7 India's experience with Bt Cotton: Case studies from Gujarat and Maharashtra[1]

N. Lalitha, Bharat Ramaswami and P.K. Viswanathan

Introduction

India grows more *Bacillus thuringiensis* (Bt) cotton than any other country in the world. While this is partly a reflection of the fact that India is the world's largest cotton producer, it is also an indication of the rapid spread of the technology since it first became available in 2002. While India was cautious in introducing the technology, it has subsequently found wide acceptance among farmers.

Cotton is grown on 9.5 million ha by about 4–4.5 million farmers (with an average cotton holding of little more than 2 ha) in nine states in India. Although it has the largest cotton area, India's production has been characterized by relatively low yields, reflecting the marginal environments in which much cotton is grown, the fact that only about one-third of the crop has access to irrigation, and inadequate crop management. However, the introduction of Bt cotton has coincided with increasing cotton yields and production in the past few years.

In this chapter we are particularly interested in the seed and pesticide markets that help determine farmers' ability to take advantage of Bt cotton. The goal is to understand whether there are gaps in the information utilized by growers in making decisions about crop management. These gaps could arise because of market failures or deficiencies in other institutions such as government regulation, product testing and agricultural extension.

The chapter is based on a farm-level survey carried out during the 2007–08 cotton season in two states, Gujarat and Maharashtra. Although cotton is widely grown in India, these two states together accounted for 55 per cent of cotton output and 60 per cent of cotton area in 2007. In addition, they provide a useful contrast for the study; Gujarat is one of the more advanced cotton-growing states, with widespread access to irrigation, while Maharashtra is home to many of the most resource-poor cotton growers, farming on marginal land. An additional contrast is that Gujarat is the first place that unauthorized Bt cotton seed was sold, at least as early as 2001, before the release of the authorized varieties. Gujarat continues to have the highest

1 We sincerely thank our research investigators who helped us collecting the primary data from farmers in both the states. Particularly we thank Ila Mehta, Devendra, Laljibhai, Bhimbhai and Prabhat who worked tirelessly in Gujarat. In Maharashtra we were ably assisted by Mr. Atul Sharma and his team members Kishore, Promod, Mayur and Vaishali.

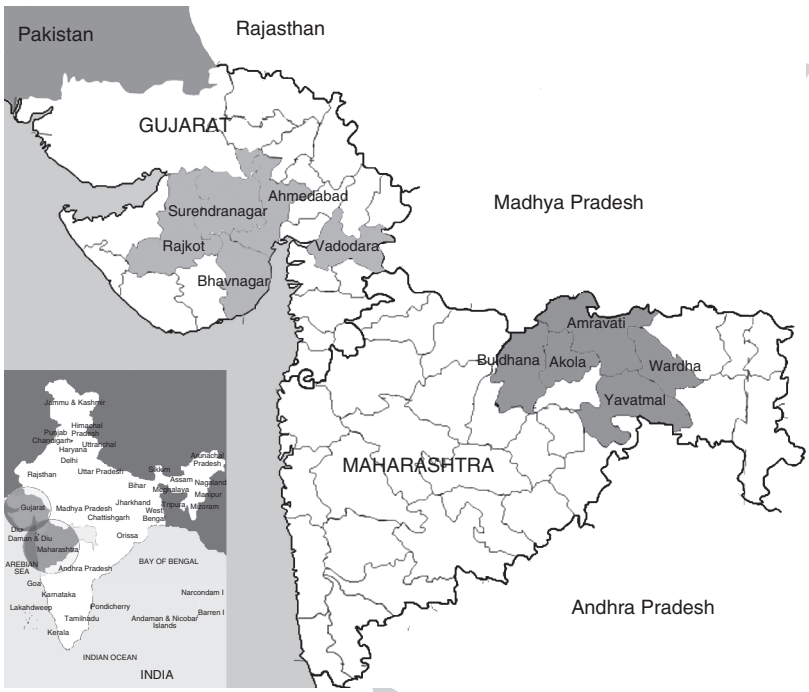

Figure 7.1 Location of survey areas in India

concentration of unauthorized Bt cotton varieties and thus provides an interesting opportunity to follow the progress of an underground seed market.

In Gujarat, the farm survey was carried out in five leading cotton-growing districts (Ahmedabad, Bhavnagar, Rajkot, Vadodara and Surendranagar) which together account for 65 per cent of cotton area in the state. This choice was partly determined by the fact that we had done an earlier study of cotton farmers in these districts in 2003–04 and could thus assess changes in the intervening years. The study in Maharashtra was done in traditional cotton-growing areas in the Vidarbha region, covering five districts (Wardha, Amaravati, Akola, Yavatmal and Buldhana) which together account for about 40 per cent of the cotton area in Maharashtra. The survey areas are indicated on the map in Figure 7.1.

In each district, approximately 40 cotton growers were randomly selected through a three-stage process. Within each district, four *talukas* (an administrative unit smaller than a district) were randomly selected and within each taluka, two villages were randomly sampled. The target was to sample five cotton growers within each village. In Maharashtra, the sample design accommodated more than five growers in some villages because of concerns over attrition during the length of the survey.

The study involved three visits to each farmer. The first visit took place shortly after planting and data collection focused on farm and household characteristics and current and historical variety choices. The second visit came during the growing season and focused on insect control practices, including a careful recording

Table 7.1 The study sample

District	*No. of farmers interviewed*	*Total no. of cotton plots planted by sample farmers*	*No. of focus plots for study of insecticide use*
Gujarat Districts			
1. Rajkot	40	108	89
2. Bhavnagar	40	115	85
3. Vadodara	40	89	75
4. Surendranagar	40	128	87
5. Ahmedabad	40	106	81
Total Gujarat	200	546	417
Maharashtra Districts			
1. Wardha	43	91	83
2. Amaravati	40	118	101
3. Akola	40	100	86
4. Yavatmal	43	77	69
5. Buldhana	39	88	83
Total Maharashtra	205	474	422

of all use of insecticide. (Farmers had been provided with notebooks during the first visit to help record their insecticide practices.) The final visit was shortly after harvest; it completed the inventory of insecticide use as well as collecting yield and other data. As many farmers have several plots of cotton, we recorded basic data about all the plots. However for detailed analysis on crop management, such as decision-making about seed choices, insecticide practices, harvesting and post-harvest management practices, we focused on a maximum of three plots for each farmer, choosing the largest plots that provided information about the range of variety types the farmer was growing. The basic characteristics of the sample farm households and holdings are summarized in Table 7.1.

The rest of the chapter is organized as follows: we first look at the utilization of Bt cotton by summarizing some of the most important characteristics of the cotton farmers in our sample and the nature of the Indian seed market, followed by an examination of the patterns of Bt cotton adoption and its impacts on yields. The next section looks more closely at how cotton farmers choose the seed they will plant; it reviews the types of Bt cotton available to farmers and then looks at the criteria they use in making seed choices. The following section examines how farmers use insecticides and the relationship between Bt technology and insecticide use. The chapter closes with some conclusions about the ability of farmers to take advantage of Bt technology.

The utilization of Bt cotton

The cotton farmers

Cotton is grown in contrasting environments in the two states. In the study districts of Gujarat, cotton is an important crop accounting for 27–51 per cent of cropped area. Other crops grown in these districts include groundnut, wheat, pearl millet and sesame. A few rows of crops such as maize, castor or mung beans are sometimes

Table 7.2 Sample farmer characteristics

District	*Total cultivable area/farmer (ha)*	*Cotton area/farmer (ha)*	*Average no. cotton plots per farmer*	*% land irrigated*	*% total income from cotton*
Gujarat					
1. Rajkot	6.11	3.40	2.2	79.5	70.38
2. Bhavnagar	8.86	6.19	2.5	77.9	78.62
3. Vadodara	8.46	4.67	2.0	91.4	62.63
4. Surendranagar	8.00	5.73	2.9	53.0	85.30
5. Ahmedabad	7.26	5.41	2.2	60.3	79.08
All districts	7.70	5.08	2.7	72.6	75.33
Maharashtra					
1. Wardha	7.15	2.10	2.1	56.54	40.35
2. Amaravati	4.41	2.11	2.7	32.16	55.58
3. Akola	8.27	2.54	2.5	51.25	34.63
4. Yavatmal	5.43	1.67	1.9	19.48	37.88
5. Buldhana	6.31	1.67	2.3	75.66	34.97
All districts	6.30	2.02	2.3	49.02	40.92

Source: Survey data.

sown intercropped in cotton fields. Cotton is planted in the month of June and most of it is harvested by December, but for some long-duration varieties the last picking may take place in March. Gujarat's cotton area has been expanding in recent years, rising from 1.7 million ha in 2001 to about 2.5 million ha in 2007.

