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Bt Cotton and Farmer Suicides in India

Reviewing the Evidence

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ABSTRACT

Suicides in general, including farmers' suicides, are a sad and complex phenomenon. Hence, their underlying causes need to be addressed within an equally complex societal framework. Here, we provide a specific case study on the potential link between technological choices and farmer suicides in India. Although officially recognized for having increased production and farmers' income, Bt cotton, genetically-modified, insect-resistant cotton, remains highly controversial in India. Among other allegations, it is accused of being the main reason for a resurgence of farmer suicides in India.

In this paper, we provide a comprehensive review of evidence on Bt cotton and farmer suicides, taking into account information from published official and unofficial reports, peer-reviewed journal articles, published studies, media news clips, magazine articles, and radio broadcasts from India, Asia, and international sources from 2002 to 2007. The review is used to evaluate a set of hypotheses on whether or not there has been a resurgence of farmer suicides, and the potential relationship suicide may have with the use of Bt cotton.

We first show that there is no evidence in available data of a "resurgence" of farmer suicides in India in the last five years. Second, we find that Bt cotton technology has been very effective overall in India. However, the context in which Bt cotton was introduced has generated disappointing results in some particular districts and seasons. Third, our analysis clearly shows that Bt cotton is neither a necessary nor a sufficient condition for the occurrence of farmer suicides. In contrast, many other factors have likely played a prominent role. Nevertheless, in specific regions and years, where Bt cotton may have indirectly contributed to farmer indebtedness, leading to suicides, its failure was mainly the result of the context or environment in which it was planted. We close the paper by proposing a conceptual framework for empirical applications linking the different agricultural and institutional factors that could have contributed to farmer suicides in recent years in certain districts of Central and Southern India.

Keywords: cotton, genetically modified crops, farmer suicides, India

1. INTRODUCTION

In July 2007, Indian government authorities approved commercialization of 73 new varieties of cotton genetically modified to contain Bacillus thuringiensis (Bt) to make it resistant to cotton bollworms. At that time total of 135 hybrid Bt cotton varieties was available on the Indian market (SABP 2007). In 2006, four years after its introduction, Bt cotton covered 3.8 million hectares or more than 39 percent of total cotton area (*Economic Times* 2007b). 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* 2007), making India the leader 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* 2007), potentially including 60 percent of total cotton area. These different indicators demonstrate the remarkable commercial success of Bt cotton in India.

However, 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 producer and activist groups have contested its effectiveness, reporting that many farmers have lost income while using it because it required more pesticides and obtained lower yields. Others report that it had toxic effects on domestic animal health, despite contradicting evidence. Many groups have objected to the high prices for Bt cottonseeds charged by Monsanto, the multinational biotech company. Yet perhaps the most talked-about controversy relates to the alleged resurgence of suicides by farmers in certain Indian states stemming from the use of Bt cotton.

In recent years, a large number of 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 were reported in the four states of Andhra Pradesh, Karnataka, Kerala, and Maharashtra (Mukherjee 2007). Other sources have reported much higher figures: in particular, the National Social Watch, a coalition of civil society organizations, reports 11,387 farmer suicides in the same period in India, almost all in those four states (*The Statesman* 2007), while the National Crime Records Bureau reports more than 16,000 farmer suicides every year. In most cases, male farmers committed suicide after experiencing failed crops and increased indebtedness. The largest number of reported cases was concentrated in districts of northeast Maharashtra (Vidharba District), northwest Andhra Pradesh, and northern Karnataka, where cotton was increasingly planted in the 1990s in response to demand generated by the large textile industry in Mumbai (Saunders 2007).

Reports initially limited to local newspapers and radio broadcasts rapidly spread to national and international media, with coverage from some prominent global newspapers and magazines. The reputed cause of the suicides differs across sources, some accusing Bt cotton, some attacking cash cropping and industrial agriculture, and others blaming multinational companies and developed-country subsidies that lower world prices for cotton (*The Economist* 2007a). Along with the media hype, the issue progressively caught the attention of the policy sphere, becoming a prominent concern in the affected Indian states and in New Delhi.[1]

Since the beginning of this crisis, many reports have been published by the government, national and international nongovernmental organizations (NGOs), and other groups of stakeholders involved in agricultural issues in India (e.g., Krishnakumar 2005, Sahai 2005, Nadal 2007). Some of these reports focused on the relationship between Bt cotton and farmer suicides, while others concentrated on conditions facing farmers and the context in which they committed suicides, or on the socioeconomic conditions of farmers in modern India in general. Still, most reports tend to reflect the polarized views on Bt cotton itself, without providing a comprehensive understanding of the actual situation that led to the observed resurgence of farmer suicides in India and therefore the potential role (or absence thereof) of Bt cotton in this picture.

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

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 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. We also delve into a study of other plausible causes of farmer suicides and whether they have a direct relationship to the commercialization of Bt cotton in the country.

In undertaking 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, magazine articles, and radio broadcasts, from India, Asia, and international sources from 2002 to December 2007. We also had the opportunity to obtain feedback on this specific topic from the Solution Exchange for the Microfinance Community (SEMC), an internet discussion group organized by the United Nations Development Program (UNDP) that specializes in issues of microfinance and credit in India. Nineteen group members from as many institutions provided feedback, references, and sources of information on the subject of Indian farmer suicides and Bt cotton.

In the next chapter, we formulate the main hypotheses that will be evaluated in this study. We then present the evidence of suicides, provide a comprehensive analysis of the effects of Bt cotton in India, and evaluate the potential role of this technology, particularly in the two states of Andhra Pradesh and Maharashtra, where both cultivation of Bt cotton and the number of suicides are high.

2. LINKING BT COTTON TO FARMER SUICIDES: FORMULATING HYPOTHESES

As a basis of analysis, we propose two opposed sets of hypotheses. The first, supported at least partially by media reports (.e.g., Gentleman 2006), personalities (Lean 2008), and by a number of civil society organizations (e.g., Sahai 2005), is based on two major assertions:

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

1b. The main reason for these suicides is indebtedness due to negative farm income from failing cash crops. Because Bt cotton is a costly and ineffective technology, it is a major contributor to the resurgence of farmer suicides in these regions of India.

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

2a. Farmer suicide is a long-term phenomenon; there is no clear evidence of a "resurgence" of such suicides in the five-year period covered by this study (2002–07).

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

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

Assumptions 1a and 2a, which are directly opposed, are examined in Chapter 3, which reviews the empirical evidence on farmer suicides in India. Assumptions 1b, 2b, and 2c are mainly supported by the arguments in Chapters 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 farmer suicides. We then provide a synthesis of our analysis, reconstructing the evidence in Chapter 6 and closing the paper with some concluding remarks on the policy implications of our results in Chapter 7.

3. FARMER SUICIDES IN INDIA: REVIEWING THE DATA

As noted in the introduction, evidence on reported cases of farmer suicide is contradictory. Yet, after examining various reports, it appears that two sources of official data have primarily been used to support the argument that Bt cotton is a cause of suicides. The official data in IndiaStat (www.indiastat.com), the web portal for data on the Indian economy, provides relatively low estimates of farmer suicides (Table 1). It is important because government officials in Parliament cited these data during question-and-answer sessions in the summer of 2006, and journalists and several researchers cited the data in their papers on Bt cotton or farmer suicides in India. For instance, Mitra and Shroff (2007) use it as the basis of their recent analysis on the causes of farmer suicides in Maharashtra. Still, we find that these data are inconsistent across states and years, that data are missing, and that several points are reported by crop year, while others are by calendar year. Apparently these data were obtained by state governments in 2006.

Table 1. The first official version: Number of farmer suicides in selected Indian states

State	2000/01	2001/02	2002/03	2003/04	2004/05	2005/06	2006 a
Andhra Pradesh	**191**	**267**	**313**	**393**	**1,126**	**300**	**11**
Gujarat		**13***	**6***	**3***	**7***	**7***	
Karnataka [b]	**2,630**	**2,505**	**2340**	**708**	**271**	**152**	
Kerala		**56***	**69***	**74***	**135***	**120***	**52**
Maharashtra		**50***	**122***	**170***	**620***	**572***	**746**
Orissa		**2**	**1**	**0**			
Punjab [c]			**13**	**11**	**6**		

Source: Indiastat 2006.
* These numbers refer to the whole calendar year listed first: for example, 2001 rather than 2001/02.
a. Figures for 2006 are counted until June.
b. 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 the State Agriculture Department.
c. The Punjab State Government has recently indicated that between 1997 and September 2005 the total number of farmer suicides was 179, not broken down by year.

The second main source of data is the National Crime Records Bureau (NCRB) of the Ministry of Home Affairs, which publishes annual reports on accidental and suicidal deaths in India. One of the main tables provided in the reports published in the last 10 years is the state distribution of suicides by profession, which includes a category for self-employed persons in agriculture (Table 2).

Table 2. The second official version: Farmer suicides in selected states and all India, 1997–06

State	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Maharashtra	1,917	2,409	2,423	3,022	3,536	3,695	3,836	4,147	3,926	4,453
Andhra Pradesh	1,097	1,813	1,974	1,525	1,509	1,896	1,800	2,666	2,490	2,607
Karnataka	1,832	1,883	2,379	2,630	2,505	2,340	2,678	1,963	1,883	1,720
Madhya Pradesh	2,390	2,278	2,654	2,660	2,824	2,578	2,511	3,033	2,660	1,375
Gujarat	565	653	500	661	594	570	581	523	615	487
Other states	5,821	6,979	6,152	6,105	5,447	6,892	5,758	5,909	5,557	6,418
All India	13,622	16,015	16,082	16,603	16,415	17,971	17,164	18,241	17,131	17,060

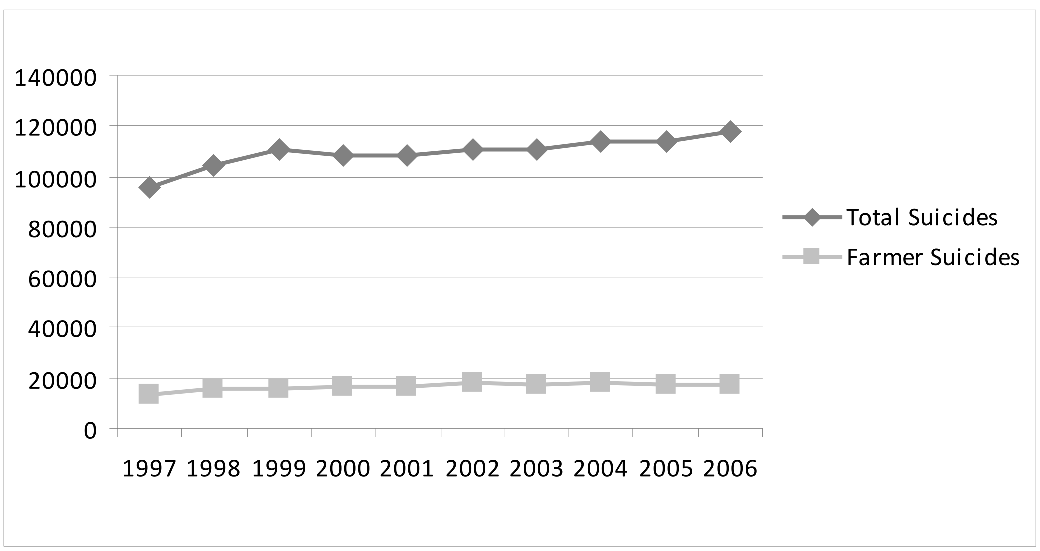
Source: NCRB various years.

As shown in Table 2, the number of farmer suicides reported is much larger (about 17,000 annually, compared with 1,000–2,000 in Table 1) and much more consistent across states and years than in 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 some also question the accuracy of these figures, others consider these much larger numbers underestimates of the real farmer suicide figures (for example, Nagaraj 2008). This implies that the first source of data is likely to be even more unreliable and negatively biased. The other advantage of these figures is that they are not isolated; they are presented consistently with overall estimates of the number of suicides in India and in each state.

While acknowledging the existence of two contradictory official sources of data, we decided to use the NCRB data as the main basis of this analysis, not only because we (and others) believe these data to be much more reliable and likely to be closer to actual figures, but also because they are more comparable across states and for analysis over longer periods of time.

Using data from this second source presents the trends in farmer and total suicides in India between 1997 and 2006, and shows that farmer suicides only represent a relatively minor and stable share of total suicides in India (Figure 1). 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 a slight rising trend in total suicides with growth accelerating 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 over time, visibly accelerating in 1997–99 and again in 2004; in 2005, however, the number fell back to the level of 2003. Generally, these national aggregate figures provide a 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.

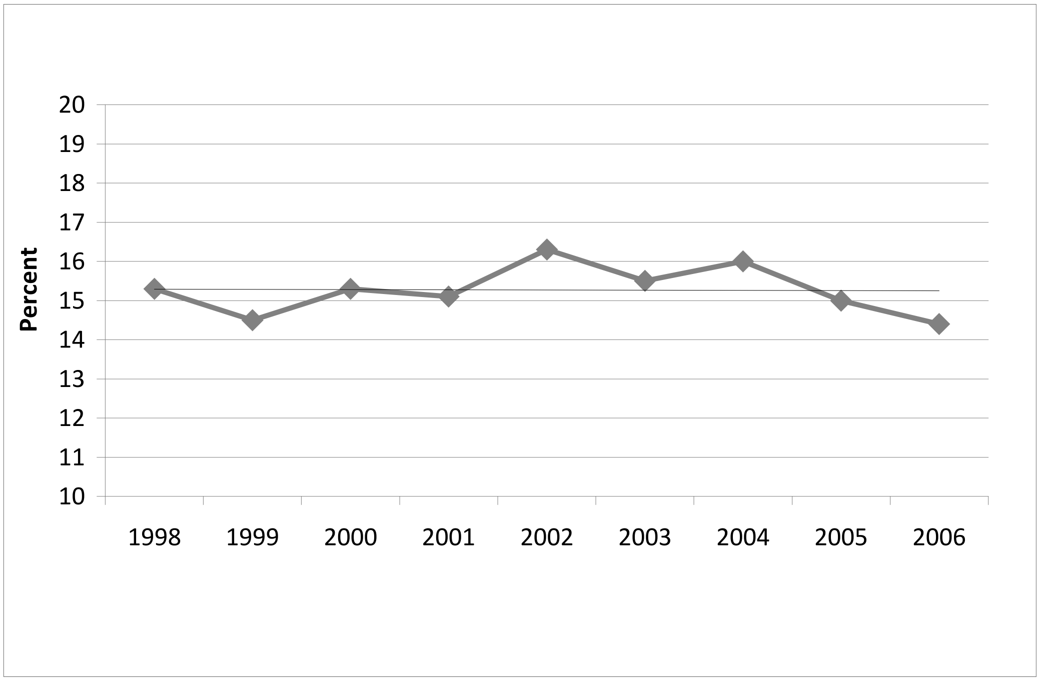
Figure 1. Farmer and total suicides in India, 1997-2006



Source: NCRB various years.

