Journal of Development Studies,
Vol. 43, No. 1, 158–176, January 2007

Naturalising Transgenics: Official Seeds, Loose Seeds and Risk in the Decision Matrix of Gujarati Cotton Farmers

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ABSTRACT *Cotton farmers in Gujarat, western India, faced a novel decision matrix when Delhi gave provisional approval, in March 2002, to Mahyco–Monsanto Biotech Ltd. to release three* Bt-*cotton varieties. These varieties represented India's first legally commercialised transgenics: official seeds. Unofficial transgenic seeds were also available to farmers both as unpackaged, unbranded 'loose seeds' – mostly* F_2 *progeny of a popular but banned transgenic variety – and as packaged, branded local gray-market* Bt *cultivars not approved by government. This essay utilises original field research to analyse the reasoning frame of farmers in choosing which seeds to plant. It finds that* Bt *cotton varieties were valued by farmers for reduction of pest damage, pesticide cost and thus improvement of yields and income. Second, choices among* Bt *varieties are complex, riding on seed-cost differentials between official and stealth cultivars and variable fit of varieties to local agronomic conditions. Third, some farmers chose non-*Bt *cultivars, for various reasons, including preference for organic cultivation – though some considered* Bt *cotton compatible with organic agriculture. Cotton farmers in Gujarat have in effect naturalised transgenic varieties, slotting them into familiar strategies to hedge risks.*

I. Indian Cotton, *Bt* and Risk

India has more area under cotton than any other country in the world, but cotton lint yield has been among the lowest. India's 22 million acres represents about one quarter of the world's total cotton area and occupies 5 per cent of India's cultivated area (for comparative data, James, 2002b). Farmer suicides in India's cotton belt, especially in 1998 and especially in Warangal district, Andhra Pradesh, underlined the risk of growing cotton. Debts sometimes overwhelmed farmers caught in a cost-price squeeze.[1] Farmers most at risk are those with fewest resources. To the extent

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ISSN 0022-0388 Print/1743-9140 Online/07/010158-19
DOI: 10.1080/00220380601055635

risk-reducing innovations are scale-neutral, there is considerable potential to improve the condition of small producers (DuPuis and Geisler, 1988). This is the pro-poor potential claimed for biotechnology. But no insurance is risk-free (Eyzaguirre et al., 2004; Smil, 2004). Agricultural history is replete with cases in which early adoption of technology disproportionately advantaged more prosperous farmers (Dovring, 1973). Risks tend to intensify during experimental phases of new technologies. Thus, as Ortiz (1990) observes, peasant farmers cope by continually modifying their 'insurance' strategies and often pay a premium for seeds and other inputs to avoid worst-case income or property losses. Michael Lipton (1968) emphasised in a classic treatment that it is a rare farmer who does otherwise.

Among the most serious risks to cotton farmers in India are unmanageable pests, particularly the 'American' (green) bollworm (*Helicoverpa armigera)*. Pesticides are costly and not always effective; resistance has developed in major pests. Biotechnology firms argue that their products can reduce this risk; *Bt*[2] cotton plants produce an endotoxin effective against bollworms. They are appealing to farmers if enhanced seed cost is compensated by savings of reduced pesticide applications and higher yield, improving net gains and insuring against risk of crop loss. Indian farmers are subjected to a tempest of claims and counter-claims, from extremely positive results to press reports of 'the failure of *Bt* cotton' (Parmar and Vishvanathan, 2003; Herring, 2005).

Gujarat is a major cotton-growing state in India, agro-ecologically falling into the central zone with the states of Maharashtra and Madhya Pradesh. Area under cotton was about 1.61 million hectares in 2001. The Asiatic types of cotton have been cultivated in Gujarat for thousands of years, and Gujarat has historically been an important centre of cotton production and trade. Attempts to introduce the New World species *G. hirsutum* were made in the eighteenth century. The world's first hybrid cotton *Shankar*-IV (or H-4) was released in 1971 by Gujarat's Cotton Research Station in Surat. Thus, Gujarat's farmers were among the first to experiment with hybrid cottons. Cottons are grown with intensive agro-chemical inputs; many farmers in Gujarat believe that heavy applications of pesticides and inorganic fertilisers threaten soil exhaustion. Farmers who exhaust their soils must change management practices or relocate to new lands, an option infeasible in a country where demand for land is endlessly backlogged. India's land per agricultural capita over 30 years has fallen by half, from 0.44 ha in 1970 to 0.22 ha, in 2000. Farmers are pressured to intensify production on what land they have through new management strategies and technologies. There are good reasons to consider new options, and *Bt* cotton has some attractive features.[3]

Seed choice is fundamental to crop risk; unreliable seed supply and adulteration plague Indian cotton farmers. There is frequently a large gap between demand for certified seed and supply (Siddhu, 1999). Shortage of certified seeds necessitates seed trading with fellow farmers and unauthorised seed sellers and traders (Lalitha, 2003). Cotton farmers typically buy hybrid seeds from recognised companies for reliability and to avoid loss of 'hybrid vigour', despite the lower cost of saved seeds. Compared to traditional indigenous (*desi*) seeds, hybrid seeds also require more industrial approaches to farming – more chemical fertilisers and pesticides, with attendant risks – and increased irrigation – a continuing crisis in Gujarat.