In Maharashtra, on the other hand, cotton area has remained steady at about 3 million ha in the past decade. There is less irrigation than in Gujarat; other crops that are grown include wheat, sorghum, onions, pigeon peas and pulses. Cotton area has recently been losing out to soybeans, which also enjoy greater policy support from the state government. Normally cotton is planted in the middle of June and harvested in the month of December. In Maharashtra cotton fields are often intercropped with occasional rows of pigeon pea, mung bean or black gram.

Table 7.2 summarizes some of the principal characteristics of the two state samples.

In both areas, cotton farmers buy all of their production inputs in shops located in nearby towns whose dealers represent seed and chemical companies. The only exception is fertilizer in Gujarat, where many farmers get fertilizer on credit through cooperative societies. All cotton farmers sell their seed cotton to private buyers who then deliver it to ginneries. The cotton is not graded at the time of purchase and farmers receive a standard price. Although the government declares a minimum support price, this has little influence on the prices paid for cotton procurement.

The cotton seed industry

Indian farmers have had access to a range of cotton varieties for many years. It is important to note that India was the first country in the world to commercialize

cotton hybrids, the outcome of a public sector research program that led to the first cotton hybrid in 1970. Through the 1970s and 1980s the public sector agricultural research system released many location-specific hybrids whose seed was sold by state seed corporations. Although the first privately bred, proprietary hybrid was released in 1979, it was only in the 1990s that private sector efforts gained momentum. In 1996 hybrid varieties accounted for about 55 per cent of the total cotton area, but two-thirds of this was covered by public hybrids. By 2004, hybrids covered 6 million ha (two-thirds of the cotton area), of which 5 million ha were sown to proprietary hybrids (Murugkar *et al.* 2007). Hybrid cotton spread more rapidly in the southern and central zones of India than in the northern zone (e.g. Punjab), where the late maturity of most hybrids made them less compatible with local cropping systems, but the popularity of Bt cotton (combined with increased private breeding efforts) has meant that even states such as Punjab have now moved towards Bt hybrids.

Thus long before the advent of Bt cotton many cotton growers in India were familiar with hybrid seed and with the practice of purchasing seed from dealers each year. Nevertheless, the early experiences with Bt cotton in Gujarat and Maharashtra exhibit some important differences.

Gujarat is the home of the first cotton hybrid (H4), developed by the Gujarat Agricultural University and sold to farmers through the Gujarat State Seed Corporation (GSSC). H4 and its successors held sway among Gujarat cotton farmers for a long time, although proprietary hybrids also began making significant inroads.

Before the approval of the first Bt varieties from Mahyco Monsanto Biotech (MMB) in 2002, an unauthorized Bt cotton hybrid was discovered in farmers' fields in Gujarat. The discovery was made in 2001, but the variety may have been present even earlier. The unauthorized variety was NB151, a variety registered with the Gujarat government as a conventional hybrid and belonging to Navbharat Seeds, a firm based in Ahmedabad. Later investigation confirmed that the Bt gene in NB151 was the one developed by Monsanto and used in the approved varieties. After initial threats by the state government to destroy all fields with NB151, farmers were allowed to harvest and market their crop, but the company was barred from the cotton seed business and has been prosecuted for violating the biosafety laws.

Despite the ban on Navbharat, the unapproved Bt hybrids continue to be widely available and highly popular in Gujarat. Although the unapproved seed is particularly prevalent in Gujarat, it can be found to a lesser extent in some other states, including Andhra Pradesh and Punjab. It would appear that the breeding lines for the NB151 hybrid have been provided to a number of informal seed enterprises who produce the seed on farms in Andhra Pradesh and Gujarat. In the early years the variety was in such high demand that second generation (F2) seed of the hybrid was also sold. It was usually identified as such and sold for a lower price than the F1.

The unauthorized Bt varieties are hybrids, and because hybrid seed production requires organization, capital and specialized labour, unauthorized seed production and distribution is unlikely to be the outcome of individual acts of piracy (Ramaswami *et al.* forthcoming). **[AQ]** Rather, the seed is produced through a loose

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network of seed growers (many of whom were former contract seed growers for Navbharat) and their agents. It is not clear how many people in this network obtained the Navbharat inbred parental lines, but their ownership seems fairly dispersed. As a result, there has been wide experimentation and the male parent (with the Bt gene) often has been crossed with different female lines producing a range of hybrids well adapted to local conditions.

Although the seed producers are careful not to advertise on a wide scale, the unauthorized seeds are sold under locally known brand names, or simply known as NB151. It may be sold as loose seed, but is more frequently packaged. Many of the packages superficially resemble those of legitimate brands, but the name and location of the seed company is absent and the package often includes a disclaimer stating that it does not contain commercial seed but is merely an opportunity for farmers to exchange seed among themselves. If the production and distribution of unauthorized seeds occurs through individual growers saving and exchanging seed, as allowed by Indian seed law, governments have limited powers to enforce biosafety laws. This loophole has allowed the state government to claim ignorance of the extent of unauthorized plantings, although seed law would allow inspectors to raid shops and seize at least the unauthorized seed sold in individual packets. For their part, unauthorized seed sellers try to soften their challenge to the law by taking care to mask their sales as seed exchange. The unauthorized seeds are sold without a bill of purchase. Although it is still not on display in any shop, some dealers are now willing to talk openly about it, as they have seen that the state government has not attempted to restrict the sale of what is still a very popular type of seed.

The immense popularity of the unapproved Bt hybrid in Gujarat captured a large part of the market previously in the hands of legitimate seed producers, both public and private. While hybrid cotton seed was previously 25 per cent of the turnover of the GSSC, this dropped to 5 per cent by 2003–04. Vikram Seeds, previously the leading private hybrid cotton seed provider in the state, lost most of its market, compounded by the fact that it was not among the first Indian companies to license the Bt gene for its own breeding program (Murugkar *et al.* 2007). It is only recently that legitimate seed companies with approved Bt cotton hybrids have begun to make an impression on the Gujarat market.

In addition, some farmers in Gujarat also grow local (*desi*) cotton. These are traditional varieties of *Gossypium arboreum* which are known for their drought tolerance and resistance to sucking pests. They tend to go be planted on unirrigated land, usually by larger farmers, and they receive less intensive management than the hybrids.

The cotton seed situation in Maharashtra is somewhat more straightforward. Before the introduction of Bt cotton, many Indian seed companies had established a market share for their proprietary hybrids in the state. In addition, some public hybrids produced and sold by the Maharashtra State Seed Corporation were also popular. The original approved Bt varieties were only available from one company (Mahyco) and a few farmers began to plant them. Some unapproved seed was also available, but the authorities in Maharashtra have been quite strict in controlling the availability of such seed. Dealers say they would be closed down if they were found selling it, and no farmer in our Maharashtra sample claimed to

Table 7.3 Bt cotton adoption trends for sample farmers

Gujarat			
	Aggregate cotton area (ha)	*Aggregate Area under Bt cotton (ha)*	*Proportion of cotton area under Bt cotton*
2003/04	737.25	394.33	0.54
2004/05	781.78	519.43	0.67
2005/06	879.76	704.86	0.80
2006/07	967.21	832.79	0.86
2007/08	1014.57	912.55	0.90
Maharashtra			
	Aggregate cotton area (ha)	*Aggregate Area under Bt cotton (ha)*	*Proportion of cotton area under Bt cotton*
2003/04	376.92	6.48	0.02
2004/05	406.88	18.62	0.05
2005/06	414.17	65.59	0.16
2006/07	450.61	244.94	0.54
2007/08	414.57	300.81	0.73

Source: Survey data.

be growing unapproved Bt cotton. As the companies who had been providing conventional hybrids to Maharashtra farmers became able to license the Bt gene from Monsanto they were soon able to bring to market Bt versions of some of the varieties that farmers had been planting. In addition, other new Bt hybrids began to appear on the market in Maharashtra.

Adoption of Bt cotton

The trends in the adoption of Bt cotton are summarized in Table 7.3. In Gujarat, only 10 per cent of the sample area is under non-Bt cotton and almost all of this is *desi* varieties. The adoption of Bt cotton has occurred along with an increase in area under cotton, possibly because the yield advantages of Bt cotton are edging out other competing crops. In Maharashtra, area under cotton is leveling off and the adoption of Bt cotton lags behind Gujarat. The big jumps in adoption have occurred more recently than in Gujarat, in 2006 and 2007, corresponding to similar trends at the national level.

Another way to look at the adoption process is to compare the number of farmers that grow only Bt varieties, only conventional varieties, or both types of variety. Table 7.4 shows that in 2003–04, almost the entire sample in Maharashtra and nearly half the sample in Gujarat grew only non-Bt varieties. Since then, the situation has rapidly changed in both states. The number of growers with only non-Bt cotton has diminished to negligible levels in Gujarat and to only 30 growers in the Maharashtra sample. The rest of the farmers grow either only Bt cotton varieties or a combination of Bt and conventional varieties.