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

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



Source: NCRB various years.

Several authors have also tried to compile suicide rates (per 100,000 population) for different years, generally using population numbers extrapolated from the 2001 census data (deriving rates that are therefore not completely accurate). For instance, Table 3 provides suicide rates from Sainath (2007a) and the share of farmer suicides from Figure 2. Despite their limitations, these numbers show first that total suicide rates have not increased rapidly, and second, that the farmer suicide rate as a share of total population has not increased significantly between 2000 and 2005—even though it reached higher levels in 2002 and 2004—which again goes against the charge of a sustained resurgence in farmer suicides.

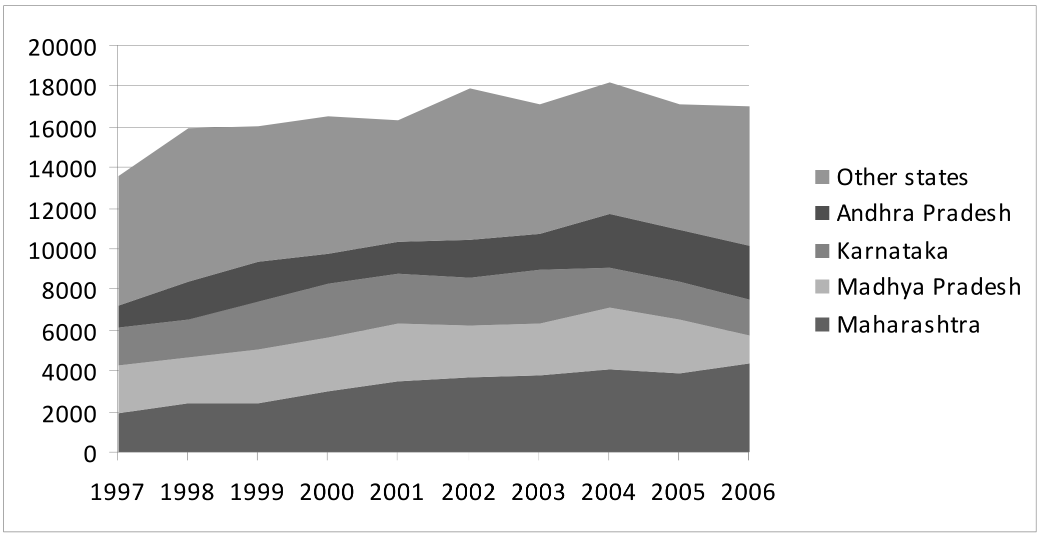
Table 3. Rates of farmer and total suicides, 1997–2005

Year	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).

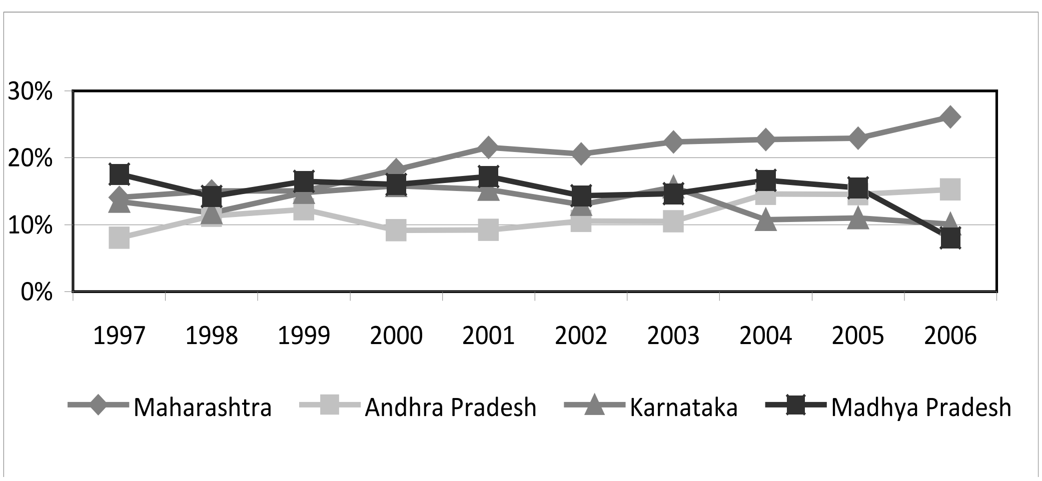
Looking at a more disaggregated spatial level, the distribution of suicides and farmer suicides across states is not uniform. By studying trends in suicides for all Indian states Nagaraj (2008) classifies states into four groups based on the size of their suicide numbers, their farmer suicide rates, their share of farmer suicides in total suicides, and the overall growth of farmer suicides during 1997–2006. The first group includes four big states of central and southern India: Andhra Pradesh, Karnataka, Madhya Pradesh, and Maharashtra, which account for 52 to 65 percent of the total reported farmer suicides in recent years (with a 10-year average of 60 percent) and a significant number of total suicides (for example, 40 percent in 2001, according to Nagaraj 2008).[2] Figure 3 shows the number of suicides for these states and others between 1997 and 2006. Figure 4 shows the share of farmer suicides in total suicides for each of these states in the same period, and Figure 5 shows the relative change in farmer suicides from one year to the next between 2002 and 2006.

Figure 3. Farmer suicides by state, 1997-2006



Source: NCRB various issues.

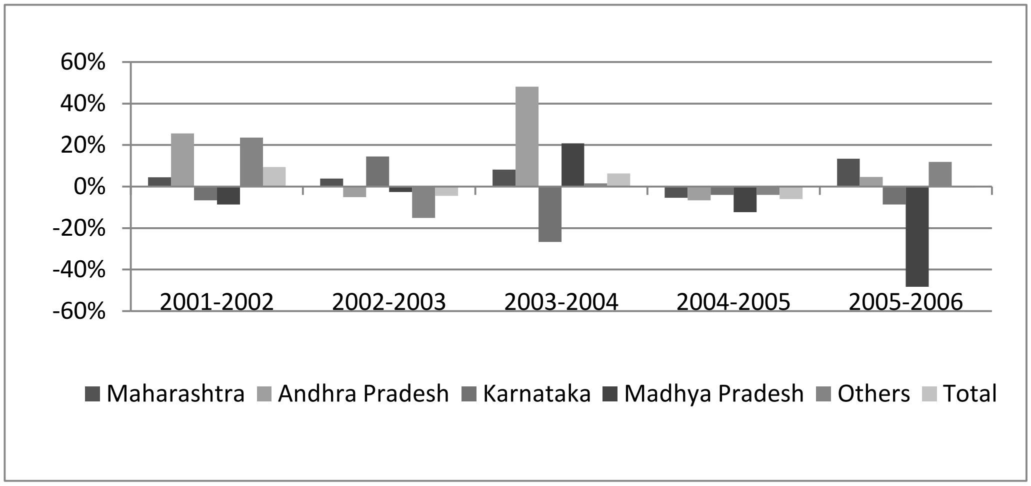
Figure 4. Shares of total Indian farmer suicides in the four states, 1997-2006



Source: NCRB various years.

[2] The other 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.

Figure 5. Percentage change in farmer suicides in selected Indian states, 2001-2006



Source: NCRB various issues.

Excluding the "other states" category, Maharashtra has a higher number of suicides than the three other states (Figure 3) and also a steadier annual rate of increase in farmer suicides (Figure 4). Its growth in the rate of suicides was unsteady, with peaks in 2003–04 and 2005–06 (Figure 5). Karnataka and Madhya Pradesh initially had almost as many farmer suicides as Maharashtra (Figure 3), but farmer suicides in both states decreased steadily in the 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 suicide numbers, but its suicide rate 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 2001 and 2002 and between 2003 and 2004. These two periods also represent the only years when the total farmer suicide numbers in India showed a relative increase during the period 2001– 06.

We can draw several simple conclusions from this rapid review of the evidence. First, data sources on farmer suicides in India contradict one another, providing very different ranges of estimates. The more comprehensive and consistent source of data estimates that farmer suicide numbers ranged from 14,000 to18,000 per year, or between 14–16 percent of total suicides in India every year since 1997.

Second, the phenomenon of farmer suicides is not new or recent. Based on the observed national trend from 1997 to 2006, one can clearly reject the assertion that the growth in suicides has accelerated in the last five years or so. The number of farmer suicides is significant and tends to be growing over time, but so is the total number of suicides in the general population.

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

Last, 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 mind, we turn to a chapter explaining the story of Bt cotton in India and its economic effects to see if and how it could have been related to the discrete increases in the number of suicides, particularly in these two states.

4. THE EFFECTS OF BT COTTON IN INDIA

The Approval of Bt Cotton in India

Cotton is an important commodity crop for India, growing in most agroclimatic zones and providing a livelihood for more than 60 million people engaged in agriculture, processing, and textiles (James 2002). According to 2007 data of the International Cotton Advisory Committee, cotton is grown on over 9 million hectares in India, making it the global leader in cotton production area.

Yet productivity of cotton in India was among the lowest in the world until recently. Table 4 compares average cotton production, area, and yields in the 10 largest producing countries between 1997 and 2006. During this period, India was the third largest producer of cotton overall, with the largest area (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. Average cotton lint production, area, and yields in the 10 leading cotton-producing countries, 1997–2006

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: FAO various years.

Table 5 shows the evolution of yield levels in India over time; according to these official data, the productivity growth in cotton has been rather slow in India for the last 50 years, and the yield level remained far below the global average in 2003.

Table 5. All-India area, production, and yield of cotton

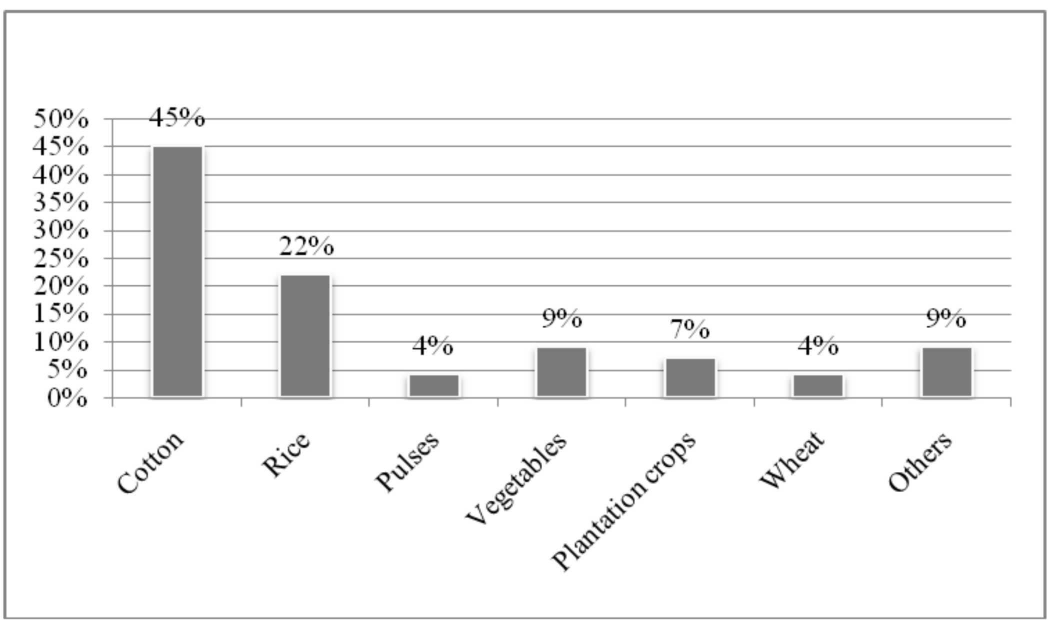
Year	Area (million ha)	Production (million bales)	Yield (kg/ha)	% Irrigated area
1950-51	5.88	3.04	88	8.2
1960-61	7.61	5.6	125	12.7
1970-71	7.61	4.76	106	17.3
1980-81	7.82	7.01	152	27.3
1990-91	7.44	9.84	225	32.9
2000-01	8.53	9.52	190	N/A
2001-02	9.10	10.09	189	N/A
2002-03	7.48	9.31	212	N/A
2003-04	7.64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

Source: Ministry of Agriculture (2004).
Notes: Each bale weighs 170 kilograms; N/A stands for "not available".

This significant yield gap is due to various factors, including a 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 al. 1999). Thus the variability in yields is largely dependent on the monsoon. Another major factor is infestations of pests, especially the American bollworm, which attack cotton plants at various stages of their life cycle.

This implies that farmers have to incur large expenditures on pesticides every year. Figure 6, which give the pesticide consumption by different crops, shows that cotton consumes about 45 percent of pesticides used in Indian agriculture (Choudhary and Laroia 2001). Rice is a distant second, consuming 22 percent of pesticides, while pulses, vegetables, and other plantation crops consume a miniscule 4, 9, and 7 percent, respectively.

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



Source: Choudhary and Laroia (2001).

Higher doses of pesticides are also used more frequently as many insects have developed a resistance to the commonly used chemicals. According to the background report on Bt cotton published by the Ministry of Environment and Forests (MoEF), this has mandated repeated applications of pesticides leading to increased costs in cotton production (MoEF 2002a). At the end of the 1990s, Bt cotton, a genetically engineered insect-resistant cotton, with the potential to provide protection against bollworm *(Helicoverpa armigera*), one of the major cotton pests, was considered a possible solution to the high cost of pesticide use in the country. After a review of satisfactory biosafety data and successful field trials by the regulatory authorities, partly prompted by the intrusion of unofficial Bt cottonseeds in India in 2001, the government gave permission for official varieties of Bt cotton to be commercially cultivated in 2002.

Table 6. 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 of several thousand hectares are discovered in Gujarat. Seeds are traced back to Navbharat Seeds, a company using 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 a 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.

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

Table 6 provides a quick summary of the history of the approval of Bt cotton, the only transgenic crop approved for commercial release up to date in India. Table A.1 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 that is toxic to cotton bollworms, the pest largely responsible for widespread damage 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, the Genetic Engineering Approval Committee (GEAC), in charge of approval decisions, approved 62 varieties of hybrid Bt cotton. 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 and 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) 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.

Bt Cotton at the National Level: Observed Effects

Currently, Bt cotton is cultivated in more than 10 states of India, the major ones being Andhra Pradesh, Gujarat, and Maharashtra. Appendix Table A.1 shows that the first varieties were approved in the central and southern zones; the northern zone received Bt cotton a few years later. Table 7 gives the estimated area of adoption of Bt cotton by state between 2002 and 2006.

