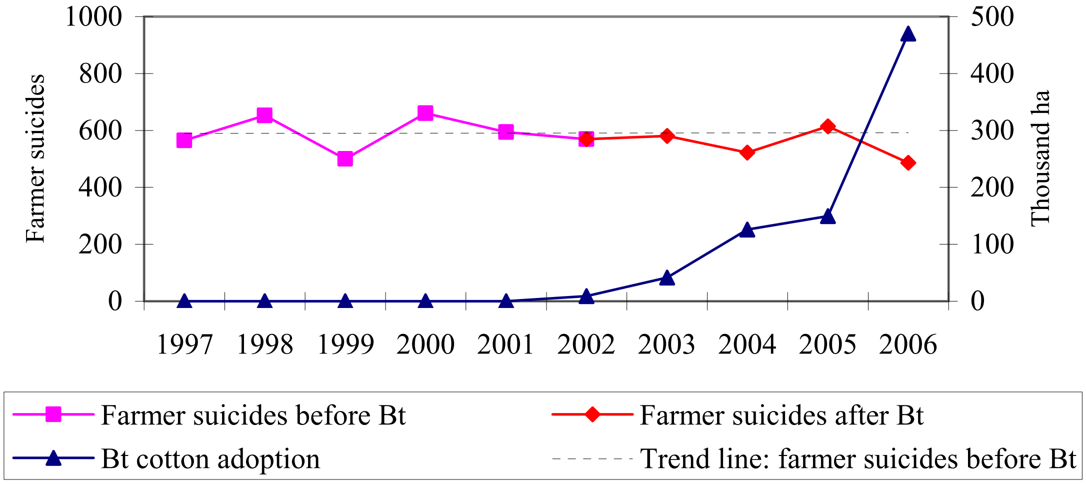

Figure A4. Farmer suicides and Bt cotton area in other States (1997-2006)