Table 7.4 Adoption trends by number of growers[1]

Year	*Gujarat No. of farmers growing:*			*Maharashtra No. of farmers growing:*		
	Only Bt	*Bt and non-Bt*	*Only non-Bt*	*Only Bt*	*Bt and non-Bt*	*Only non-Bt*
2003/04	102	10	69	3	0	169
2004/05	122	16	49	9	3	174
2005/06	160	12	25	29	17	142
2006/07	170	19	10	92	46	60
2007/08	174	21	4	134	42	30

Source: Survey data.

Note
1 A few sample farmers are not included in the earlier years because they were not able to clearly identify the varieties they were growing at that time.

Table 7.5 The diffusion of illegal seeds in Gujarat (sample area)

	Area under illegal seeds (ha)	*Proportion of Bt cotton area under illegal varieties*	*No. of farmers growing only illegal Bt varieties*	*No. of farmers growing only legal Bt varieties*	*No. of farmers growing both legal and illegal Bt varieties*
2003/04	304	0.77	81	23	8
2004/05	425	0.82	102	24	12
2005/06	481	0.68	106	43	23
2006/07	525	0.63	98	51	40
2007/08	535	0.59	100	62	34

Source: Survey data.

Table 7.5 shows that while the total area under unauthorized Bt seeds has increased in Gujarat, this phenomenon peaked in relative terms in 2004–05. Since then, the area under authorized Bt seeds has expanded much more rapidly, although by 2007–08 the proportion of Bt cotton area under unauthorized seeds was still greater than 50 per cent. The table also looks at the diffusion of unauthorized seeds by number of growers. In the early years, most Bt growers adopted unauthorized varieties. After 2004–05, while the number of unauthorized Bt growers has remained stagnant, the number of authorized Bt growers has grown. The early authorized Bt varieties did not necessarily have all the agronomic qualities of some of the conventional varieties, but starting in 2005 a much wider range of commercial Bt hybrid varieties became available. This may have played a role in the steadily increasing adoption of authorized Bt varieties in Gujarat.

Who adopts Bt cotton?

Because almost all farmers in Gujarat plant at least some Bt cotton, and the vast majority in Maharashtra do so, we have difficulty analysing differences between

Table 7.6 Adoption of Bt in Maharashtra

Farmer characteristics	*Farmers who use some or all Bt*	*Farmers who use no Bt*	*Significance*[1]
No. of farmers	176	30	—
Average age	43.76	45.1	ns
Average education (years)	11.12	9.46	*
Average landholding (ha)	6.7	3.5	***
Average cotton holding (ha)	2.09	1.55	*
% income from cotton	39.7	46.7	ns

Source: Survey data.

Note
1 ns = not significant,
* significant at 10% level,
** significant at 5% level,
*** significant at 1% level.

Table 7.7 Differences between growers who use unapproved seed and others, Gujarat

Farmer characteristics	*Farmers who use only unapproved varieties*	*Other Bt growers (who use some or all approved varieties*	*Significance*[1]
No. of farmers	100	96	—
Average age	46	46.8	ns
Average education	9	10.2	ns
Average landholding (ha)	6.68	8.91	**
Average irrigated landholding (ha)	4.11	7.26	***
Average cotton holding (ha)	4.94	5.24	ns
% income from cotton	82	69	***

Source: Survey data.

Note
1 ns = not significant,
** denotes significance at 5% level,
*** denotes significance at 1% level.

adopters and non-adopters of Bt. Table 7.6 compares the characteristics of those farmers in Maharashtra who plant no Bt cotton with those who plant some or all Bt cotton. The minority who do not use Bt cotton appear to have somewhat smaller landholdings and less area in cotton, although they depend as heavily on cotton for their incomes as do the adopting farmers.

For Gujarat, the most interesting comparison is between those who grow only unapproved Bt cotton varieties and those who plant at least some approved varieties (Table 7.7). The biggest difference is that the greater the extent of irrigated land and total area, the more likely it is that the grower does not use unapproved seeds. This possibly reflects the fact that households that have

irrigation prefer to plant approved seeds. In addition, the greater the percentage of income from cotton, the greater the probability that a grower chooses unapproved seed. Thus it appears that smaller farmers with less irrigation and less diversified cropping systems continue to rely on unauthorized seed, perhaps because it is cheaper.

Cotton yields

Table 7.8 reports our sample median seed cotton yields in Gujarat and Maharashtra for 2005–07. (We use medians as opposed to averages because they are more robust to outliers and measurement errors. In most of the cases considered here the medians are close to, but lower than, area-weighted average yields.)

In both states median Bt cotton yields are higher than non-Bt cotton yields. In Gujarat the gap is large and statistically significant, but by the time of our survey there were very few non-Bt fields in Gujarat, and most of those were planted to *desi* cotton, which receives less management attention. For Gujarat we also examined the average yields for approved and unapproved Bt cotton varieties (Table 7.9). In all years, the yield for approved varieties is higher than that of unapproved varieties, although the difference in median yields is statistically significant only in 2006. This is a reversal of the situation in 2003–04 where our survey found unapproved varieties to generally outperform approved varieties (Table 7.10). The gap in yields between Bt and non-Bt hybrid cotton noted in the earlier survey is consistent with, and indeed helps explain, the rapid adoption of Bt varieties in Gujarat.

The gap between Bt and non-Bt cotton yields shown for Maharashtra in Table 7.8 is smaller than the gap noted for Gujarat (Table 7.10), which might also help explain the slower pace of adoption of Bt in that state. Yields are considerably lower in Maharashtra, in part because most cotton is grown without irrigation.

Figure 7.2 shows average seed cotton yields for Gujarat, Maharashtra and all India. It can be seen that that there is a fairly consistent upward trend beginning in 2002, which corresponds with the release of Bt cotton. The increase is particularly sharp in Gujarat, which is consistent with the rapid shifts towards Bt observed in our data. The yields seem to level off in Gujarat from 2005 (consistent with our survey results), which can be explained by the fact that by this time most of the growers had already shifted to Bt cotton and therefore this source of technological change was largely exhausted. In Maharashtra, average yields have risen in parallel with the shift to Bt cotton; the upward trend is not as sharp as in Gujarat, perhaps because of the slower pace of the shift to Bt cotton varieties, but is still continuing. The recent yield increase noted for India may have several explanations. For instance, there is some evidence that farmers often provide better management for the expensive new Bt varieties (e.g. Narayanamoorthy and Kalamkar 2006; Qaim *et al.* 2006). But a very substantial part of the increase is surely due to the improved production provided by the protection from insect damage offered by the Bt varieties that are now widely grown.

Table 7.8 Median seed cotton yields for sample farmers

Year	*Gujarat*						*Maharashtra*					
	Cotton yield (kg/ha)	*No. of plots*	*Bt cotton yield (kg/ha)*	*No. of plots*	*Non-Bt cotton yield (kg/ha)*	*No. of plots*	*Cotton yield (kg/ha)*	*No. of plots*	*Bt cotton yield (kg/ha)*	*No. of plots*	*Non-Bt cotton yield (kg/ha)*	*No. of plots*
2005/06	2058	328	2196	282	988	46	988	349	1235	63	988	285
2006/07	1966	403	2164	367	865	36	1186	426	1383	238	988	188
2007/08	1729	337	1801	315	988	22	1317	390	1376	310	1112	80

Source: Survey data.

Table 7.9 Yields of approved and unapproved varieties in Gujarat, 2005–07 (kg seed cotton per hectare)

Gujarat	*Approved varieties*		*Unapproved varieties*	
	Cotton yield kg/ha	*No. of plots*	*Cotton yield Kg/ha*	*No. of plots*
2005/06	2470	87	2161	195
2006/07	2398	137	1976	230
2007/08	1801	177	1729	138

Source: Survey data.

Table 7.10 Yields of approved and unapproved varieties in Gujarat, 2003–04 (kg seed cotton per hectare)

Type of variety	*Desi*	*Non-Bt hybrid*	*Legal Bt*	*Illegal F1 Bt*
Yield (kg/ha)	492	1613	2468	2836

Source: Ramaswami *et al.* (forthcoming).[AQ: Please update the reference.]