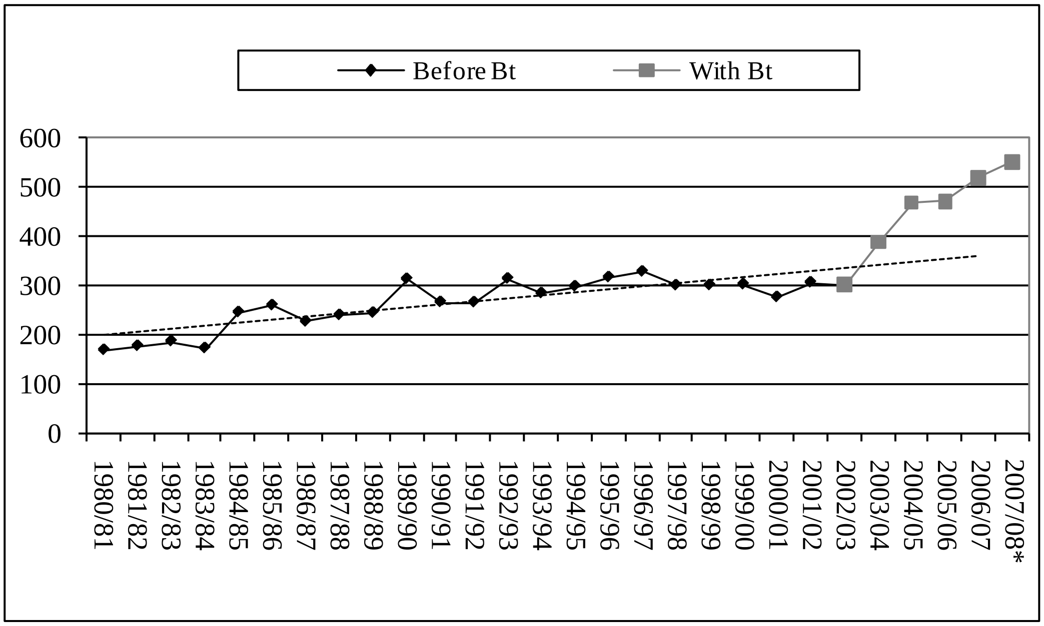
Table 7. Area of adoption of Bt cotton in ha, by state, 2002–2006

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: Indiastat (2005) for 2002–-05, ISAAA (2006) for 2006.

According to the Cotton Advisory Board, 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 2006a). To confirm this conclusion, Figure 7 shows the change in average cotton yields at the national level before the introduction of Bt cotton (1980/81–2001/02) and after, 2002/03–2007/08). The difference between the trend in national average yields before and after Bt cotton suggests a significant jump in productivity exactly when Bt cotton was introduced. Perhaps more striking is the fact that the average yield level reached almost 400 kilograms per hectare in 2003/04 for the first time in history and that the yield level exceeded 500 kilograms per hectare only three years later in 2006/07. In comparison, it took about 15 years, from 1982 to 1997, for the national yield level to increase from 200 kilograms per hectare to an annual average of 300 kilograms per hectare.

Figure 7. Average cotton yields in India (kg/ha), 1980-2007

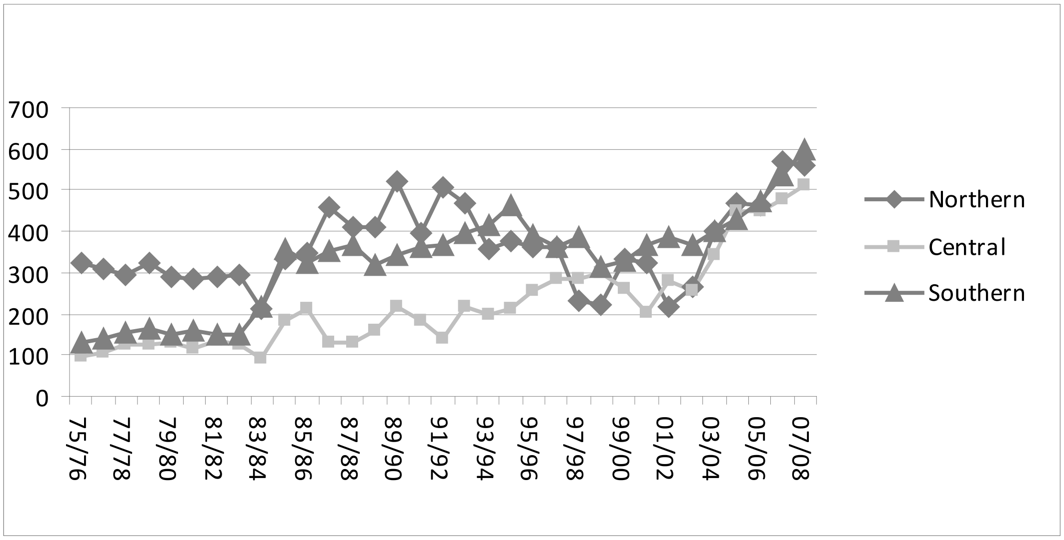


Source: International Cotton Advisory Committee (2008).
Note: Data for 2007/08 is an estimate.

Interestingly, this evolution does not reflect changes in all regions of India. Figure 8 shows the regional trends between 1975/76 and 2007/08. Although the lines for the three regions[3] converge at the end of the 30-year period, the Northern and Southern regions are closer to their long-term trends. 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 shows the same evolution for selected states that have adopted Bt cotton, indicating that all states except Madhya Pradesh have reached record average yield levels in recent years. But the southern states of Andhra Pradesh and Karnataka did not do so until 2007/08 (estimates), while the other states reached record levels one or more years earlier. Among the central states, Gujarat shows the most striking upward trend in yields, from less than 300 kilograms per hectare in 2000/01 to more than 800 kilograms per hectare 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 500 kilograms per hectare by 2007/08. Instead, the level of yields in Gujarat reached 750 kilograms per hectare in 2007/08—50 percent higher.

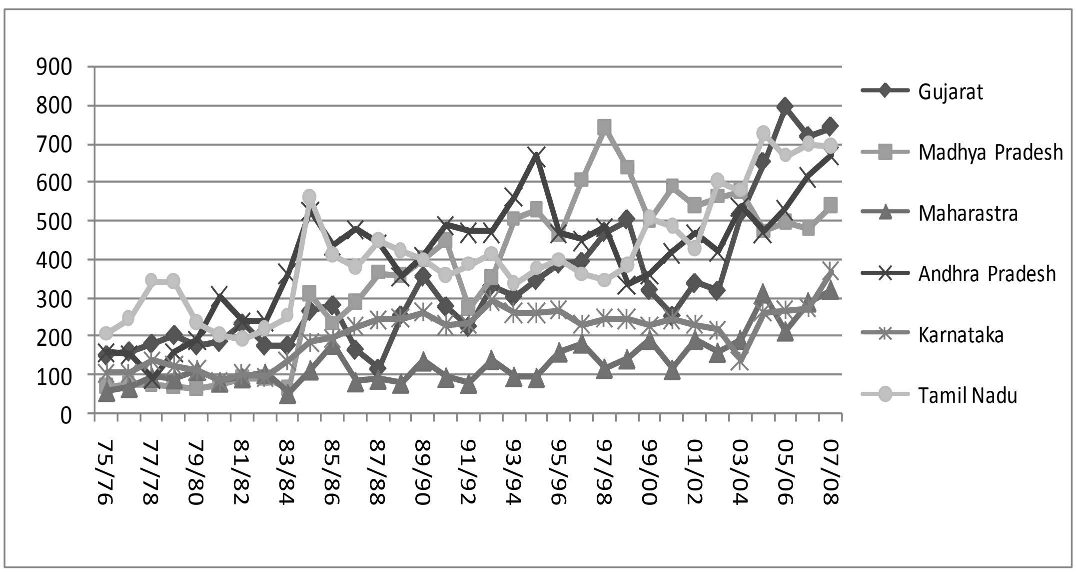
[3] The three cotton regions are defined as follows: Northern: Punjab, Haryana, and Rajhastan; Central: Gujarat, Madhya Pradesh, and Maharashtra; Southern: Andhra Pradesh, Karnataka, and Tamil Nadu.

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



Source: Directorate of Cotton Development, Government of India (2008); East India Cotton Association.(2008).

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



Source: Data provided by Directorate of Cotton Development, Government of India (2008); East India Cotton Association (2008).

To sum up, although measuring the actual net effects of the introduction of Bt cotton would require formal empirical analysis, our simple overview of the average yield levels helps 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, leading to record high yield levels in India post 2002–03. Second, regional data show that Bt cotton may not have had the same marginal effects in each state. In particular, it seems to have had a larger effect in the Central region, and in 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	3,850	3,706	2,034	2,133
Maharashtra	3135	3724	3385	3030

Source: Agricultural statistics provided by the Government of India.

In terms of input reduction, it is difficult to find precise data on the use of pesticides on cotton in specific regions of India. But there are data on total pesticide use. Table 8, which presents total pesticide consumption in Andhra Pradesh and Maharashtra between 2001 and 2005, shows that pesticide use has been going down since 2002 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 concurrent with the adoption of Bt cotton in these two states, a 45 percent reduction in Andhra Pradesh.

The Bt Cotton Controversy: The Institutional Context

Even with the yearly increases in adoption, production, and yields, Bt cotton has had its share of controversy. Farmers lack of information on growing conditions, pesticide use, the importance of planting proper seeds, and the earnings to be expected from using this technology seem to be behind the controversy shrouding Bt cotton's performance. 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 cottonseeds initially cost about 1,650 rupees (Rs) for a 450-gram packet, compared with Rs 300 for a 450-gram packet for the local hybrid variety DCH32 (Acharya 2006). This prompted a booming market for spurious seeds, which were sold at much lower prices. However, these seeds were mostly a mix of Bt and non-Bt cotton as well as seeds of unapproved varieties. Mostly sold by local traders, the seeds were targeted to farmers trying to save on seed costs. The germination rate of these seeds was inconsistent and often resulted in crop loss and disappointment for many farmers. Indian legislation such as the Seed Act has been of limited effect, since it did not provide for legal action on the sale of unpackaged or unlabeled seeds. The New Seed Bill of 2004 tried to remedy this situation by removing the distinction between notified and other varieties. If this bill is passed, all seeds, whether packaged or not, will have to be registered. This would help reduce 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 Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, and Tamil Nadu, along with three new states of Haryana, Punjab, and Rajasthan (as shown in Appendix Table A.1).

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 driven mainly by demonstrations from farmers who have had success cultivating it (Ministry of Environment and Forests 2003a). Very few agriculture extension services were provided and were located in 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). Faced with choosing among the numerous brands of Bt cottonseeds released between 2004 and 2005, farmers were practically gambling on the seed they used (Stone 2007).

Third, the high use of pesticides even with Bt cotton seems to have played a role (SEMC 2007). Cotton has been the crop most dependent on pesticides in India. It is cultivated in only 5 percent of the area but receives 45 percent of the pesticides used in India, pesticides account for 42–50 percent of the total cost of cultivation (Shetty 2004). The higher price paid for Bt cottonseeds is justified by the reduction in pesticide use since the plants themselves guard against bollworms. 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 to the secondary pests that used to be covered by the wide-spectrum pesticides used before Bt cotton.

However, farmers, lacking knowledge about the requirements for Bt cotton, followed their own spraying schedules. In a survey of farmers in Maharashtra and Gujarat, Shetty (2004) found that farmers in Guntur and Warrangal districts sprayed cotton 20 to 30 times, when the optimum required was only 15 times. This indiscriminate spraying led to development of resistance in the bollworm and hence pest infestation returned, 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 has improved according to a more recent report (ASSOCHAM-IMRB 2007), showing that Bt cotton farmers have largely reduced pesticide consumption, compared with 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 published by various institutes and cited one after the other by the media or selectively by opponents or proponents to Bt cotton. However, there has been no visible public effort toward a comprehensive and synthetic assessment of the effects of Bt cotton in the field. The proliferation of reports supporting both sides of the argument has contributed to the public confusion on the use of genetically modified crops among educated readers. Yet, as shown in the next section, a comprehensive review of the literature shows a convergence in the empirical evidence on Bt cotton, progressively dismissing any controversy on the observed productivity and income effects of the technology.

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 effects of Bt and non-Bt cotton in terms of pesticide use, yields, cost of seeds, other costs, and net revenues. Among them, more than 15 studies have been published in peer-reviewed journals, while other unpublished studies 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 conclusions on the observed effects of Bt cotton and the controversy surrounding the use of this technology.

Smale, Zambrano, and Cartel (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 extensive heterogeneity of the growing environment, pest pressures, farmer practices, and the social context. Second, they show that views have polarized on the effects of Bt cotton, which may be reflected in some of the reported studies from groups that are vocal proponents or opponents of the technology. Third, they 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 convincing explanation of the observed findings of existing studies. In particular, the results widely vary 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 2007b; 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 on 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 states, and all years. This inconsistency in the results surely played a role in fueling the controversy over the use of Bt cotton and its benefits for Indian farmers.

We summarize the methods, data, and results of each distinct study in the Appendix, Table A.2. Because several research teams used the same data in different papers, we differentiate the groups of studies by their source of data rather than by papers. Table A.2 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 NGOs in certain districts of Andhra Pradesh obtained very large negative results (Qayum and Sakkhari 2003; Sahai and Rahman 2003).

Later, a number of studies by academic researchers (such as Bennett, Ismael, and Morse 2004) showed more moderate effects with the use of Bt cotton. A number of more recent studies focus on explaining the original observed discrepancy. Bennett, Ismael, and Morse (2005) analyze the effect of varietal differences to show that the host germplasm played a 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 conditions than under rainfed conditions. Naik, Qaim, and Zilberman (2005) and Qaim et al. (2006) show the role of different varieties in terms of the cottonseed quality and local conditions. If the Mahyco Bt varieties have the same ginning ratio as non-Bt varieties, their staple has a smaller length than 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 during the 2002/03 season, Bt cotton was very effective in Tamil Nadu, Karnataka, Maharashtra, and Tamil Nadu, but that it failed in Andhra Pradesh, in part because of 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, Bennett, and Ismael (2007a) explain the effects of Bt cotton adoption in terms of inequality: they show that adopting Bt cotton reduced inequality among growers, but it increased inequality for nonadopters.

In sum, these later studies use empirical analysis to show that there is 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 limited knowledge of the technology among cotton growers (for example, use of the wrong variety, improper pesticide use, and the perception of Bt as a "silver bullet"). In other words, the technology, represented by the Bt trait, should not be blamed, instead, the conditions in which it was introduced, sold, and used explain some of the observed losses in specific regions of India.[4] At the same time, taken together, these later studies show that despite all these constraints, on average, a large majority of Indian farmers gained significantly by adopting Bt cotton varieties in most locations and seasons.

[4] Pemsl, Waibel, and Orphal (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 discredit those of larger empirical surveys on the reported positive and significant effects of Bt cotton in damage control in most locations.