The diffusion-adoption literature on agricultural technologies overflows with examples of 'treadmill' behaviours. That is, structural pressures lead to adoption of state-of-the-art technologies to avoid ceding ground (often literally) to even earlier adopters (Cochrane, 1965). Today, this competition for 'adopter rents' is not limited to the farmer next door. In a world of receding protective tariffs and continued subsidies for farmers from richer countries, Indian cotton farmers find themselves competing with cotton farmers from around the globe. There is thus pressure from within – the stressful agricultural environment of Gujarat – and from external movements in prices and yields to experiment with new solutions. Gujarati cotton farmers cannot afford to be conservative.

Severe risk introduced by inadequacy of existing methods of pest control was manifest in September 2001, when a massive bollworm infestation struck Gujarat, devastating hybrid cotton varieties. There was one notable exception – *Navbharat* 151 (NB151), an unapproved *Bt* variety produced locally. Subsequently, Mahyco–Monsanto Biotech Ltd (MMB) found that NB151 contained the *Cry1Ac* gene for pest control present in the experimental varieties that firm simultaneously had undergoing politically charged biosafety tests. MMB claimed that Navbharat Seeds Limited – a small company based in Ahmedabad – had been selling NB151 seeds for the previous three years and demanded punitive action against the firm.[4] Once the transgenic pedigree of NB151 was discovered, the Genetic Engineering Approval Committee in Delhi ordered the Gujarat Biotechnology Coordination Committee to burn all illegal plantations, sequester the crop and sterilise the fields. These orders were not carried out. Resistance from mobilised farmers and the political importance of Gujarati farmers to the state government over-ruled Delhi.[5]

The discovery of illegal *Bt* cotton eased the way for approval of official *Bt* cotton: the crop was a *fait accompli*. In June 2001, Mahyco–Monsanto had sought approval from the government's Genetic Engineering Approval Committee (GEAC) for commercial cultivation of *Bt* cotton, but GEAC ruled that existing field-trial data were unreliable. Specifically, the crops had been grown when pest incidence was low (Iyengar and Lalitha, 2002). GEAC required MMB to repeat the field trials on a larger scale under the supervision of the Indian Council of Agricultural Research (ICAR). Ten months later, in March 2002, the government granted permission to MMB to sell three *Bt* varieties, provisionally for a three-year period. Deciding otherwise would have been pointless: the state government of Maharashtra had already legalised the seeds from 1 January 2002 and the state government of Gujarat had essentially told Delhi that its farmers would grow this crop if they wished. MMB released three transgenic cotton varieties under the brand name Bollgard (MECH-12, MECH-162, and MECH-184). In 2002–03, against a background of wide-spread crop failure produced by 'bollworm rampage' (Joshi, 2001) and now-legal transgenic cotton cultivars, Gujarati farmers had new planting options before them: Bollgard varieties; illegal non-Bollgard *Bt Navbharat* 151; offspring of NB 151 – the so-called 'loose' seeds of uncertain parentage;[6] and emergent branded (e.g., *Vaman*) *Bt* varieties locally but illegally produced (Jayaraman, 2004). How should new varieties fit into cropping strategies, if at all? Does official approval of some *Bt* seeds and not others matter? How did farmers think about managing new risks that might accompany whatever insurance strategy they pursued – for example, possible crop failure, heightened supplier dependency, adulterated seeds, higher production costs?

II. Mahyco–Monsanto's Survey of its Official Seeds: Comparisons Across States

At the time Gujarati farmers were making cropping decisions in 2002, the national picture was still dominated discursively by the 'Monsanto-terminator-suicide-seed' hoax (Herring, 2005). Monsanto was portrayed widely as a threat to India and to Indian farmers: why would farmers buy seeds from such a firm? The answer found in a large all-India marketing survey, and consistent with the in-depth Gujarat survey discussed below, is quite simple: higher profits.

Having marketed its three varieties of Bollgard seeds widely in 2002 and 2003, Mahyco–Monsanto sought to discover what farmers thought of their product. ACNielsen was retained by MMB for a nationwide survey.[7] That survey found improved yields, reduction in pesticide sprays against bollworms and higher profits in five cotton-growing states: Maharashtra, Madhya Pradesh, Andhra Pradesh, Karnataka and Gujarat for the growing season 2003–04 (Table 1). The study concluded that:

> ... there has been an approximately 30 per cent or 1.7 *quintals* per acre yield increase in Bollgard fields, when compared with conventional cotton fields. The net profit to farmers from Bollgard cultivation has increased significantly by nearly 80 per cent or Rs. 3126 per acre.

Moreover, 'the reduction in bollworm pesticide sprays ... translates into an average savings of Rs.1294 per acre (reduction of 2–3 sprays per acre) for Bollgard farmers'. Of the surveyed farmers, 'more than 90 per cent of Bollgard users and 42 per cent of non-users express their intention to purchase Bollgard in 2004' (ACNielsen 2004a: 1). These results are not unlike findings in China and elsewhere (James, 2002b).