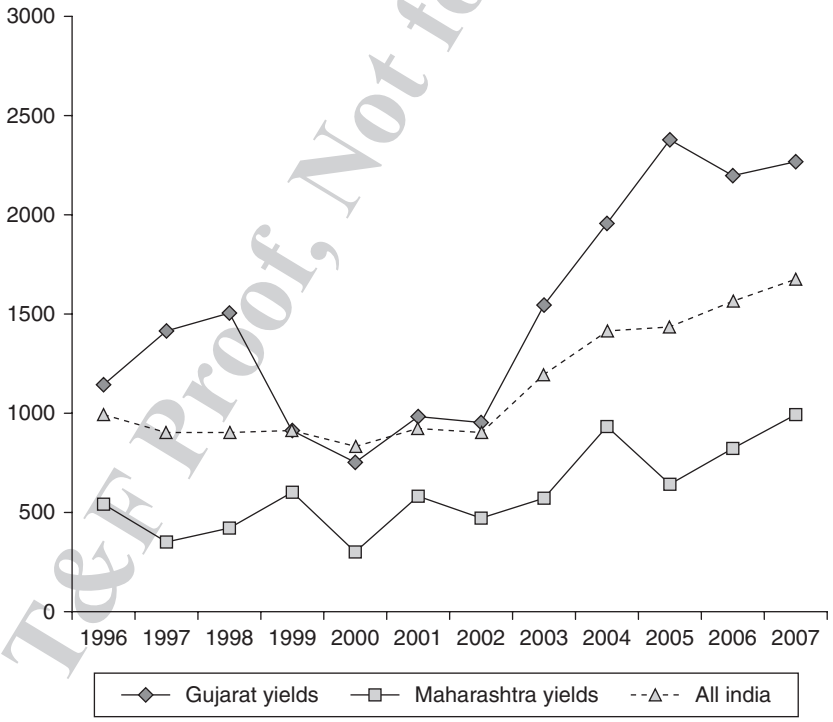

Figure 7.2 Seed cotton yields (kg/ha) Gujarat, Maharashtra and all India

Source: Cotton Advisory Board.

Seed choice

The cotton seed market

When the first approved Bt hybrids were brought to market, their price was four times that of conventional hybrids. Several state governments protested and established a maximum price for Bt seed (equivalent to approximately twice the price of conventional hybrid cotton seed), which turned into a national price cap. The unapproved seed originally sold for somewhat less than the approved seed (about three times the price of conventional hybrids), but because of competition from the many new approved Bt varieties that have been released the price of the unapproved seed has dropped drastically, to the point where it now sells for slightly less than conventional (non-Bt) hybrid cotton seed. In 2007, seed with Monsanto's 'Bollgard II' gene became available in hybrids produced by several Indian seed companies. The price was set at three times the conventional hybrid price, but in 2008 state governments again stepped in and limited the price to that of the other Bt varieties.

All seed of approved cotton hybrids (conventional and Bt) is sold in packets of 450 grams, calculated to be sufficient to plant 1 acre. The seeding rate for hybrid cotton is significantly less than that for conventional seed, so the high price of the hybrid is partially compensated by the low seeding rate. But the high price of hybrid seed presents an added risk to farmers in marginal environments subject to drought or flooding. Hybrid Bt cotton represents an investment of about US$40 per hectare. If an Indian farmer is able to demonstrate that purchased seed (of any crop) was of poor quality and did not germinate, he or she may be able to press for compensation, and consumer courts will hear such cases. But there is no mechanism for insuring against loss due to natural calamities. During our study we heard of a few cases where a company was willing to provide fresh seed of a Bt hybrid to a farmer who had lost the initial planting because of flooding, but this is unusual. In some cases in Gujarat, farmers with a poor initial plant stand of an approved Bt hybrid buy seed of an unapproved hybrid to fill in the gaps.

Farmers in both Gujarat and Maharashtra face a complex seed market that offers many choices. Table 7.11 provides an indication of this complexity by summarizing the aggregate number of distinct varieties reported by the farmers in our survey over the past five years. (The complete range of cotton varieties in these two states is of course wider than this, but these figures provide a useful estimation.) We distinguish between Bt and non-Bt varieties and in Gujarat we also show the number of distinct authorized and unauthorized varieties. We consider distinct varieties as those known by distinct names. If the same variety is called something different in another village or district it would enter in the survey as a distinct variety. This is a particular challenge for the unauthorized varieties and it is possible that many of these differ little from each other but are simply sold under different local names.

In both states farmers currently have at least 50–60 approved Bt hybrids to choose from, and this number has been growing steadily. On the other hand, the number of conventional hybrids grown by the sample farmers has been declining. The most remarkable difference between the two states comes from the unapproved varieties in Gujarat.

Table 7.11 Number of distinct varieties sown by sample farmers, 2003–07

Year	*Gujarat*					*Maharashtra*		
	No. of distinct varieties	*No. of distinct Bt varieties*	*No. of distinct non-Bt varieties*	*No. of distinct authorized Bt varieties*	*No. of distinct unauthorized varieties*	*No. of distinct varieties*	*No. of distinct Bt varieties*	*No. of distinct non-Bt varieties*
2003–04	79	56	21	13	43	62	4	57
2004–05	89	65	22	15	50	66	10	55
2005–06	116	103	12	27	76	90	20	68
2006–07	148	135	12	34	101	86	32	53
2007–08	190	180	9	54	126	98	62	36

Source: Survey data.

Table 7.12 Number of varieties grown by sample farmers

Year/ growers	*Gujarat averages*			*Maharashtra averages*		
	No. of distinct varieties per grower	*No. of distinct Bt varieties per grower*	*No. of distinct non-Bt varieties per grower*	*No. of distinct varieties per grower*	*No. of distinct Bt varieties per grower*	*No. of distinct non-Bt varieties per grower*
2003–04	1.31	0.83	0.50	1.63	0.03	1.71
No. of growers	199	181	181	201	172	172
2004–05	1.40	1.03	0.39	1.65	0.08	1.63
No. of growers	200	187	187	204	186	186
2005–06	1.62	1.40	0.22	1.80	0.34	1.52
No. of growers	200	197	197	204	188	188
2006–07	1.97	1.80	0.17	2.13	1.21	0.94
No. of growers	200	199	199	203	198	198
2007–08	2.50	2.37	0.13	2.29	1.72	0.57
No. of growers	200	199	199	206	206	206

Source: Survey data.

Table 7.12 presents the average number of distinct Bt and non-Bt varieties grown by cotton farmers in Gujarat and Maharashtra. (In some cases neither the grower nor the interviewer could identify the variety type grown in past years, so the number of farmers for which we have identifiable variety information is less than the total number of growers.) The table shows that (a) the average number of varieties grown by a cultivator is increasing over time and (b) in the last couple of years, cultivators on average grow two or more distinct varieties. The first trend may be regarded with some suspicion because the data are based on recall, but the second feature of the table is more robust and demonstrates that farmers either hedge their bets or experiment with some new varieties, or both. When we examine the proportion of farmers growing different numbers of varieties, the figures for Gujarat and Maharashtra are remarkably similar. About 30 per cent of farmers grow only one variety, another 30 per cent grow two varieties, and the remaining 40 per cent grows three or more varieties. The table also demonstrates a third feature – as the importance of Bt varieties has grown, farmers have also expanded their choices of Bt varieties.

With so many different varieties available, and the average farmer planting about two varieties, it is important to consider the patterns of farmers' seed choice. Farmers buy their seed each year from shops, each of which carries the stock of a certain number of seed companies. The companies may offer incentives

to the dealers to promote their products, and often provide items such as calendars that can be given to farmers. In addition, there is a great deal of advertising propaganda promoting different brands. There is thus much opportunity for the manipulation of farmers' choices, and it is worthwhile to look in more detail at how these are determined.

Criteria for seed choice

A study of Bt cotton in Warangal District, Andhra Pradesh, describes how farmers 'face a frenzied turnover in the seed market (which they encourage with their penchant for new products), deceptiveness in seed brands...and a noisy and unreliable information environment' (Stone 2007: 76). We can use our survey data to examine how typical this description of faddish and uninformed behaviour is for cotton seed markets in other parts of India.

In order to understand the extent to which the cotton seed markets in our study sites are unstable, we examined the distribution of cotton varieties for the 2007 and 2006 seasons. In Maharashtra, 13 varieties account for 70 per cent of all the cotton area in the sample in 2007. Of these 13 varieties, 9 are Bt and 4 are conventional; all are private varieties except for one conventional variety sold by the state seed corporation. The previous season (2006) the top 13 varieties in Maharashtra accounted for 71 per cent of cotton area in the sample. **[AQ]** Only 3 of the top 13 from 2006 fail to appear in the top 13 the following year, and 2 of those are hovering just outside the top rank.

[AQ: Should the sentence be 'In the previous season (2006)…']

The situation in Gujarat is somewhat more complicated, particularly because of the presence of many different names of unauthorized varieties. In 2007, the top 25 varieties covered 65 per cent of the sample area and the top 10 varieties account for 45 per cent of the area. The previous year (2006) the top 25 varieties covered 74 per cent of the area and the top 10 accounted for 52 per cent of the area. **[AQ]** The only new entry in the top 10 for 2007 was a recently released 'Bollgard II' variety. There is more change in the top 25 varieties between the two years in the Gujarat sample, but some of this is because the unauthorized varieties are described by so many different names. In addition, some farmers in Gujarat were less precise than their counterparts in Maharashtra in being able to name approved varieties.