To confirm or reject this last conclusion, we conducted a simplified meta-analysis of Bt cotton effects in India. Using all the studies described in Table A.2 from 2002/03 to 2004/05,[5] we collected the estimated average effects with Bt cotton and obtained a pooled 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 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, weighted and unweighted, based on the number of plots for these two groups of studies. We find that the differences across average estimates do not differ that much. According to these empirical studies, on average, Bt cotton reduces the number of pesticide sprays by 32–40 percent, reduces pesticide costs by 30–52 percent, increases the total costs of production by about 15 percent, has no clear effect on seedcotton prices, increases yields by 34–42 percent, and raises net returns by 52–71 percent. By deriving standard deviations among studies, we also compared our average results to zero and find that all the 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 use the results from the general studies for the rest of this section.

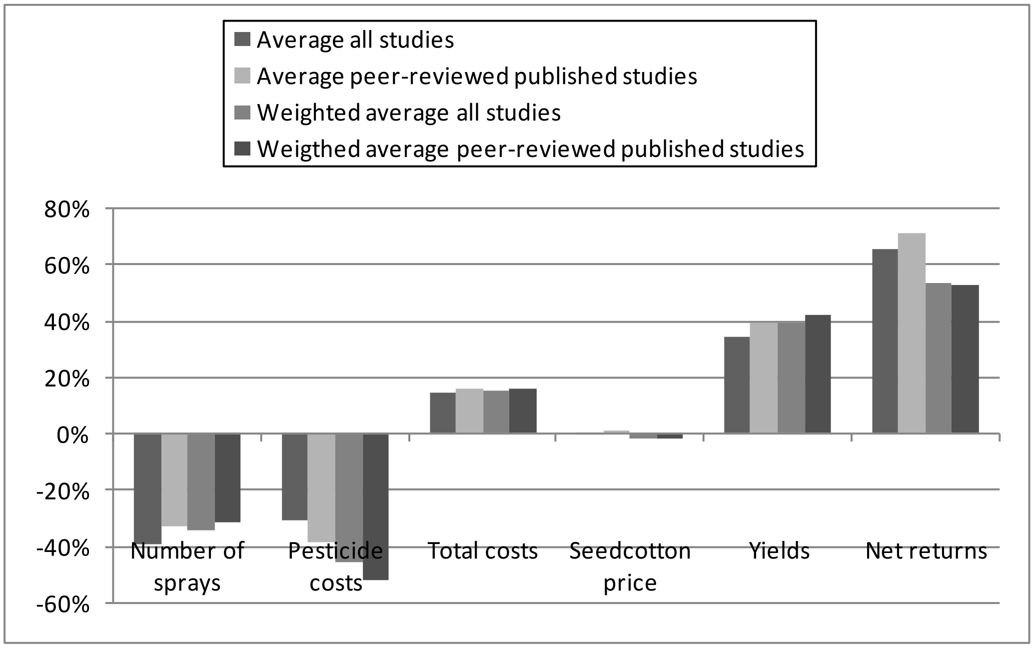
Table 9. Average effects of Bt cotton, compared with non-Bt cotton, based on all farm-level studies and only on peer-reviewed published studies

		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%

Source: Compiled by authors based on peer-reviewed studies.
Note: * Significantly different from zero at the 5% level.

[5] By restricting our analysis to 2002/03–2004/05, we excluded the results of studies from field trials before 2002, which tend to overestimate 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 than all previous studies and includes the first results with Bt II (Bollgard II), a more efficient Bt cotton recently introduced in some of states.

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



Source: Compiled by authors based on peer-reviewed studies.

It is important to note that a significant caveat of these results is that not only do these studies not share a methodology (for example, only a few provide regression estimates of effects), but virtually all of the studies, whether peer-reviewed or not, make no effort to correct for the potential presence of self-selection bias (Crost et al. 2007; Morse, Bennett, and Ismael 2007b). Because adoption is a nonrandomized process, Bt cotton adopters may be more productive farmers than nonadopters, and neglecting this fact could result in overestimating the actual net effect of Bt cotton compared with non-Bt cotton. Indeed, Crost et al. (2007) and Morse, Bennett, and Ismael (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, Bennett, and Ismael [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 percent) 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 (9,361) in 460 villages located in eight Indian states and selected using a multi-criteria matching process based on 2001 census data (that is, before adoption of Bt cotton); they show that in 2006, Bt and non-Bt farmers shared many similar socioeconomic characteristics (including 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. Although Bt cotton appears to be an expensive technology, raising overall production costs, it 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 400 kilograms per hectare and likely to reach 500 kilograms per hectare for the first time in history. National cotton acreage has remained 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 separate 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 are shown in Table 12.

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%*

Source: Compiled by authors based on peer-reviewed studies.
Note: * Significantly different from zero at the 5% level; n.a. means not available.

Table 11.Weighted average of the effects of Bt cotton relative to non-Bt cotton by state, using number 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%

Source: Compiled by authors based on peer-reviewed studies.
Notes: n.a. means not available.

Table 12. Average effects of Bt cotton, compared with non-Bt cotton, by season, 2002/03 to 2004/05 (%)

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%*

Source: Compiled by authors based on peer-reviewed studies.
Note: * Significantly different from zero at the 5% level.

The results in these three tables show that the 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 Maharashtra and Karnataka (although for the latter, yield and return effects are insignificant), Bt cotton is associated with higher production costs and potentially lower cotton prices but a large yield increase resulting in significant net income gains. Andhra Pradesh represents the third group: there, Bt cotton did not reduce pesticide costs much and had a negative but insignificant effect on price and an insignificant but 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 over time, even as the average net returns from the technology have increased. Bt cotton has reduced pesticide costs over time, and the total cost of Bt cotton also decreased. The average yield effect was reduced from +36 to +26 percent, yet the net return from Bt increased from +53 to +94 percent. However, it is important to note that if the pesticide cost, total cost, and yield effects were significantly different from zero in every year, the effect on net returns 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,— two years that correspond to peaks in suicides in Andhra Pradesh and Maharashtra.

Because the largest variances across results are reported in Andhra Pradesh, Karnataka, and Maharashtra, three suicide-prone states, we separated the results obtained for these three states (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 over time, going from negative to positive, apparently due to better average yield effects in 2004/05 than in the previous two years. Sahai and Rahman (2004) argue that cotton growers progressively replaced MECH varieties (the official Bt varieties of Monsanto-Mahyco) with Navbharat unofficial varieties, which may have performed better under local conditions, but whose seeds also cost less than official varieties. The increase may also be due to farmers' abandoning the technology; the largest losers probably did not purchase the same Bt seeds a second season in a row. Only the ones who did not incur losses and potentially gained would purchase the same 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%

Table 13. Continued

	Pesticide use	Pesticide costs	Total costs	Price cotton	Yields	Net returns
			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%

Source: Compiled by authors based on peer-reviewed studies.
Note: * 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 ranged from 5 to 21 percent while seedcotton prices decreased as much as 10 percent, but both remain within a reasonable range. In contrast, yield effects with Bt cotton range from –35 to +46 percent and net return effects present enormous differences across studies from –142 to +380 percent. The negative estimates were particularly large in NGO studies conducted in areas known to have had difficulties with Bt cotton. In any case, this observed variance explains why neither average yields, nor average net return effects are significant.

Results obtained in the state of Maharashtra, the second suicide-prone area, are more consistent across studies (Table 13). 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 are compensated for by much lower total cost effects. Yields and net return effects appear to be positive in all studies, but there is more variance in 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 percent), yields (from –3 to 73 percent), and net returns (from –30 to 172 percent). On average, these latter two are positive (even for weighted averages), but it is clear that the discrepancy across results during the same season shows that the Bt cotton varieties adopted in these states had various effects on cotton productivity and farm income.

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 (Mayee 2003). According to this report, Bt cotton cultivation increased yields in most areas 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 points out that Bt cotton worked well in irrigated areas (Gujarat), while the problem of wilting found in many central states like Andhra Pradesh, Madhya Pradesh, and Maharashtra was the result of physiological stress on the plant due to low moisture during dry spells. The incidence of bollworms was low across both Bt and non-Bt varieties, hence a distinction could not be made. Bt cotton had more bolls per tree but the size of the bolls was often smaller than the traditional variety. The report argues that the farmers in most states were not educated regarding Bt technology, which is a major factor in crop losses (Mayee 2003).

State government reports, on the other hand, are often more critical of the technology (Andhra Pradesh 2002; Maharashtra 2002). Both of these surveys show that in the first season, the Bt cotton hybrids performed rather poorly, compared with the popular non-Bt hybrids. In Andhra Pradesh, especially in Warangal district, the performance of Bt cotton was particularly poor, consistent with the conclusions 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 the cotton produced was relatively low, which resulted in lower market value for the crop (Andhra Pradesh 2002).

The situation improved later, according to a 2006 report by India's Ministry of Environment and Forests on Bt cotton and related issues, based on a season with no sale of Mahyco seeds in the state.[6] The new varieties sold were RCH-2Bt and RCH-20 Bt from Rassi Seeds and Pro Agro 368, Bt Pro Agro, NCS-145 and NCS- 207 from Nuziveedu Seeds. The incidence of spurious seeds was a significant concern because it had resulted in crop losses for many farmers in the state in previous years. Among other things, the 2006 report noted (1) higher yields for Bt varieties (10–15 quintals, compared to 8–10 quintals) depending on soil type and climatic conditions; (2) lower costs of cultivation with Bt; (3) larger and better quality bolls with Bt cotton, compared with non-Bt; and (4) a decrease in the maximum retail price to Rs 600–700.

The Maharashtra state government report of 2005 indicates a similar trend between 2002/03 and 2005/06. In this state almost 97 percent 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 cotton ranged from 16 to 60 percent.

In 2004/05, in most districts in Maharashtra, Bt cotton performed quite well. No significant difference between plant heights was observed. Infestation of sucking pests in both Bt and non-Bt cotton plants was moderate to heavy. This required an average of 5 or 6 sprayings for non-Bt hybrids and 2 or 3 sprayings for Bt hybrids. The average yield of Bt cotton, too, was higher than that of non-Bt hybrids (Table 14). Bt cotton yields varied from 1,510 to 2,498 kilograms per hectare, while those of non-Bt hybrids ranged from 962 to1,814 kilograms per hectare. As the table shows, Bt cotton yields were higher than the non-Bt hybrids in all divisions.

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

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

Name of Division	Total yield in four pickings	
	Bt Cotton	Non-Bt Cotton
Nasik	1,510	1,375
Aurangabad	1,686	962.16
Latur	1,853	1,606
Amravati	2,449	1,814
Nagpur	2,498	1,587
Total	9,996	7,344.16

Source: Commission of Agriculture, Maharashtra.

The performance report for Madhya Pradesh in 2005 also shows a positive effect for Bt cotton in the state (Madhya Pradesh 2005). The cost of cultivation for Bt cotton is higher (Rs 22,000–25,000 per hectare) to the one obtained with non-Bt hybrid cotton (Rs 18,000–20,000 per hectare). At the same time, Bt cotton resulted in higher productivity (20–25 quintals per hectare), compared with non-Bt (18–20 quintals per hectare). 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 per hectare, compared with 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 is susceptible to the phenomenon called “New Wilt,” a physiological disorder probably due to a change in agroclimatic conditions. It was particularly evident in Bt crops sown before the onset of the monsoon. 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 a greater number of open balls at the time when the wilt strikes, increasing moisture requirements, compared with non-Bt 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 outlook, viewing the suicides as an indicator of a more systemic problem in agriculture and society, especially in the central and southern states.

In the conclusion of his report on farmer suicides in India, Nagaraj (2008) explains that a “mono-causal explanation for farmer suicides would be totally inadequate.” Instead Nagaraj argues that a complex set of socioeconomic factors 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 causes particularly related to agriculture: the heavy indebtedness of farm households, particularly in the suicide-prone states.

Analyzing the social roots of suicide, Durkheim (1951) 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. A modern perspective defines the “phenomenon of suicide 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 the result of mental health troubles but are often caused and conditioned by social factors.[7] Social factors, which are external to yet constraining on the individual, regulate human social actions and act as a constraint to human behavior. In the case of the Indian farmer, indebtedness from repeated crop losses and a fall in social status due to loss of income and the inability to maintain the same level of expenditure are characteristic indicators leading to anomic suicide. This, coupled with hopelessness regarding any possible improvement in the situation, plays a role in encouraging suicide as the only possible way to redeem oneself from social disgrace.

Causes of indebtedness include changes in cropping patterns, plant resistance to pesticides and hence increased spending on pesticides, a shift from low-cost food crops to high-cost cash crops, lack of access to institutional credit, and 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 that farmers engage in with the hope of becoming debt-free if the harvest is sufficient. This phenomenon of “going for broke and losing out” is likely related to the increased instance of suicide among farm households. Table 15 shows the level of household indebtedness in four states of India.

According to these data, the percentage of farm households in Maharashtra who are indebted is higher among those who own less than 1 hectare of land or more than 2 hectares (36.0 and 37.9 percent, respectively). Comparatively, in Andhra Pradesh indebtedness is definitely higher among the small and marginal farmers who own less than 1 hectare of land (55.7 percent). It is also clear from the table that in Andhra Pradesh, private moneylenders are the main source of loans (53.4 percent), while cooperative societies (48.5 percent) are the main source in Maharashtra. Until recently, the government contributed only a minimal amount toward farm loans in both states. The increasing dependence on local moneylenders and other private sources for crop loans means that the rate of interest is high thus resulting in greater indebtedness with crop failures.

[7] In the case of Australian, Judd et al. (2006) noted that mental health problems could not explain the high rate of suicides among farmers. Instead, individual personality, gender and community attitudes that limit the ability of individuals to express their troubles may play a significant role.

Table 15. Indebtedness of farm households in four states (%)

Percent of farm households	Maharashtra	Andhra Pradesh	Kerala	Punjab	All India
Among rural households	55.7	42.3	43.9	61.8	60.4
Indebted	54.8	82.0	64.4	65.4	48.6
With cultivation as main income	57.9	53.7	16.8	45.6	57.2
Indebted with cultivation as main income.	62.6	54.4	14.4	52.7	56.9
Indebted with land <1 hectare	36.0	55.7	87.7	53.3	61.0
Indebted with 1–2 hectares of land	26.2	21.8	9.1	15.8	18.9
Indebted with land > 2 hectares	37.9	22.4	3.2	31.0	20.1
Taking loan for farming activities	75.4	61.5	21.4	62.4	58.4
Taking loan from government	1.2	1.0	4.9	1.9	2.5
Taking loan from cooperative societies	48.5	10.4	28.3	17.6	19.6
Taking loan from bank	34.1	20.0	49.1	28.4	35.6
Taking loan from moneylenders	6.8	53.4	7.4	36.3	25.7
Taking loan from other sources	9.4	15.1	10.2	15.8	16.7

Source: NSSO 2005.

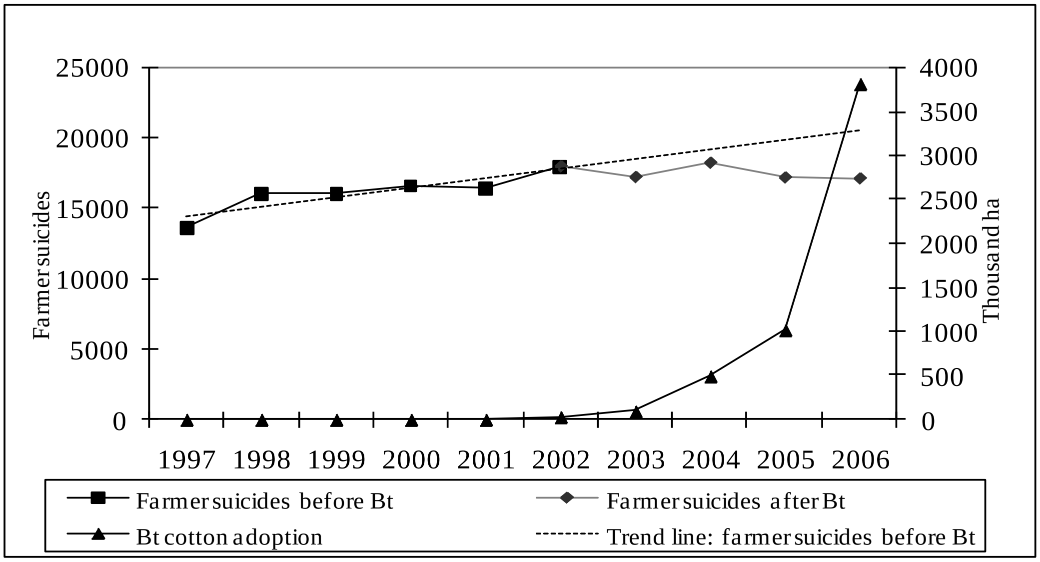
The alleged potential link between farmer suicides and Bt cotton is based on the assertion that it may have contributed to higher costs of production and to crop failures, both increasing the chance of indebtedness and the likelihood of suicide. In the next section, we specifically look at the evidence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

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 provide information about the concerned farmers' characteristics. In particular, there are no numbers on the actual share of farmers committing suicide who cultivated cotton, let alone Bt cotton, and among them, those who committed suicide because their Bt cotton crop failed. In particular districts, some qualitative evidence has been gathered, based on reported stories of suicides among cotton growers, but the core of support to the argument that Bt cotton leads to suicide has 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 only try to evaluate the possible (and hypothetical) role Bt cotton may have had in this process. We start by looking for a potential link at the aggregate level. We combine data on the adoption of Bt cotton with the numbers of farmer suicides at the national level between 1997 and 2006 (Figure 11). 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

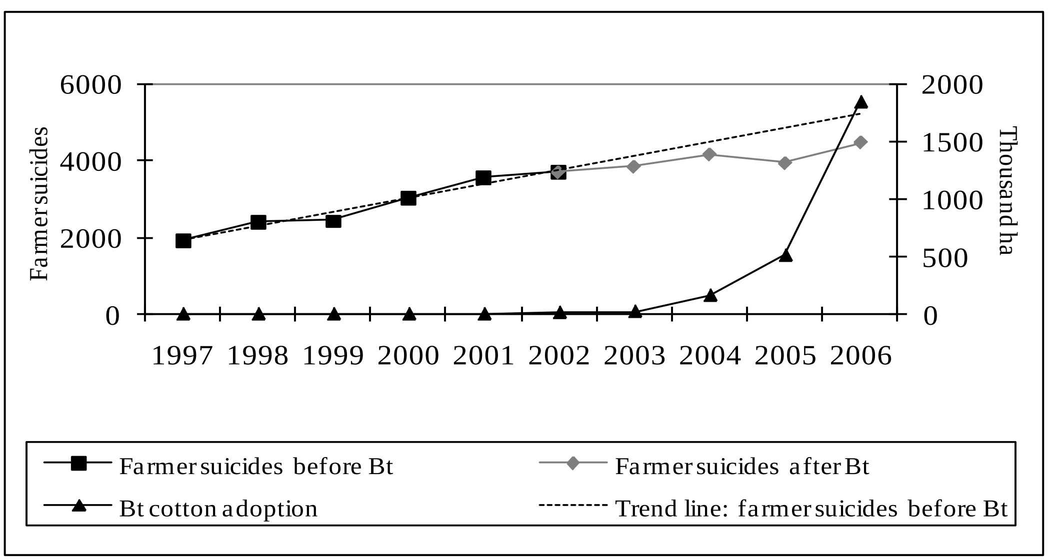


Source: Combined data from Tables 2 and 7.

Three clear conclusions emerge from Figure 11: (1) there is no observed correspondence (or causality) between the national Bt cotton adoption rate and farmer suicides, (2) the annual growth in suicides actually diminishes after the introduction of Bt cotton, (3) the two more recent peaks in farmer suicides in 2002 and 2004 happened during years when adoption of Bt cotton was limited, 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 hold at a lower spatial level. We provide similar figures for Maharashtra (Figure 12); Andhra Pradesh (Figure 13); and Madhya Pradesh in the Appendix Figure A.1, Karnataka (Appendix Figure A.2), and other states (Appendix Figure A.3).

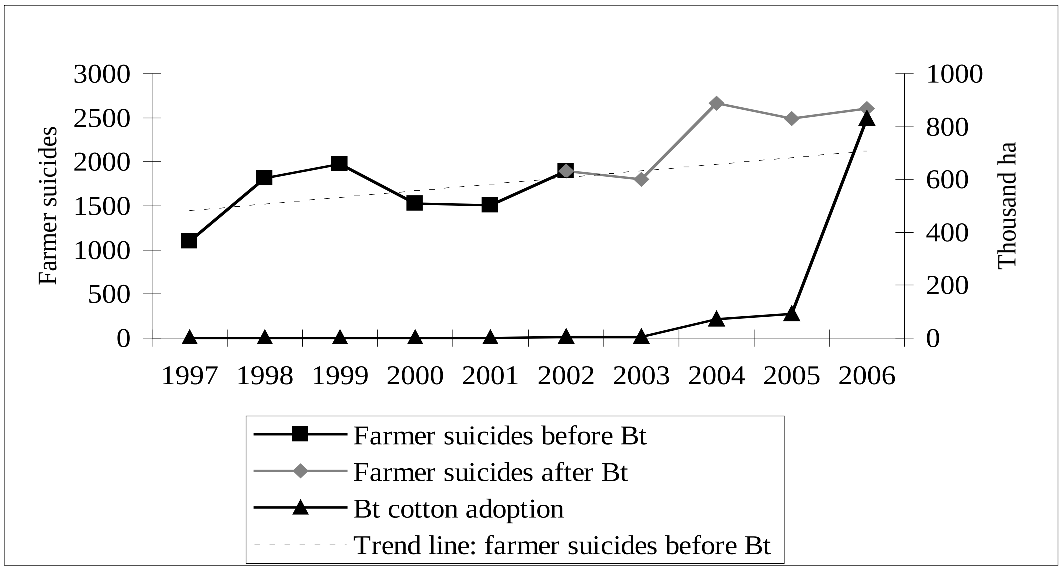
Figure 12. Farmer suicides and Bt cotton area in Maharashtra, 1997-2006



Source: Combined from Table 2 and Table 7.

For Maharashtra, the combination of suicide and adoption rates leads to similar conclusions (Figure 12). Maharashtra tends to be a good proxy for what happens 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 helped slow the process.

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



Source: Data combined from Tables 2 and 7.

The case of Andhra Pradesh is more ambiguous, because the farmer suicide numbers have followed a much less regular (and less linear) pattern during the period as a whole (Figure 13). The linear trend of suicides before Bt shows that the rate of suicide may have increased after the introduction of Bt cotton. Based on this sole evidence, we cannot reject a possible partial correlation between adoption of Bt cotton and suicide growth, even though there were many farmer suicides and a clearly 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. In that year, Bt cotton had only been partially adopted. In the following two years, which saw a much larger acceleration in adoption of Bt cotton, negative and positive relative changes in suicide rates in Andhra Pradesh were limited.

A rapid overview of the same figures for the other states (presented in Appendix Figures A.1 to A.4) show that Bt cotton adoption happened simultaneously with a clear decrease in farmer suicides (in Karnataka and Madhya Pradesh) or with stagnation of farmer suicide numbers (in Gujarat and other states aggregated). The case of Gujarat (shown in Figure A.3) is particularly interesting, as it provides another piece of evidence on the lack of a clear general relationship between Bt cotton and farmer suicides.

Gujarat shares a number of similarities with the bordering state of Maharashtra, including climatic and socioeconomic factors. Gujarat, an important agricultural state with more than 50 million inhabitants, happens to be the initial state where Bt cotton was adopted and the third largest adopter of Bt cotton (behind Maharashtra and Andhra Pradesh), with an area reaching an estimated 470,000 hectares (or about 25 percent of its cotton area) in 2006. Yet it also has one of the lowest numbers of reported farmer suicides, totaling around 500 per year or less than 3 percent of total farmer suicides in the country

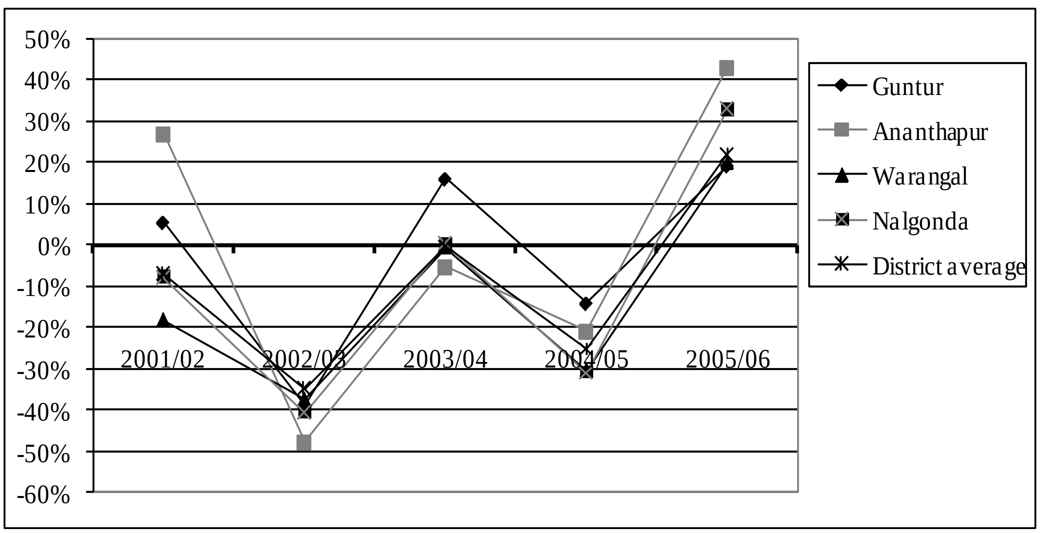
(Nagaraj 2008). Nagaraj (2008) placed Gujarat in Group 3, a group in which farmer and overall suicides are not prominent or growing.

To sum up, based on 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 a high number 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 increase in farmer suicides in certain states and years, especially during the peak of 2004 in Andhra Pradesh and Maharashtra.

Bt Cotton and Discrete Suicide Growth in Andhra Pradesh and Maharashtra

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

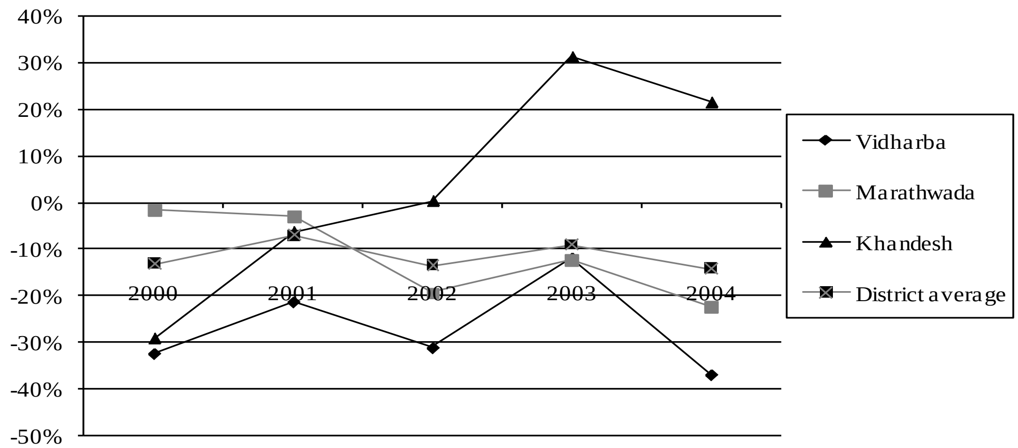
Figure 14. Precipitation deviation from mean in four districts and district average for Andhra Pradesh, 2001-06



Source: www.indiastat.com

[8] The largest difference in total farmer suicides between 2001 (before Bt) and after 2002 (after Bt) is only 1,800, which represents about 11 percent of the total farmer suicides in 2001. In other words, 89 percent of the total annual cases of farmer suicides had already been reported before Bt cotton was even introduced.

Figure 15. Average deviation from normal precipitations in three suicide prone regions of Maharashtra, compared to district average, 1997-2004



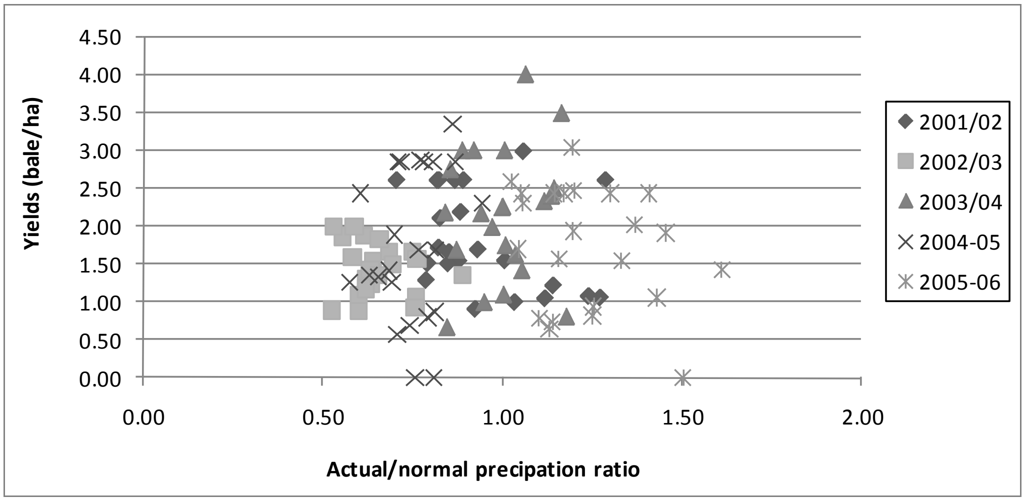
Source: www.indiastat.com

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. In looking at the deviation from normal rainfalls in several suicide-prone districts of Andhra Pradesh between 2001 and 2006, Figure 14 clearly shows a drop in rainfall in 2002/03 and 2004/05 in these districts and the state as a whole. For three districts that are known to have a high concentration of suicides in Maharashtra (Figure 15) the pattern is less clear, although both Vidharba and Marathwada districts had rainfall below the norm in 2002 and 2004.