[AQ: Should the sentence be 'In the previous year (2006)…']

This examination of the most popular varieties provides some evidence of stability in variety choice at the aggregate level, but we need to understand more about individual farmer choices. The analysis for Andhra Pradesh distinguishes seed choices based on farmer experimentation ('environmental learning') and those based on persuasion or imitation ('social learning') (Stone 2007). Although social learning can itself have a basis in environmental observations, the suggestion is that social learning is also likely to be subject to very many biases that may reflect social pressures rather than first-hand experience.

There is no straightforward method for identifying a farmer's planting practices as experimental. A minimum requirement is that the farmer plant more than one variety, and we have seen that in our samples approximately 70 per cent of

Table 7.13 Cumulative distribution of novice plantings, sample farmers

Less than x% of total novice plantings	*Maharashtra*	*Gujarat*
	Proportion of area under novice plantings	*Proportion of area under novice plantings*
1%	0.08	0.02
5%	0.12	0.07
10%	0.14	0.08
25%	0.20	0.15
50%	0.33	0.25
75%	0.50	0.40
90%	0.90	0.71
95%	1.00	1.00
99%	1.00	1.00

Source: Survey data.

the farmers are planting two or more cotton varieties. There are various reasons for growing more than one variety. For our entire sample we found a modest correlation between number of varieties and total cotton area, and a stronger correlation with number of plots, which would indicate that farmers may target varieties to the varying conditions of their different plots or take advantage of multiple plots to test different varieties.

It is natural to suppose, however, that growers who intend to experiment will allocate small areas to varieties that they intend to evaluate. Table 7.13 examines the area devoted to 'novice plantings', the term Stone uses for varieties planted for the first time. (In Maharashtra this accounts for 44 per cent of cotton land and in Gujarat it covers 41 per cent of the cotton area.) The table shows the cumulative distribution of novice plantings (measured as proportion of total cotton area) among individual growers. In Maharashtra, 50 per cent of novice plantings are allocated to plots less than 33 per cent of a farmer's total cotton area. In Gujarat, the median value is 25 per cent of total area. These figures are similar to a classic study of the adoption of hybrid maize in Iowa which found that farmers planted a median of 18–30 per cent of their total maize acreage to hybrid seed when they first tried it (Ryan and Gross 1943). However, they are vastly different from Stone's study in Andhra Pradesh which found that as many as 70 per cent of novice plantings occupied the entire cotton area.

A key implication of the environmental learning hypothesis is that growers maintain continuity in their variety choices over time. We have already seen that more than 50 per cent of cotton area is accounted by varieties planted in the past history of the grower. Another implication of the environmental learning hypothesis is that current area allocations to varieties depend on the grower's experience with that variety. To test this effect we regress the area allocated to variety x on 4 dummies. The first dummy takes the value 1 if in 2007 variety x is in the second year of planting. The second dummy takes the value 1 if in 2007 variety x is in

Table 7.14 Varietal history and area allocation: Maharashtra[1]

Experience with variety	*Coef.*	*Robust std. err.*	*t*	*P>t*
2nd year of planting	0.75	0.15	4.84	0.00
3rd year of planting	0.60	0.24	2.47	0.01
4th year of planting	1.90	1.06	1.79	0.08
5th year of planting	0.97	0.40	2.41	0.02
Total cotton area	0.21	0.04	6.07	0.00
Constant	1.73	0.11	15.63	0
R^2		0.33		
No of observations		474		

Source: Survey data.

Note
1 See text for explanation of variables.

Table 7.15 Varietal history and area allocation: Gujarat[a]

Experience with variety	*Coef.*	*Robust std. srror*	*t*	*P>t*
2nd year of planting	1.18	0.44	2.69	0.01
3rd year of planting	1.56	0.62	2.53	0.01
4th year of planting	2.21	0.66	3.36	0.00
5th year of planting	2.31	0.67	3.43	0.00
Total cotton area	0.21	0.03	7.15	0.00
Constant	0.53	0.41	1.29	0.20
R^2		0.33		
No of observations		547		

Source: Survey data.

Note
1 See text for explanation of variables.

the third year of planting. The third and fourth dummies are defined similarly. The constant term then represents the effect if the variety is planted in 2007 for the very first time. The results are shown in Tables 7.14 and 7.15 and clearly indicate that the area allocation to a particular variety increases with greater farmer experience with that variety. In Maharashtra the area allocation reaches its peak in the fourth year of planting, while in the Gujarat allocation the experience effect continues to increase through the fifth year. These results attest to the strength of the environmental learning hypothesis.

If experimental plantings are subtracted from novice plantings, the remainder represents plantings due to social learning. While it is difficult to quantify the importance of different sorts of social learning, it is possible to see how much of novice planting involves varieties that are market leaders. This can be called the 'imitation effect'. While such social learning could stem from a herd instinct and therefore need not have any basis in environmental learning, it would also seem that observing varieties in the fields of other farmers or demonstration plots, or

Table 7.16 Types of planting (novice, experimental and imitation) for sample farmers, 2007

	Maharashtra (%)	*Gujarat (%)*
Proportion of total cotton area that is planted with:		
a) varieties farmer has grown in previous seasons	56	59
b) 'novice plantings' (varieties farmer plants for first time)	44	41
Proportion of 'novice planting' area that is:		
c) 'experimental' (occupies less than 30% of total cotton area)	38	44
d) 'imitation' (planted with varieties that were among 13 most popular in 2006)	50	24
e) 'imitation' but not 'experimental' (i.e. planted in *more than* 30% of total cotton area)	34	14
f) 'experimental' plus 'imitation' (c + e)	72	58

Source: Survey data.

exchange of information with other growers, is a lot more probable with the varieties that are popular than with varieties that are highly localized. This is particularly compelling when there are a large number of varieties on offer.

We quantify the imitation effect in the following manner. In both states, we suppose that a novice planting in 2007 embodies an imitation effect if the variety belonged to the top 13 list in the 2006 season. Table 7.16 expresses estimates of the imitation effect as percentage of all novice planting area. The gross estimate (line d) is the proportion of novice planting area due to the imitation effect. In the net estimate (line e), the imitation effect is computed after removing experimental plantings (defined as those novice plantings that account for 30 per cent or less of total area). The imitation effect is much stronger in Maharashtra. To see why the imitation effect is lower in Gujarat, we looked at the 15 varieties that had the highest share of novice plantings. Ten of these were varieties that were not ranked among the popular set in 2006. And of these ten varieties, seven were approved Bt varieties. It therefore seems that Gujarat farmers are moving towards approved Bt varieties and hence it is likely that the ranking of market leaders will change in future years. Farmer experimentation and imitation effects together explain 72 per cent of novice plantings in Maharashtra and 58 per cent in Gujarat.

Information sources

A question in the survey asked growers about their information sources when a variety was first planted. Table 7.17 summarizes the sources of information for

Table 7.17 Sources of information about Bt cotton seeds (percentage responses)

Principal response[1]	*Maharashtra*	*Gujarat*		
		All	*Approved*	*Unapproved*
Neighborhood farmer	15	45	31	56
Seed dealer	29	28	44	15
Seen variety in fields of others	25	14	7	20
Advertisements in media	9	2	5	0
Demonstration plots	11	1	0	1
Others	10	10	13	9

Source: Survey data.

Note

1 The answers to this question sometimes had multiple responses. The table is compiled based on the first response, but including second responses does not change the relative importance of different information sources.

Bt varieties. There is an interesting contrast between Gujarat and Maharashtra. Consultation with local farmers (and observations in nearby fields) is most important for Gujarat farmers using unapproved seeds. In contrast, they rely heavily on dealers' advice for the approved varieties. Local learning (from neighbouring farmers and observing the variety in other fields) is most important for Maharashtra farmers, although seed dealers also play an important role. Advertisements and demonstration plots hold comparatively little sway although their influence is much more in Maharashtra than in Gujarat. It would seem that dealers' direct advice is the primary channel for companies to influence seed choices.

A follow-up question asked growers if they were able to buy their preferred varieties and in the required quantities. This was meant to ascertain whether seed dealers manipulate choices by denying growers their preferred seeds. In more than 90 per cent of cases in Gujarat and Maharashtra, growers obtained their variety of choice and in quantities sufficient for their requirements.

Insect control

The insecticide market

Farmers buy insecticides from input dealers, often the same ones that sell them seed. Many of the insecticides on the market are out-of-patent chemicals that are manufactured by large firms as well as by small formulators. In addition, there are a few newer (and often more expensive) proprietary insecticides on the market. Many insecticides are fairly heavily advertised on billboards and posters. Most farmers in the sample purchased their insecticides with cash.

Despite the relatively large number of products on the market, farmers are usually able to identify the insecticides that they use. In some cases they know the

Table 7.18 Labour use for insecticide application and farm size

Farm size class[a]	*Proportion of plots*					
	Gujarat			*Maharashtra*		
	Self or family labour	*Only hired labour*	*Both or other*	*Self or family labour*	*Only hired labour*	*Both or other*
Marginal	59	36	5	47	46	7
Small	51	46	3	19	70	11
Medium	22	71	7	16	73	11
Large	25	75	0	–	–	–

Source: Survey data.

Note
1 Farm size classes are defined as: a) marginal: 0–1 ha, b) small: 1–2 ha, c) medium: 2 –10 ha, d) large: above 10 ha.

product by its chemical name (e.g. monocrotophos), although this may be provided by a number of different firms; in other cases farmers know a trademarked name, especially for newer products (e.g. 'Confidor'); and in other cases farmers only know a brand name (e.g. 'Tiger') without necessarily knowing the active ingredient.

When farmers were asked about their source of information when they first purchased a particular insecticide, the majority (60 per cent in Gujarat and 67 per cent in Maharashtra) said that they followed dealers' recommendations. The second most important source of information on insecticides was other farmers.

Farmers apply most of their insecticides by mixing the purchased powder or liquid with water in the tank of a backpack sprayer. Farmers also purchase other products that are applied to cotton as sprays, sometimes mixed with insecticides in the same sprayer tank. We collected data on foliar fertilizers, growth regulators and fungicides, but do not report those here.

Insecticide practices

Almost all of the farmers in our sample apply insecticides using backpack sprayers. In some cases the farmer or another family member does the spraying, while in other cases hired labour is used. In many of these latter instances, the labourers provide their own spraying equipment. Table 7.18 examines the relationship between farm size and hired labour for insecticide spraying and shows that larger farms more frequently delegate the task to hired labour.

There is a sharp difference between the two samples in the number of times that farmers spray their cotton with insecticide. The frequency distribution for the number of times a plot is sprayed with insecticides is shown in Tables 7.19 and 7.20. In Gujarat, the median number of sprays is seven while it is only three in Maharashtra.

Table 7.19 Number of insecticide sprays applied to fields (Gujarat)

No. of sprays	*No. of plots*	*% of plots*	*Cumulative percent*
0	18	4.3	4.3
1	6	1.4	5.8
2	8	1.9	7.7
3	29	7	14.6
4	36	8.6	23.3
5	43	10.3	33.6
6	52	12.5	46
7	50	12	58
8	66	15.8	73.9
9	53	12.7	86.6
10	17	4.1	90.6
11	2	0.5	91.1
12	12	2.9	94
13	7	1.7	95.7
14	5	1.2	96.9
15	12	2.9	99.8
20	1	0.2	100
Total	417	100	

Source: Survey data.

Table 7.20 Number of insecticide sprays applied to fields (Maharashtra)

No. of sprays	*No. of plots*	*% of plots*	*Cumulative percent*
0	18	4.33	4.33
1	16	3.85	8.17
2	72	17.31	25.48
3	166	39.90	65.38
4	92	22.12	87.50
5	36	8.65	96.15
6	14	3.37	99.52
12	2	0.48	100.00
Total	416	100	—

Source: Survey data.

One of the most important features of insecticide application for cotton in India is the frequency with which farmers mix two or more insecticides in the same tank. Entomologists caution strongly against this practice, but farmers either feel that the spraying will be more effective with several insecticides or wish to save time and labour by applying several products at once (sometimes targeted at different pests). In Gujarat the majority of farmers mix two or more insecticides in a single spraying, while in Maharashtra slightly less than half of the sprayings contain multiple insecticides (Table 7.21).

To understand if growers receive any guidance in the use of pesticides, we asked them whether their fields were visited by any outside agency such as extension

Table 7.21 Number of insecticides used in each spraying

No. of insecticides used in each spraying	*Gujarat*		*Maharashtra*	
	No. of sprays	*(%)*	*No. of sprays*	*(%)*
1	569	20.13	695	54.51
2	1483	52.48	461	36.16
3	622	22.01	88	6.90
4	118	4.18	23	1.80
5	22	0.78	2	0.16
6	9	0.32	6	0.47
7	3	0.11	0	0.00
Total	2826	100.00	1275	100.00

Source: Survey data.

officials, representatives from the state agriculture departments or pesticide companies. The answer was positive for only 8 per cent of the sample in Maharashtra and 16 per cent in Gujarat, and the most common category of visitors (47 and 40 per cent, respectively) were representatives of seed and pesticide companies. During interviews, many farmers noted their lack of information especially when dealing with new pests, and contact with the extension system was negligible for most of the growers in the sample. There are state programs that teach farmers principles of insecticide resistance management (IRM), but only about 5 per cent of farmers had heard about them and even fewer had participated.

Insecticide use on different types of variety

There are several ways to examine differences in insecticide practices for different varieties. The most straightforward method is to compare the number of insecticide sprayings per plot. In Maharashtra, there was little difference between the two types of variety; the average number of sprayings was 3.23 for Bt varieties and 3.35 for non-Bt varieties, and the distribution of sprayings over time was also similar for the two variety types.

In the survey, the farmer was asked to identify the pest(s) that were targeted in each spraying. In some cases the farmer gave two responses, but a preliminary analysis indicated that analysing only the first response did not lead to significantly different results. We classified the answers into bollworms (i.e. those *Lepidoptera* with some susceptibility to the Bollgard toxin), *Spodoptera*, sucking pests and others. Only one farmer in Maharashtra mentioned *Spodoptera* (as a secondary target), so we do not include this in our analysis for that state. Table 7.22 presents sprays by time period, primary target and type of variety. The table shows that in every time period, Bt cotton plots are sprayed more against sucking pests than non-Bt cotton plots. On the other hand, non-Bt cotton plots are sprayed more against bollworms than sucking pests. Aggregate numbers of sprays per plot are not much different between Bt and non-Bt plots.

Table 7.22 Insecticide sprays per plot, by pest and by time period: Maharashtra

Days after sowing	*Pest target*	*Sprays per plot*			*Percentage of all sprays during period*		
		Bt cotton	*Non-Bt*	*All*	*Bt cotton*	*Non-Bt*	*All*
1–30 days	Sucking pests	0.41	0.34	0.40	65.00	57.14	63.45
	Bollworms	0.06	0.13	0.07	9.00	22.45	11.65
	Others	0.13	0.07	0.12	20.50	12.24	18.88
	Unknown	0.03	0.05	0.04	5.50	8.16	6.02
	Total	0.63	0.60	0.63	100.00	100.00	100.00
31–60 days	Sucking pests	0.75	0.61	0.72	50.53	40.00	48.32
	Bollworms	0.28	0.39	0.30	18.90	25.60	20.30
	Others	0.25	0.27	0.26	16.99	17.60	17.11
	Unknown	0.20	0.26	0.21	13.59	16.80	14.26
	Total	1.49	1.52	1.50	100.00	100.00	100.00
61–90 days	Sucking pests	0.34	0.12	0.30	36.82	13.16	31.99
	Bollworms	0.31	0.44	0.33	32.77	47.37	35.75
	Others	0.12	0.27	0.15	13.18	28.95	16.40
	Unknown	0.16	0.10	0.15	17.23	10.53	15.86
	Total	0.94	0.93	0.93	100.00	100.00	100.00
91–120 days	Sucking pests	0.05	0.02	0.05	27.12	8.00	21.43
	Bollworms	0.07	0.20	0.10	38.98	64.00	46.43
	Others	0.01	0.02	0.01	5.08	8.00	5.95
	Unknown	0.05	0.06	0.06	28.81	20.00	26.19
	Total	0.19	0.30	0.21	100.00	100.00	100.00
Above 121 days	Sucking pests	0.003	0.00	0.00	23.08	0.00	23.08
	Bollworms	0.01	0.00	0.01	76.92	0.00	76.92
	Others	0.00	0.00	0.00	0.00	0.00	0.00
	Unknown	0.00	0.00	0.00	0.00	0.00	0.00
	Total	0.013	0.00	0.01	100.00	0.00	100.00
Entire season	Sucking pests	1.553	1.09	1.47	48.04	32.54	44.87
	Bollworms	0.73	1.16	0.81	22.58	34.63	24.67
	Others	0.51	0.63	0.54	15.77	18.81	16.45
	Unknown	0.44	0.47	0.46	13.61	14.03	14.01
	Total	3.23	3.35	3.28	100.00	100.00	100.00

Source: Survey data.

Because farmers often mix two or more insecticides in a single spraying, it is also possible to consider the number of 'insecticide applications', where each instance of insecticide in the tank gets counted as an application. Table 7.23 shows the insecticide applications per plot by variety and over the growing season. The number of applications is larger than the number of sprayings, as is to be expected. There is also a greater difference between Bt and non-Bt plots, suggesting that multiple insecticides are more common for the latter.