However, these figures only present data derived from annual precipitation, which is a poor proxy of drought. Moreover, the lack of precipitation does not provide information on the actual crop productivity in 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 to 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.

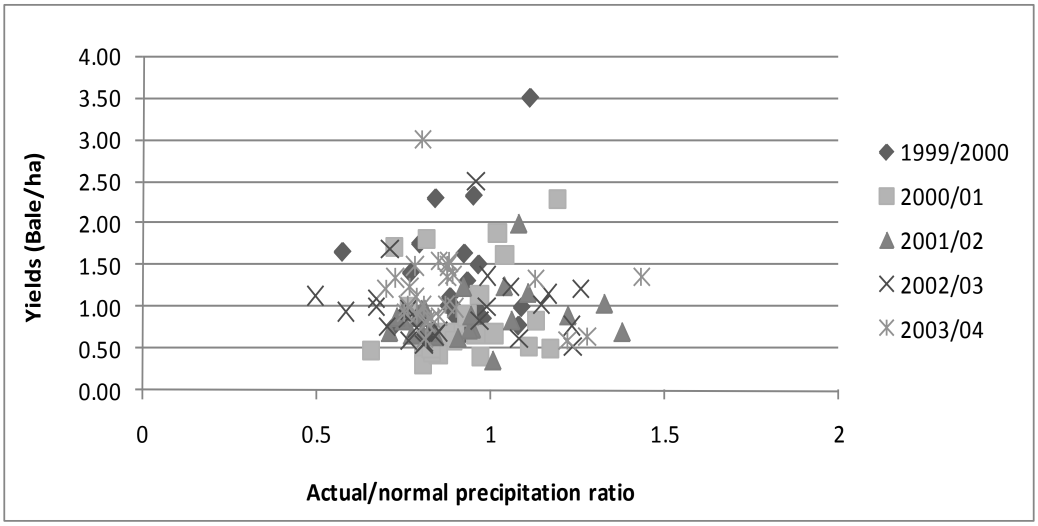
Figure 16. Precipitation and cotton yields levels in 23 districts of Andhra Pradesh, 2001-2004



Sources: www.indiastat.com; Government of India 2004.

Figure 16, depicting the case of Andhra Pradesh, is particularly interesting because each year follows a different pattern. First, 2001/02 seems to be an average year, with some districts dry and others receiving more rain, and a rather even, medium distribution of yield levels across districts, as depicted by a relatively spread out cloud of points around the average. In contrast, 2002/03 shows a homogeneous set of points, concentrated in an area on the left-hand side of the figure; this means that precipitation was low in all districts and therefore conditions were dry. At the same time, the yield distribution is much more condensed and at a low level; 2002/03 was a bad year for cotton in most districts. 2003/04 is centered toward normal precipitation, but compared to the two earlier years, it presents a wide range of yield levels across dry or less dry districts (including a record yield in one district). This variation cannot be completely explained by precipitation: technology differences may have contributed to this increased variance (that is, Bt cotton may have increased inequality between adopters and nonadopters, as shown in Morse, Bennett, and Ismael 2007a). Yield levels also varied in 2004/05, although less than in the previous year, but precipitation was clearly lower than 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, in 2005/06, precipitation was much higher than normal. The monsoon was particularly strong that year, which may have contributed to the moderately low and high yields observed in different districts.

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



Source: www.indiastat.com; Government of India 2004.

The picture in Maharashtra is much more obscure. It is very difficult to distinguish any pattern across years in Figure 17. Most points are located to the left of a ratio of 1, meaning that most districts had less than average rainfall in these years and relatively low yields. Perhaps the only visible feature for seasons before and after 2002 is the widespread rainfall estimates across districts— some having large excesses of rainfall, 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 comment on the role of rainfall in 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 tends 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, reaching low points in 2001/02 and again in 2004/05 (Table 16). The four listed Indian varieties also reached a minimum price in 2001/02 and 2004/05 (except the variety DCH-32 whose price did not change much 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 year of low prices. Combined, these two successive "bad" seasons, with cotton 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), potentially resulting in low or even revenues by cotton farmers in certain districts.

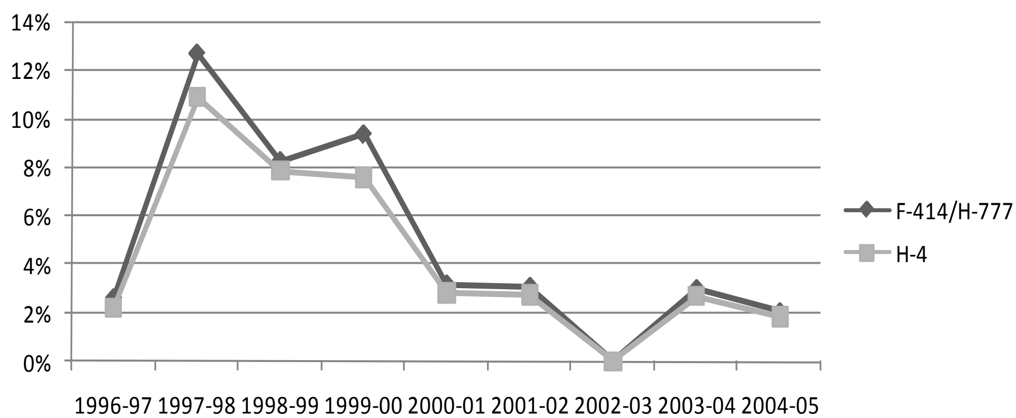
Table 16. International and Indian prices for cotton, 2000/01–2005/06

	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

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

Minimum support prices (MSP), which are designed as default prices for farmers unable to sell at market, also did not respond proportionally to these relative lows. Figure 18 shows that the increase in support prices was lowest in 2002/03 and 2004/05. Yet figures from 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 279,000 bales, twice as much as the former record level in 1985/86).

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



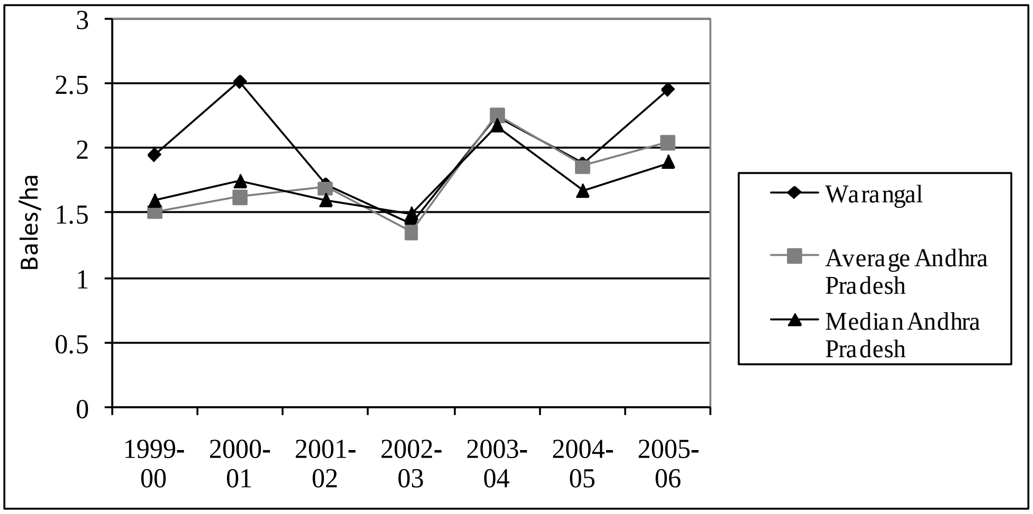
Source: www.indiastat.com

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 stands out. The most talked-about suicide area in Andhra Pradesh is the Warangal district, where Bt cotton did not perform well in 2002 (Andhra Pradesh 2002). Figure 19 shows that yield levels were down in this district first in 2002/03 and again in 2004/05. Reports on the effects of Bt cotton in the Warrangal district in the *kharif* season of 2004/05 are highly contradictory (Gandhi and Namboodiri 2006; Quayum and Sakkhari 2005).[9] However, two reports (Ramgopal 2006; Dev and Chandrasekhara 2007), based on surveys conducted in various

[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 higher positive results for Bt than for non-Bt.

cotton districts of Andhra Pradesh during the *kharif* season 2004/05, found that average returns for cotton during that season were negative. In both cases, Bt cotton led to relatively high yield and net return effects than non-Bt cotton, but Dev and Chandrasekhara found that both Bt and non-Bt cotton had negative average net income, while Ramgopal found that Bt farmers had positive but non-Bt farmers had negative net income. The main reported reasons for these negative outcomes were the drought and the low average output price that year in the region. These two elements and the conclusions of these reports do match our data on yields, rainfall, and prices.

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

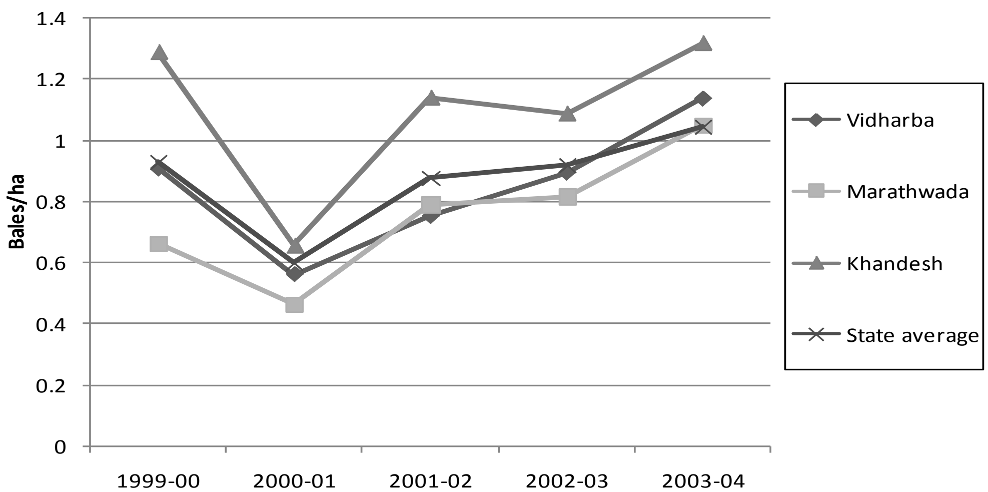


Source: www.indiastat.com

In the case of Maharashtra, economic studies tend to follow the national trend (Figure 20). Despite a large variance across seasons and datasets, all available studies found an advantage for Bt over non-Bt cotton, and if there was a multiyear deficit in rainfall, no year stood 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 stop in 2003/04, but despite the lack of precipitation, yield levels increased significantly in the regions said to be suicide-prone between 2000/01 and 2003/04 in Maharashtra. Vidharba, which is arguably the most talked about suicide prone area, actually almost doubled 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; Maharashtra, Government of 2005).

Although we can confer some of these results to our observations on prices, we were not able to find state- or district-level price data for Maharashtra at that time. Mitra and Shroff (2007) point to a variety of factors surrounding cotton cultivation that could lead to low prices, including trade liberalization, but only the high cost of cultivation is reported to be related to Bt cotton. But because they do not provide any specific data on Bt versus non-Bt cotton, we cannot confirm or deny any of their conclusions on the possible effects of Bt cotton. The case of 2006/07 is even more difficult to relate to Bt, as our only piece of evidence reports record high profits with Bt cotton (ASSOCHAM-IMRB 2007).

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



Source: Government of India (2004).

To sum up, even if there is no robust quantitative data that links Bt cotton adoption to farmer suicides in Maharashtra and Andhra Pradesh, available evidence shows that, in the face of low rainfall, low output prices, inadequate institutional context, and inadequate information, cotton in general and Bt cotton in particular could have contributed to lower farm revenues, increasing indebtedness, and therefore indirectly 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, together, likely contributed to indebtedness, which could have led to farmer suicides, particularly in the two states we focus on.

More General Factors and Trends Linked to Increased Indebtedness

General Change in Cropping Patterns toward Risky Nonfood Crops

Agriculture in Andhra Pradesh and Maharashtra, which used to be dominated by rain-fed, low-cost food crops, has gradually moved toward cultivation of cash crops. The area under food crops has declined in both states (Mishra 2006a; Shridhar 2006). In Maharashtra, cash crops like oilseeds have significantly increased (Mohanty and Shroff 2004). A comparison of cropping patterns in1958 and 1998 in Andhra Pradesh shows a rising trend toward cash crops such as groundnuts and oilseeds. A change in the cropping pattern toward cash crops in itself 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 parts of these states, farmers have been pushed toward financial distress.

Increased Dependence on Monsoons

Increased area under cash crops was not accompanied by increased irrigation, despite the importance of adequate water for 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, Qaim, and Zilberman 2005). Yet, Bt and non-Bt cotton are 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 (Narayanamoorthy and Kalamkar 2006).

Inadequate water supply has been a problem faced by farmers in Andhra Pradesh for a long time (Andhra Pradesh 2004). Public investment for irrigation has declined in the 1990s and so have the sources for surface irrigation (Shridhar 2006). Ongoing irrigation projects have stalled due to lack of funding (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 to discover reasons for farmer suicides find failure of the wells to be a major cause of indebtedness among farmers in Andhra Pradesh (Sridhar 2006). When wells fail, farmers not only lose the money spent in digging, but also may lose the cotton crop for lack of water (Andhra Pradesh 2004). In 2004, following a delayed release of water from the nearby Nagarjuna Sagar Dam, crop losses in parts of the state were not confined to cotton but also affected food crops (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 2006b).

Access to Rural Credit

Another factor leading to indebtedness is the lack of access to institutional credit. Most of the farmers who committed suicide in both states had high, unpaid loans. In Maharashtra, the share of total credit utilization going toward agriculture declined from 20.2 to 11.2 percent from 1991 to 2004 (Mishra. 2006b). In Andhra Pradesh, the share of moneylenders and other sources of credit going to agriculture is much higher, reaching about 68 percent (Mishra 2006b). A survey conducted by the government of Andhra Pradesh showed that 80 percent of all agricultural loans come from noninstitutional sources. The interest rate from these sources is high at 24–36 percent.[10] In both states, many of the families directly affected by suicide accessed local moneylenders for credit (Andhra Pradesh, Government of 2004). The advent of new technologies (not only Bt cotton and other hybrid crop varieties with high-priced inputs like seeds and also fertilizers and pesticides) made seed and pesticide sellers the new-age moneylenders (Rao and Suri 2006). Their high interest rates on loans became a major burden on farmers, particularly when cash crops failed to give them sufficient returns on their investments.