Table 7.23 Insecticide applications per plot: Maharashtra

Days after sowing	*Bt plots*	*Non-Bt plots*	*All*
1–30 days	0.84	0.96	0.87
31–60 days	2.11	2.67	2.23
61–90 days	1.58	1.55	1.57
91–120 days	0.36	0.50	0.39
121–150 days	0.00	0.00	0.00
151–180 days	0.00	0.00	0.00
181 days and above	0.01	0.00	0.01
Total	4.91	5.68	5.07

Source: Survey data.

Table 7.24 Insecticide use per ha against target pests in Maharashtra

Target pests	*Bt plots*			*Non-Bt plots*		
	Lt/ha	*Kg/ha*	*Total*	*Lt/ha*	*Kg/ha*	*Total*
Sucking pests	0.55	0.1	0.65	0.95	0.04	0.99
Bollworms	0.36	0.05	0.41	1.4	0.15	1.55
Others	0.17	0.03	0.2	0.54	0.04	0.58
Unknown	0.19	0.03	0.22	0.43	0.01	0.44
Total	1.28	0.22	1.5	3.32	0.24	3.56

Source: Survey data.

In addition, it is possible to compare the quantities of insecticide applied on cotton fields. Table 7.24 compares the quantities of liquid insecticides (in liters) and powdered insecticides (in kilograms) applied to the two types of variety. The differences between Bt and non-Bt plots are quite noticeable, and the major factor is the higher amount of insecticide used to control bollworm on the non-Bt plots. So although there is virtually no difference in the number of times farmers spray their Bt and non-Bt cotton, the non-Bt varieties tend to receive somewhat more insecticides per spraying and considerably higher total quantities of insecticide over the season. Further analysis is required to see to what extent these differences are reflected in the type of insecticides used for different varieties and the total costs of insect control.

In Gujarat the average number of sprayings per plot for approved Bt varieties (7.39) is only slightly higher than that for unapproved varieties (6.91), and the distributions over the season are also similar. Plots of the traditional *desi* varieties, which do not receive much insecticide, averaged 1.81 sprayings per season.

Table 7.25 shows sprays by time period, primary target and type of variety in Gujarat. Most of the sprays are against sucking pests. The proportion of sprays against bollworms is much less than in Maharashtra, but for all pests the number of sprays is higher in Gujarat. Plots with approved varieties receive more sprays against sucking pests and *Spodeptera* than plots with unapproved varieties.

Table 7.25 Insecticide sprays per plot, by pest and by time period, Gujarat

Days after sowing	*Pest target*	*Sprays per plot*				*Percentage of all sprays during period*			
		Approved Bt plots	*Unapproved Bt plots*	*Non-Bt plots*	*All*	*Approved Bt plots*	*Unapproved Bt plots*	*Non-Bt plots*	*All*
1–30 days	Sucking pests	0.24	0.22	0.15	0.22	72.73	56.47	44.44	61.74
	Bollworms	0.00	0.00	0.00	0.00	0.00	1.18	0.00	0.67
	Spodoptera	0.00	0.00	0.07	0.00	0.00	0.00	22.22	1.34
	Others	0.01	0.02	0.00	0.01	1.82	5.88	0.00	4.03
	Unknown	0.08	0.14	0.11	0.12	25.45	36.47	33.33	32.21
	Total	0.33	0.38	0.33	0.36	100.00	100.00	100.00	100.00
31–60 days	Sucking pests	1.70	1.48	0.37	1.50	82.42	71.62	62.50	76.00
	Bollworms	0.07	0.10	0.00	0.08	3.17	5.02	0.00	4.14
	Spodoptera	0.05	0.01	0.04	0.03	2.31	0.44	6.25	1.34
	Others	0.02	0.08	0.00	0.05	1.15	3.71	0.00	2.56
	Unknown	0.23	0.40	0.19	0.31	10.95	19.21	31.25	15.96
	Total	2.07	2.06	0.59	1.97	100.00	100.00	100.00	100.00
61–90 days	Sucking pests	1.97	1.74	0.37	1.75	77.88	74.28	83.33	75.99
	Bollworms	0.21	0.24	0.04	0.22	8.47	10.17	8.33	9.39
	Spodoptera	0.15	0.08	0.00	0.11	6.12	3.45	0.00	4.59
	Others	0.03	0.04	0.00	0.03	1.18	1.54	0.00	1.36
	Unknown	0.16	0.25	0.04	0.20	6.35	10.56	8.33	8.66
	Total	2.53	2.35	0.44	2.30	100.00	100.00	100.00	100.00
91–120 days	Sucking pests	1.33	1.09	2.00	1.14	77.78	75.16	88.89	76.58
	Bollworms	0.14	0.11	0.25	0.12	8.33	7.76	11.11	8.08
	Spodoptera	0.18	0.05	0.00	0.10	10.42	3.42	0.00	6.62
	Others	0.00	0.06	0.00	0.03	0.00	4.04	0.00	2.10
	Unknown	0.06	0.14	0.00	0.10	3.47	9.63	0.00	6.62
	Total	1.71	1.45	2.25	1.48	100.00	100.00	100.00	100.00

121 days and above	Sucking pests	0.65	0.52	0.75	0.56	86.7	77.6	100.0	83.6
	Bollworms	0.06	0.1	0	0.08	8.0	14.9	0.0	11.9
	Spodoptera	0.01	0.01	0	0.01	1.3	1.5	0.0	1.5
	Others	0.01	0	0	0	1.3	0.0	0.0	0.0
	Unknown	0.03	0.03	0	0.03	4.0	4.5	0.0	4.5
	Total	0.75	0.67	0.75	0.67	100.0	100.0	100.00	100.0
Entire season	Sucking pests	5.89	5.05	3.64	5.17	80	73	83	76
	Bollworms	0.48	0.55	0.29	0.5	6	8	7	7
	Spodoptera	0.39	0.15	0.11	0.25	5	2	3	4
	Others	0.07	0.2	0	0.12	1	3	0	2
	Unknown	0.56	0.96	0.34	0.76	8	14	7	11
	Total	7.39	6.91	4.38	6.8	100	100	100	100

Source: Survey data.

Table 7.26 Insecticide applications per plot, Gujarat

Days after sowing	*Approved*	*Unapproved*	*Non-Bt*	*All*
1–30 days	0.63	0.68	0.59	0.65
31–60 days	4.33	4.15	1.26	4.04
61–90 days	5.92	4.99	0.96	5.10
91–120 days	3.97	3.12	0.56	3.29
121–150 days	1.45	0.89	0.22	1.07
151–180 days	0.35	0.27	4.37	0.28
181days and above	0.08	0.09	1.30	0.08
Total	16.74	14.18	3.59	14.53

Source: Survey data.

Many Gujarat growers often use combinations of insecticides in a single spray, and Table 7.26 displays the insecticide applications per plot. The difference between approved and unapproved plots is proportionately greater for insecticide applications than for insecticide sprayings.

Table 7.27 examines the actual quantities of insecticide used by farmers growing the two types of variety. Gujarat presents an additional complication for measuring insecticide use because in a number of cases farmers purchased insecticide powder which they applied by hand, so the table includes three measures. Farmers using approved Bt varieties applied considerably higher quantities of insecticide than those planting unapproved varieties.

There are clear differences between Gujarat and Maharashtra in terms of the amount of insecticide applied to Bt cotton varieties. Insecticide practices vary markedly by season, so a single year's comparison is not definitive. But it would seem that Gujarat cotton farmers use significantly more insecticide than their counterparts in Maharashtra, and that this difference is not explained by variation in the types of cotton varieties planted. Whether pest pressure is greater in Gujarat, or relatively wealthier farmers with higher cotton yields choose to spend more on insecticide, is not clear.

The precise impact of Bt cotton on insecticide practices is difficult to assess from a single year's data. If we compare the Gujarat data from 2007 with results from our study in 2003 we find that the total number of sprayings has declined, for both approved and unapproved Bt varieties, by about one-third (Table 7.28). The difference is largely due to a decline in insecticide use for bollworm. It is not clear if this is due to declining bollworm populations, or farmers' increasing confidence in the efficacy of Bt varieties. We have no similar comparative data for Maharashtra, but anecdotal evidence as well as comparison with earlier studies in the same region indicates a decline in the number of sprayings per season, and this may be attributed to the spread of Bt cotton. The comparison between Bt and non-Bt varieties in Maharashtra shows that Bt growers currently spray as frequently as non-Bt growers, but tend to use less insecticides per spraying and considerably lower quantity of commercial products per spray. Further analysis is required to understand the significance of these differences, but the new technology's efficacy in controlling bollworm is clear.

Table 7.27 Insecticide use per ha against target pests in Gujarat

Target pests	*Approved Bt plots*				*Unapproved Bt plots*			
	Lt/ha	*kg/ha*	*Hand application kg/ha*	*Total*	*Lt/ha*	*kg/ha*	*Hand application kg/ha*	*Total*
Sucking pests	2.70	1.53	1.11	5.35	1.87	1.13	1.51	4.51
Bollworms	0.34	0.09	0.00	0.43	0.18	0.12	0.09	0.39
Spodoptera	0.19	0.20	0.00	0.40	0.03	0.03	0.37	0.43
Others	0.02	0.05	0.00	0.07	0.07	0.04	0.09	0.20
Unknown	0.12	0.07	0.00	0.19	0.26	0.12	0.37	0.76
Total	3.37	1.94	1.11	6.43	2.42	1.44	2.43	6.29

Source: Survey data.

Table 7.28 Number of insecticide sprays per plot in Gujarat: 2003–04 versus 2007–08

Variety	*Bollworms*		*Sucking pests*		*Others*		*Total*	
	2003–04	*2007–08*	*2003–04*	*2007–08*	*2003–04*	*2007–08*	*2003–04*	*2007–08*
Approved Bt varieties	4.18	0.48	5.2	5.89	1.76	1.02	11.14	7.39
Unapproved Bt varieties	3	0.55	5.2	5.05	1.8	1.31	10.0	6.91

[AQ: Please update this reference.]

Source: Survey data and Lalitha *et al.* (forthcoming). **[AQ]**

The opinions of cotton farmers about Bt cotton generally support our data on yields and insecticide practices (Table 7.29). The majority of farmers believe that Bt cotton has contributed to higher yields, particularly in Gujarat. Most farmers believe the technology has lowered the use of insecticides for bollworm control. However, the majority of farmers in Gujarat believe that they have seen an increase in insecticide use for other pests that accompany the uptake of Bt cotton; **[AQ]** this opinion is not so strongly held in Maharashtra (where in any case insecticide use is more moderate). Most farmers in Gujarat associate Bt cotton with higher fertilizer use, which may simply be an indication of the improved management applied to the more expensive seed, but this opinion is in the minority in Maharashtra.

[AQ: Please check change made to the sentence beginning 'However, the majority of…']

It will be interesting to follow the progress of the newly released 'Bollgard II' varieties that contain a combination of genes that are more effective against bollworm and also control *Spodoptera*. There are 21 plots in the Gujarat sample where farmers grow these new varieties. The sample is small and it is not possible to draw firm conclusions, but it is worthwhile examining this example of the early adoption of the new technology. Table 7.30 shows that the 'Bollgard II' growers are larger farmers with more irrigated area, which is not surprising for the first adopters of a more expensive variety. They also appear to use less insecticide than other Bt growers; whether this is because they are taking advantage of the new variety or because they normally use less insecticide is not certain.

Refuge management

Bt cotton seeds are sold in packets of 450 grams (supposedly sufficient for 1 acre) and they are accompanied by 150 gram packets of non-Bt seed to be planted as a refuge. The packet instructs the growers to sow the refuge seed along the borders of the Bt plot. In Maharashtra, compliance with the refuge requirement is fairly high, but not in Gujarat (for approved Bt varieties) (Table 7.31). Refuge seed is of course not sold for the unapproved seed and therefore the practice of planting a refuge is negligible for those varieties. In both states refuges are usually planted on borders, as recommended by the instructions.

Table 7.29 Farmers' opinions about Bt cotton

Effect of Bt cotton on:	*Gujarat (%)*	*Maharashtra[1] (%)*
Yield		
Increased	81.0	58.0
Decreased	9.5	26.4
No change	7.0	14.9
Don't know	2.5	0.6
Insecticide use for bollworm		
Increased	16.0	5.2
Decreased	75.5	78.2
No change	6.0	14.9
Don't know	2.5	1.7
Insecticide use for sucking pests		
Increased	80.0	51.1
Decreased	10.5	29.9
No change	7.0	17.8
Don't know	2.5	1.1
Insecticide use for other pests		
Increased	62.5	17.2
Decreased	21.5	40.8
No change	12.5	35.1
Don't know	3.5	6.9
Use of fertilizer		
Increased	80.5	39.7
Decreased	4.0	8.6
No change	13.0	51.1
Don't know	2.5	0.6

Source: Survey data.

Note
1 Only Bt growers.

Table 7.30 Characteristics of 'Bollgard II' growers in Gujarat

	Bollgard II growers	*Other Bt growers*
Number	19	177
Total cultivated area (ha)	10.9	7.3
Total irrigated area	9.7	5.3
No. of sprays per plot	5	7
No. of insecticide applications per plot	9.7	15

Source: Survey data.

Conclusions

Although debates about approval procedures and environmental concerns meant that India was relatively late in introducing Bt cotton, the subsequent diffusion of the technology has been very rapid. Farmers' willingness to pay a much higher price for the seed (and little evidence that farmers abandon the technology once

Table 7.31 Refuge management

Refuge practice	*Gujarat*[1]	*Maharashtra*
Bt plots reporting a refuge	61/223 = 27%	271/354 = 77%
% refuge as border	93%	88%
% refuge as block or separate plot	—	5%
% refuge as gap filler or mixed	4%	6%

Source: Survey data.

Note
1 Only for approved varieties.

they try it) indicates that the Bt hybrids contribute to cotton productivity. Our survey data support this conclusion.

One of the reasons that the technology was able to diffuse so rapidly throughout India's varied cotton-growing environments was the long tradition of public sector and, more recently, private sector plant breeding capacity. This meant that a very wide range of germplasm was available that could incorporate the insect-resistance transgene. One of the factors that contributed to the technology owner's decision to license the transgene to other seed companies was, paradoxically, an unauthorized plant breeding effort that demonstrated the importance of tailoring Bt varieties to particular environments.

Because India's cotton farmers had long experience with seed markets, and the majority were accustomed to buying commercial hybrid seed every year, the introduction of Bt hybrids did not require any major changes. Nevertheless, farmers' behaviour in Bt seed markets in the two states of this study exhibits important differences, determined in part by the character of the seed market before the entry of Bt and in part by state government policies on regulatory enforcement.

Cotton seed markets in Gujarat had been dominated by hybrids from the public seed corporation and a small number of private firms, none of which had immediate access to the Bt technology when it first became available for licensing. This vacuum was filled by the sale of unauthorized Bt varieties that had been developed in Gujarat, and the state government chose not to attempt control of this underground market. As a result, unauthorized varieties constituted the majority of Bt cotton area in Gujarat, and it is only recently that their dominance is declining in favour of seed from authorized companies. Although Gujarat has always been one of the more advanced cotton-producing states, its farmers are slightly behind in learning about what is currently available in the legitimate seed market.

In contrast, cotton farmers in Maharashtra had been served by a more diverse set of seed companies before the introduction of Bt technology, and many of those companies were able to bring Bt versions of their popular varieties to market quite quickly. At the same time, the state government adopted a much stricter policy of seed law enforcement, and the sale of unauthorized Bt varieties was discouraged. Because cotton farmers in Maharashtra are generally smaller and

poorer than their counterparts in Gujarat, and because they did not have access to the unauthorized varieties, their adoption of Bt technology has been slower, but they have the advantage of facing a seed market that is less confusing than Gujarat's. In addition, they are more conscientious in following refuge requirements. The technology has now spread widely, even among resource-poor farmers, although the small minority who have not yet tried Bt cotton in Maharashtra appear to be those with smaller landholdings.

Cotton seed markets in both states offer farmers many (some would say too many) choices. Nevertheless, there is evidence that in both cases the majority of farmers' decisions to try new varieties are either taken in an attempt to experiment on a fraction of their land or to adopt a variety that has become generally popular in previous seasons. This is not to say that the situation is perfect. Despite the importance of a considerable number of commercial varieties in each state, there are also many lesser-known varieties about which it is difficult to get information. The underground market is particularly chaotic, with a profusion of names and nicknames to describe the products, and this seems to be related to somewhat less precision in the process of variety selection in Gujarat.

Although Bt cotton contributes to yield increases, its original purpose was to lower the requirements for insecticide use. The major differences in insecticide management found in the study are between states and not between variety types. Gujarat farmers used much more insecticide in 2007 than did their counterparts in Maharashtra. We have no evidence on the relative importance of pest pressure or farm management strategies in explaining these differences. The more modest differences in insect management between Bt and non-Bt varieties in Maharashtra is difficult to interpret. The Bt growers spray less frequently than the non-Bt growers for bollworm, but spray more often for sucking pests. On the other hand, the Bt growers make somewhat fewer total insecticide applications and use a considerably lower quantity of insecticides.

It is not clear to what degree the farmers' insecticide practices respond to actual pest pressure or are determined by custom, misinformation or influence from pesticide markets. What is clear is that farmers have many fewer resources and opportunities to test alternative pest management strategies (in contrast to their experimentation and information exchange related to variety choice). There is virtually no extension advice available to help farmers develop more efficient insect control practices, and most information about insecticides comes from dealers. Despite the widespread access to, and productivity contributions of, transgenic cotton, there are few mechanisms that allow farmers to learn how to use the new technology as part of a more rational approach to insect control.