Rising Cost of Cultivation without Increased Minimum Support Prices (MSP)

Mitra and Shroff (2007) provide evidence of a general increase in cultivation costs, particularly in Maharashtra—an increase that was not compensated for by low or stagnating prices for cotton, therefore leading to negative net revenues. A survey conducted among the households of deceased farmers in Andhra Pradesh in 2003 found the same trend of unrecovered costs incurred in cotton also in high-yielding varieties of chilies (Rao and Suri 2006).

Most small and medium farmers sell to the local government procurement center, where prices have been very low (Dandekar et. al. 2005). However, as shown for cotton in Figure 18, the MSP did not increase as fast as cultivation costs. The Dandekar Report of 2005 claims that crops cultivated in the region were sold at a loss to farmers. According to this report, between 1996 and 2004, farmers' net losses were about 38 percent for paddy, 38 percent for cotton, 32 percent for groundnuts, 37 percent for soybeans, and 12 percent 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 suicide have consistently been harassed for immediate

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

repayment of loans even after a crop failure (Mishra 2006b). In some cases they had to sell their land and other assets to repay some of the amount owed. This factor is seen to contribute significantly to the feeling of loss of economic standing among farmers, along with the fact that they were continually relying on credit to get out of debt (Mishra 2006b). According to Sainath's communications with the families of deceased farmers, reported in *The Hindu* in June 2004, the farmers often took loans for expenses other than agriculture, including expenses related to health and weddings. Their income, however, was largely dependent on farm revenues, as they rarely had any source of nonfarm revenue. In such cases, a loss of crops, whether cotton, high-yielding varieties of chilies, or oilseeds, pushed the farmers over the brink to committing suicide.

This loss of social position was more prominent among small and marginal farmers who owned some land and hence some social standing. According to Sainath (2007b), most deceased farmers acquired loans to pay for marriages and other social events. Providing for the marriage of their daughters is thought of as an obligatory duty of the father. Farmers who lost crops and were in huge debt often concealed this fact from their families (Hardikar 2006). These observations show that the loss of social position was a concern that distressed farmers. Farmers felt it necessary to maintain an appearance of well-being to avoid the disgrace associated with the loss of social standing and their inability to perform the required social duties due to their already heavy debt burden. Committing suicide may have seemed like the only way for farmers to absolve themselves of their obligations to the moneylender and also to their families.

Availability of Toxic Pesticides

Although not noted in the section on suicide above, the annual estimates of the National Crime Record Bureau attribute about 20 percent 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 rural households in India, represent a major cause of death in rural Asia. It is estimated that 300,000 people living in rural areas of Asia commit suicide every year by ingesting toxic pesticides; this may represent 60 percent of all suicides in Asia (Gunnell and Eddleston 2003; Konradsen et al. 2007).

Government Policies: For Better or Worse?

Suicide also seems to be associated with the hope that the sacrifice of one family member will get the family back on track. This has become a distinct concern, since 2007, when the Indian government announced a major rehabilitation package for the families of farmers who had committed suicide (Kennedy 2007). While the scheme would only give 30 percent of the compensation directly to the family, while banking 70 percent to be disbursed over five years, it has definitely raised questions on the possible perverse incentive it may have created by encouraging farmers to commit suicide.

In March 2008, the Government of India also initiated a large loan waiver scheme (Rs 600 billion, equivalent to $15 billion) to allow for the clearance of debts for small and marginal farmers. Although designed as a strong response to the debt issue, this plan has been largely criticized for different reasons. Swaminathan (2008) has two major criticisms of the plan. First, he criticizes the unified definition of small and marginal farmers to whom the plan is targeted. Under the present definition, the plan provides waivers to farmers who own 1–2 hectares, which excludes many small and marginal farmers in rainfed areas, who tend to own up to 4 or 5 hectares, notably because their land is not very 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 moneylenders and traders provide a major share of the loans used by distressed farmers. By keeping these inadequate conditions, Swaminathan argues, it is clear that the plan is bound to be largely ineffective. Many others have criticized the methods of this plan. Indeed, a month after the implementation of the plan, the press was keen to report additional cases of suicide in Vidarbha as evidence of the plan's failure (Menon 2008).

6. DISCUSSION: TOWARD A SYNTHETIC CONCEPTUAL FRAMEWORK

Although we have reviewed 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 adequate 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 1 million farmers have planted Bt cotton, whereas a cumulative total of 90,000 farmers are reported to have committed suicide between 2002 (year of the commercialization of Bt cotton) and 2007. More important, the trend in farmer suicides in India appears to have slowed down since the year when Bt cotton was introduced, which would certainly not have happened if Bt cotton were responsible for increasing farmer suicides. Second, the adoption of Bt cotton *is not*, nor has 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 increased 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 was introduced represents less than 11 percent of the total number of farmer suicides before Bt. More generally, farmer suicides have happened in many other countries , including developed countries like Australia (Page and Fragar 2002), the United States (Scarth et al. 2000) or Great Britain (Thomas et al. 2003), with a diversity of crops, and most of them did not include Bt cotton (Benkimoun 2007; *The Economist* 2007b).

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 suggests that Bt cotton has been quite successful in most states and years in India, contributing to an impressive leap in average cotton yields, as well as a decrease in pesticide use and an increase in farmer revenues. So, as noted in several studies, the reality is much more complex, when one considers the conditions surrounding the use of Bt cotton, the resulting effects, and the socioeconomic constraints that have likely pushed farmers in particular regions to commit suicide during some years.

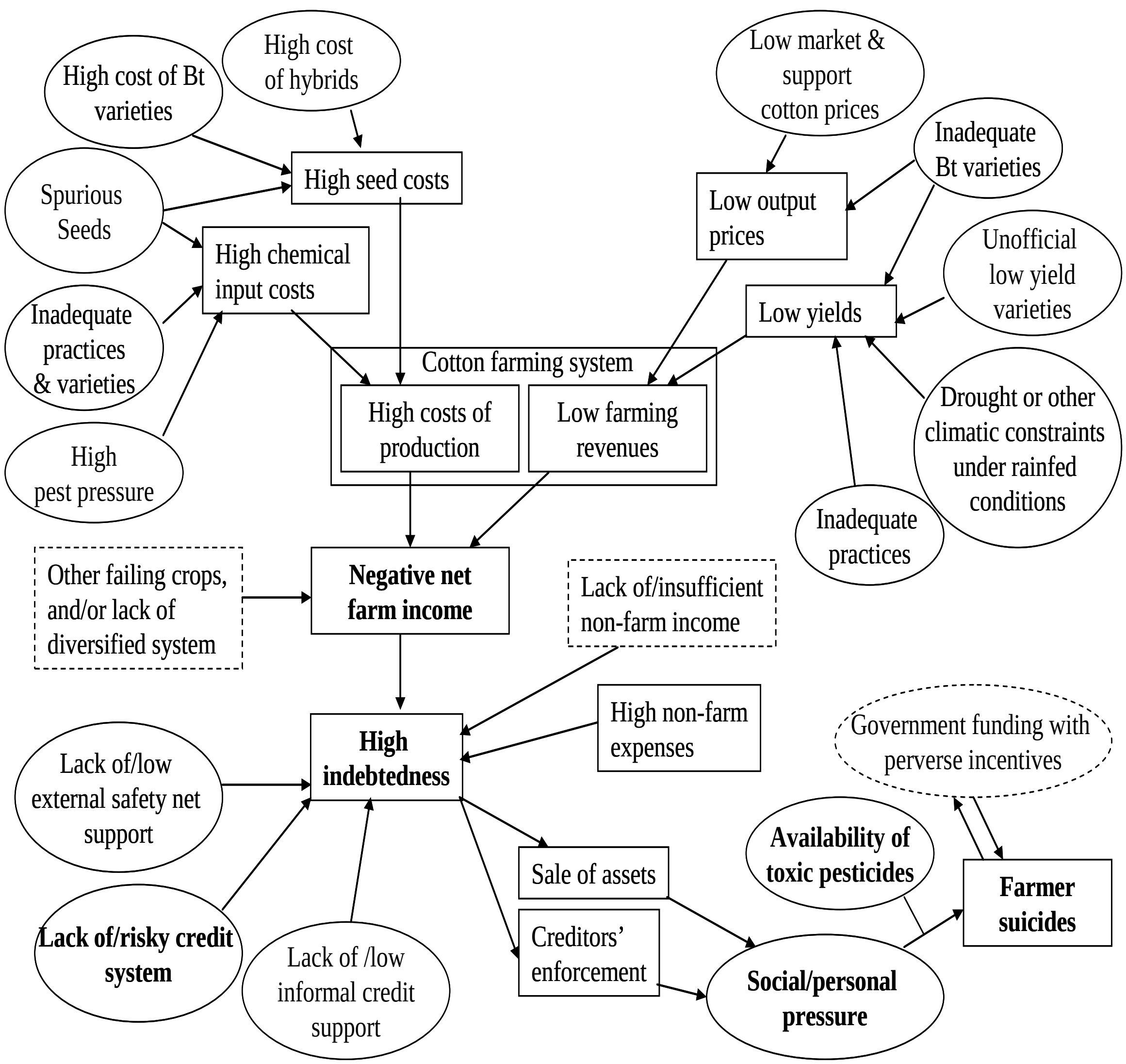
Using more disaggregated data, we explored some of the complexity on the hypothetical link between Bt cotton and farmer suicides in two states (Andhra Pradesh and Maharasthra) and specific suicide peak years: 2002, 2004, and 2006. We find that in Andhra Pradesh, low rainfall, leading to low yields and following a season with minimum prices could have played a role in the observed relative peak in suicides in 2002. Bt cotton, which had just been introduced, is unlikely to have played any significant role that year. In 2004, low rainfall and low prices, with another drought, resulted in low or negative revenues for cotton, including in some cases Bt cotton, whose seeds were sold at higher prices, and whose main official varieties were still mostly inadequate. But available evidence suggests that, on average, Bt cotton still performed significantly better than non-Bt that year, even in suicide-prone districts.

In Maharashtra, the two peak suicide years of 2004 and 2006 are more difficult to comprehend, notably because of a lack of complete or consistent data. The 2004 season was clearly one of low prices and very dry weather, especially in the suicide-stricken regions of Vidharba and Marathwada. Bt cottonseeds 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 suggests 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, which 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, including the constraints within the household, 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 socioeconomic 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 the 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. Farmer suicides and Bt cotton 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 makes suicide a relatively feasible option for highly distressed individuals. In fact, epidemiologists consider it a major factor explaining suicides in developing countries, as it is estimated to be the instrument of death in about 60 percent 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 suicide but these programs only came later (Kennedy 2007; *The Economist*/2007b). Social or other pressures may be the result of threats from within (social pressure due to the loss of earnings and being ostracized by 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 stem from high expenses and insufficient or sometimes nonexistent revenues, but they also critically depend on the formal credit constraints farmers face: a small number of formal lenders (if any), combined with high interest rates, low turnover periods, a lack of outside informal lenders (family members), or formal public support. In addition, farmers may have incurred multiple debts outside of the farm: according to some reports, nonfarm expenses, such as wedding or medical expenses or even purchases of household consumer goods, likely played a significant role in some of the distressed families (Saunders 2007). Still, farm expenses probably contributed significantly to the budget woes 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 nonfarm revenues, but we presume that farming revenues likely represent a large share of total income.

Under these assumptions, high farm expenditures and insufficient revenues probably played a role in the level of indebtedness of farmers, potentially leading some of these farmers to commit suicide. We still do not know the proportion of cotton growers among farmers committing suicide, 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 (*Press Trust of India* 2007). This may not necessarily be a successful strategy if these crops remain costly and if they still put nonirrigated farmers at risk when drought occurs. In any case, for the purpose of our framework, we assume that cotton has remained the main crop, in order to analyze in detail the potential sources of high expenses and unexpected low revenues.

High farm expenditures are common for cotton, because cotton requires a high level of chemical inputs. As explained earlier, 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 (*Economic Times* 2007a), 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 balance, Bt cotton is a costly technology compared with non-Bt cotton because of the highly priced seeds. At the same time, some farmers seem to have spent significant amounts on other inputs (fertilizers and so forth) 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 high pesticide use was still required. Other farmers seem to have purchased high-cost spurious seeds, thinking the seeds were Bt seeds, but they were duped. . Lastly, and more generally, a number of farmers bought Bt seeds without considering the type of Bt variety they were purchasing; therefore they blamed the Bt technology itself, when actually the variety they purchased was inadequate for their conditions.

Low prices or low agricultural outputs or both help explain the low farm revenues. International cotton prices have been quite low since 1999, which could play a role in the low cotton revenues. But this trend started long before the period we focus on. In fact, many farmers in these regions were only able to sell to the government for a minimum price, which was lower than the commercial price. Our review of economic empirical studies has shown that, on average, the seed cotton price from Bt fields was not statistically different from that of non-Bt seeds, but during the first few seasons, in certain locations, particularly in Andhra Pradesh, there was a difference in prices partially because of the lower quality of the cotton lint from available Bt varieties, compared with non-Bt varieties. With regard to production, the first Bt cotton varieties did have higher yields than conventional cotton in most places and seasons in India. Still, their performance varied greatly across locations, and in extreme cases they apparently did not perform well for a number of reasons, including climatic conditions (drought or a 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 probably did not apply to Bt cotton alone. Conventional cotton is also relatively high cost, more because of the price of pesticides than the price of seeds, and it is also vulnerable to drought in rain-fed conditions. Other cash crops are expensive and likely to 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 whom decided to commit suicide.

More generally, one has to read this framework as a series of possible explanations that together (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 confirmation, if not of causal relationships, at least of a correspondence between the resurgence of suicides and the various factors we identified.

7. CONCLUSION

In the last five years, India has rapidly increased its production of cotton, becoming a major exporter, and it has exceeded the production of the United States in 2007/08 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 of being 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 hypotheses 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 the 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 Bt cotton may have played a role in specific cases and seasons. These cases were mainly the result of institutional, climatic, and economic constraints, among many other factors. By compiling and synthesizing available data from official sources, research reports, and economic and policy analyses we are able to clearly reject the first set of hypotheses and support the second.

We first show that despite the recent media hype around farmer suicides, fueled by civil society organizations and reaching 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 and tragic phenomenon, but it still only represents 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, which may be underestimated, but without better data, one cannot deny that claim.

Second, we provide 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. However, 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 on average Bt cotton has had a significant positive effect on cotton productivity in India, raising farmers' income via an increase in yields and a reduction in pesticide use, despite increasing overall production costs. But we also find that Bt cotton's results during the first three seasons varied across studies and locations. It did not always perform well in particular areas and seasons, mainly because of climatic conditions, low cotton prices, inadequate farming practices fueled by misinformation about the new technology, and the widespread use of initial Bt varieties that were not adequate for all locations and farming practices. We also find that the institutional context played a significant role where the outcome with Bt cotton was not positive, including lack of or weak extension systems, lack of information on the different types of seeds, and the presence of unofficial and spurious seeds sometimes being sold as official Bt.

Third, we review 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 or 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, especially the insufficient or risky credit systems with no formal or informal support and the wide availability of toxic pesticides. Still, by using more disaggregated data on suicides and on the reported effects of Bt cotton in Andhra Pradesh and Maharasthra, two states with farmer suicide hotspots in certain seasons, we have shown that although 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 the adoption of highly costly agriculture in the risky, rain-fed conditions found in the states of Andhra Pradesh and Maharashtra. The absence of irrigation systems in drought-prone areas (especially in Maharashtra), combined with specialization in high-cost crops, low market and support prices, and the absence or failure of the credit system, is a clear recipe for failure. It is possible, therefore, that under the conditions in which it was introduced, Bt cotton, an expensive technology that has been poorly explained, often misused, and initially available in only 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 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 cannot prove their relationship in a robust manner.

One implication of this study is the critical need to distinguish the effect of Bt cotton as a technology with the context in which it was introduced. Revealed preferences based on farmer adoption rates and official or unofficial data all point toward the overall success it has had in controlling pest damage and therefore raising average yields in India. In fact, some have argued that farmers' demand played a role in approval of the technology; when the government requested that all fields of unapproved Bt cotton be burned in 2001, some farmers demonstrated against this decision, asking for clear access to the pest-resistant technology. In addition, the increasing adoption rate in two suicide-prone states, Andhra Pradesh and Maharashtra, indicates 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 a 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 costly new technologies like Bt cotton. Information should not come from seed dealers, whose job it 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 nonfarming activities to spread the risk they may incur, instead of spending everything on one single 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 toward the failure of the socioeconomic environment and institutional settings in rural dry areas of India. The absence of a 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 suicide likely all contributed to farmer suicides. This has nothing to do with cotton or the use of new technology and would suggest many potential policy changes. In several states such as Karnataka and Andhra Pradesh, some policy changes have already been proposed (Indo-Asian News 2007). Others have been implemented by the Government of India, with significant budgets but arguably inappropriately designed programs that either reward farmer suicides or offer loan waivers to only a minor portion of the distressed farming population. Rather than spending more on large programs directed toward farmer suicides because of hype in the media, a rational approach would be to use better-targeted state or district programs for distressed farmers. Also, much more federal and state investment could help prevent the 80 percent or more other cases of suicides.

APPENDIX: ADDITIONAL TABLES AND FIGURES

Table A.1. Approved Bt cotton hybrids in India 2002–07

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 (2007), GEAC website: http://www.envfor.nic.in/divisions/csurv/geac/status.html.

Table A.2. 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)	5,950 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 increases profits by 162%. All states gain from Bt cotton, the biggest relative profit increases occur in Maharashtra (+375%), Andhra Pradesh (AP) (+217%), Gujarat (+198%), and Madhya Pradesh (MP) (+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.	Observations show yield gains with Bt of 61% on average, 42% in AP, 43% in Gujarat, 70% in Karnataka, 72% in MP, and 44% in Maharashtra. Pesticide sprays are reduced by 57% in AP, 39% in Gujarat, 61% in Karnataka, 72% in MP, and 64% in Maharashtra, for an average reduction of 62%.
Bennett, Ismael, and Morse (2004)	Farm statistical survey, 7,751 plots in 2002, 1,580 in 2003	Maharashtra	2002 and 2003	Bt: MECH-162, MECH-184, MECH 12, Non-Bt: Bunny, Tulsi, NHH-44, JK-666	On average, Bt reduces bollworm pesticide use by 70-80% but has ambiguous effects 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, Ismael, and Morse (2006)					Production function analysis finds average yield effects of 33 and 48%.
Morse, Bennett, and Ismael (2005a)	7,793 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, Ismael, and Morse (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, Bennett, and Ismael (2005b)					Same results, but also provides a table on cost of seed as percentage of gross margins: 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.

Table A.2. Continued

Study	Type and data	Location	Season	Varieties	Results
Morse, Bennett, and Ismael . (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 nonadopters.
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, study finds 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 finds 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)					On average, with Bt cotton: less spraying (2.6 times less), higher costs, higher yields (mean difference 34%), higher profits. However, Andhra Pradesh suffered losses, because of high pesticide use, severe drought, and inadequate Bt varieties. Also, Bt varieties provided lower-quality fibers.

Table A.2. Continued

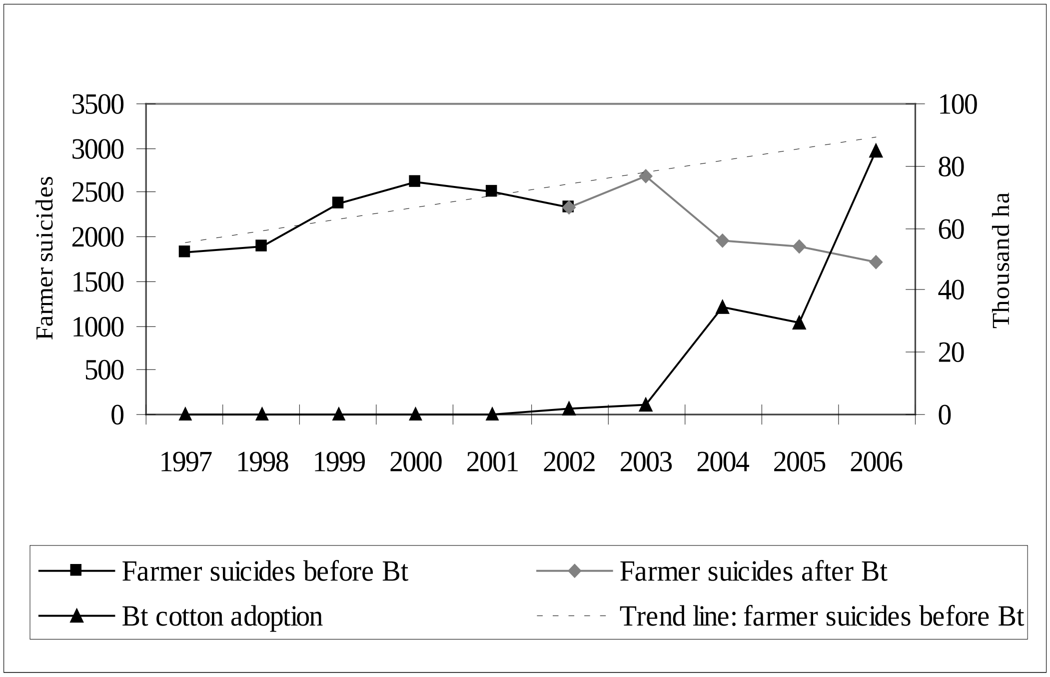
Study	Type and data	Location	Season	Varieties	Results
Narayanamoorthy and Kalamar (2006)	Statistical survey, 150 farms, including 50 non-Bt	Vidarbha region of Maharashtra: Budhana and Yuvamatal	2003/04 kharif*	Bt: MECH-162, MECH-184, Non-Bt: Bunny 145 and Ankur 161.	Early adopters are mainly irrigated farmers. Show that Bt 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 not 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, Waibel, and Orphal (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 spraying.
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 seed costs up 155%, yields down 35%, cost of cultivation up 11%, output price down 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.

Table A.2. Continued

Study	Type and data	Location	Season	Varieties	Results
Ramgopal (2007) [2006?]	180 farmers, 90 Bt, 90 non-Bt.	Andhra Pradesh: Warrangal, Guntur districts	2004/05	Bt: Rasi, MECH, unofficial. Non-Bt: Bunny, Super Bunny, Brahma, JK, Satya others.	Comparing total costs and benefits: seed costs, +171%; insecticide costs, -28%; total costs, +5%; yields,+46%; price of cotton, -0.8%; net income, +380%. In Guntur, both Bt and non-Bt had positive net income; in Warrangal only Bt led to 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 pink bollworm, and 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 yields the same, same output price, higher cost of seeds and pesticide and lower profit for Bt (no statistical difference computed). That season more unofficial seeds were distributed and MECH 162 rarely used, given its poor results in previous season.

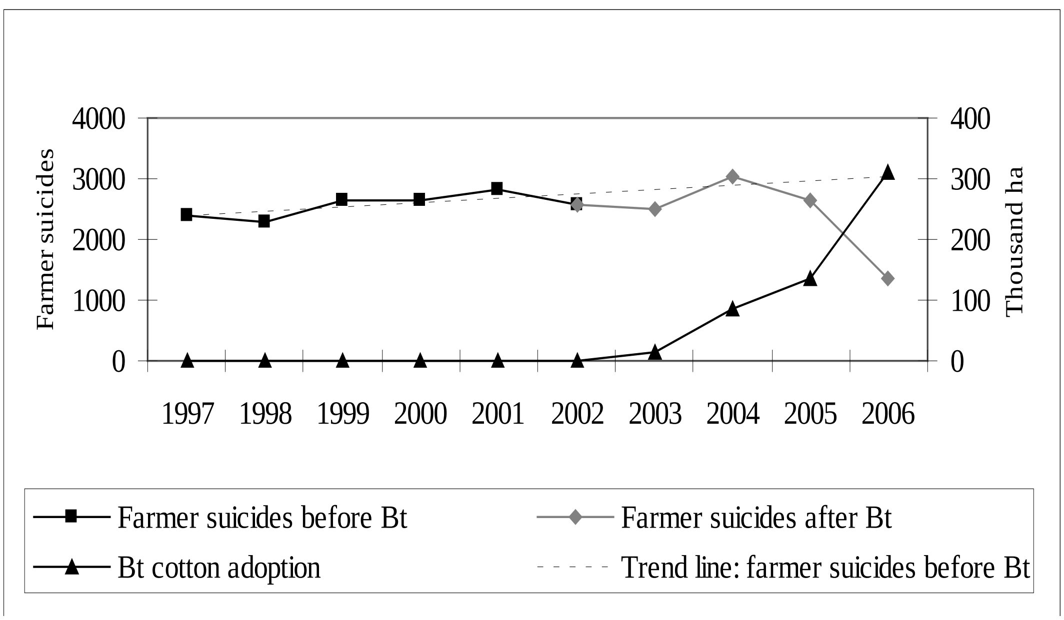
Note: * Kharif means that the crop was harvested in winter during the first calendar year of the crop season.

Figure A.1. Farmer suicides and Bt cotton area in Karmataka, 1997-2006



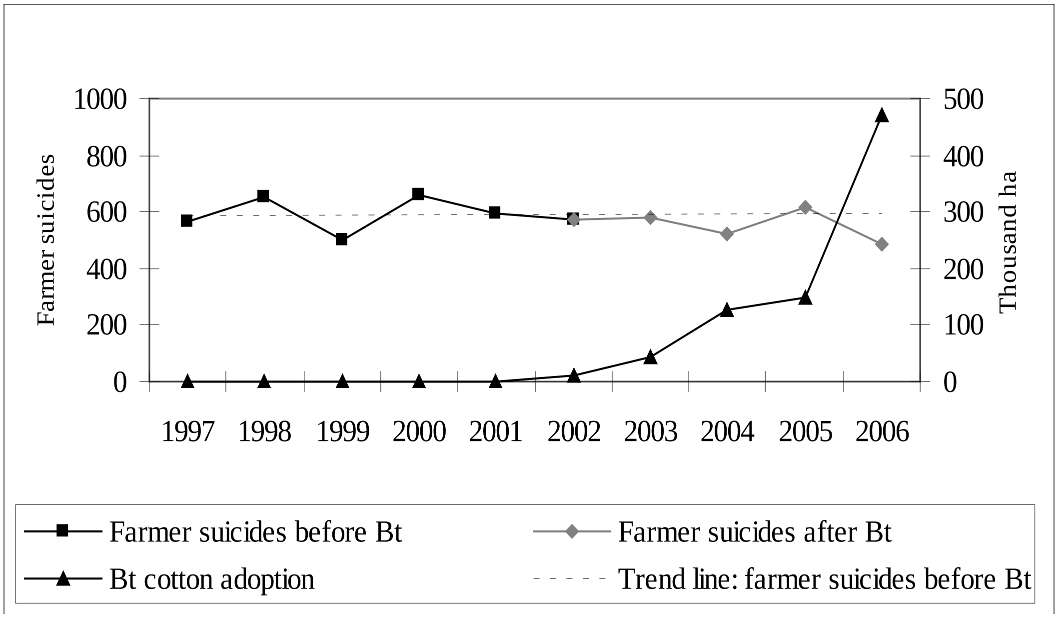
Source NCRB various years.

Figure A.2. Farmer suicides and Bt cotton area in Madhya Pradesh, 1997-2006



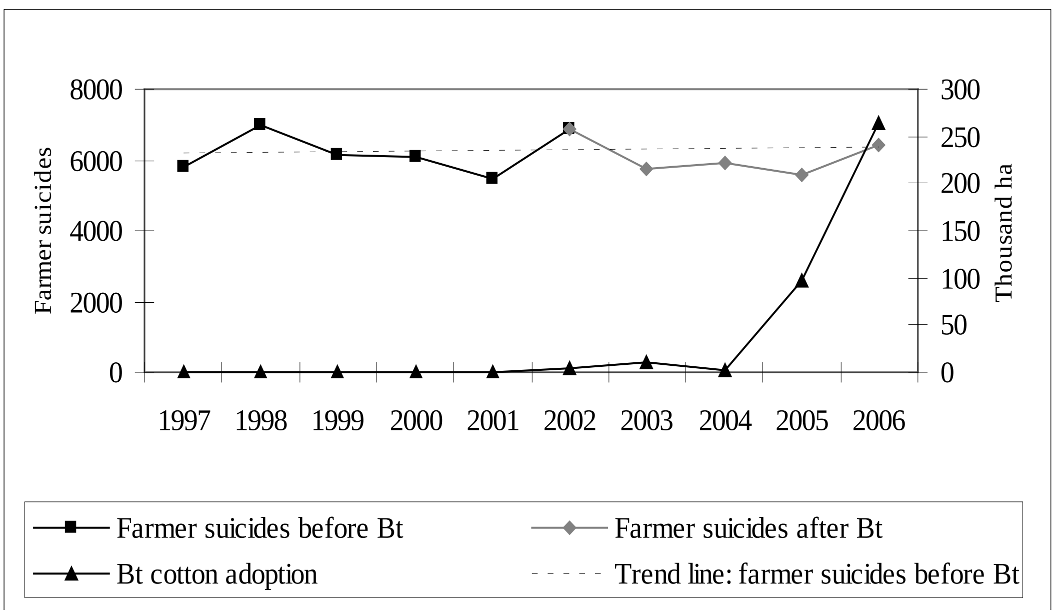
Source: NCRB various years.

Figure A.3. Farmer suicides and Bt cotton area in Gujarat, 1997-2006



Source: NCRB various years.

Figure A.4. Farmer suicides and Bt cotton area in other states, 1997-2006



Source: NCRB various years.

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