Selected performance measures for Gujarati cotton farmers using Bollgard seed are summarised in Table 1. In this data, reduction of pesticide use for bollworm reached 70 per cent (an average savings of Rs. 1392 per acre, the second highest reported among states). Average yields increased by 18 per cent (lowest among the six states), and net profits increased by 164 per cent (highest among the states). These results also indicate a strong inverse relationship between size of holding and net benefits of transgenic technology: marginal cotton farmers reported over twice the

Table 1. Bollgard outcomes across cotton-growing states

	Bollworm pesticide reduction		Yield increase		Increase in net profit	
State	%	Rs.	%	qu/ac	%	Rs/ac
Andhra Pradesh	58	1856	24	1.98	92	5138
Karnataka	51	1184	31	1.36	120	2514
Maharashtra	71	1047	26	1.48	66	2388
Gujarat	70	1392	18	1.20	164	3460
Madhya Pradesh	52	889	40	2.2	68	3876
All India weighted	60	1294	29	1.72	78	3126

Source: ACNielsen (2004a: 1).

net benefits of large farmers using Bollgard seeds.[8] The smallest producers in this data do especially well, contrary to much conventional wisdom concerning biotechnology. This outcome, if sustained in more detailed studies, conforms to a classic relationship widely reported in the agrarian-reform literature: acres in the hands of small farmers are more productive than those in the hands of large producers, primarily for reasons of labour-intensity and superior oversight (Herring 1983: 239–67).

The ACNielsen survey also found that there was a premium for Bollgard cotton lint in the market, averaging 8 per cent over conventional cotton.[9] More important for consideration of poverty, the survey found that agricultural labourers (who are paid according to the weight of cotton picked)[10] earned a significant increase in income because of the increased Bollgard yield. Though Bollgard was applied to just 1 per cent of the country's total cotton acreage in 2003, the survey projected that its use accounted for a 304,690-litre reduction in formulated pesticides used – saving some water and significant amounts of toxins.

The ACNielsen survey is widely distrusted in civil society in India because of corporate sponsorship; interpretive caution is warranted.[11] Nevertheless, it is the only nation-wide survey available. Highly aggregated data of necessity loses variance in favour of broad coverage. Probing beyond the large-scale survey in individual cotton-growing states will be necessary to interpret these results. In the following section, we explore nuances. Do the summary conclusions of the national survey accord with farmer decision-making on the ground in Gujarat?

III. The Gujarat Small-Scale Sample: *Bt* Adoption Logic

Our primary data source for this section is intensive in-depth interviews with 45 farmers conducted by the senior author in 2002–03 and supplemented by fieldwork the following summer.[12] The 45 farmers were from three different regions of Gujarat. Fifteen were from Saurashtra (Junagadh and Bhavnagar districts), 15 from north Gujarat (Sabarkantha district), and 15 from central Gujarat (Vadodara district). A summary of varieties grown by farmers in these regions is provided in Appendix 1. The sample is not representative, nor can one imagine any small sample that could be in so varied an agro-eological setting.

Of the 45 farmers in this sample, 35 chose to grow some *Bt* cotton variety in 2002–03, the first year of official seeds. Their reasons clustered around bollworm risk management and profitability. These farmers are continuously trying new varieties of cotton; most who had not yet tried *Bt* varieties planned to do so the following season, based on their assessment of local *Bt* results. After the devastating bollworm attack of 2001, which only the un-official transgenic NB151 survived well, one might wonder why some farmers rejected *Bt* technology.

Of the 10 farmers who did not grow *Bt* cotton in 2002–03, there were six in north Gujarat, two in central Gujarat, and two in Saurashtra. Of the six in north Gujarat, four were organic farmers who grew non-hybrid *Lalsanthi* seeds in 2002–03. This indigenous variety is considered less susceptible to diseases and requires less water. Two brothers who make their own herbal pesticides for organic cultivation were planning in 2003–04 to grow two-and-a-half acres of *Lalsanthi* and three acres of *Bt* cotton F_2 (loose seeds).[13] They planned to use only organic fertilisers and herbal pesticides to test loose *Bt* seeds on their land. They saw no contradiction between organic farming and transgenic seeds, though other farmers did. One organic farmer said 'My opinion of *Bt* is that the farmer likes it now. But my mind says it is not sustainable technology'. He cited research in China showing that 'American' (green) bollworm develops full resistance to *Bt* cotton in the twentieth generation. He said that the roughly 5 per cent of the farms in his area which were growing *Bt* cotton – Bollgard and *Navbharat* 151 – were susceptible to green bollworm attack. Moreover, though cotton is generally susceptible to wilting, he felt that 'in *Bt* cotton the wilting problem comes so early that fields turn dry', though this problem was more pronounced in Bollgard than in *Navbharat* 151. He worried that there is no scientific analysis of what kind of losses will be incurred and what kind of environmental pollution will occur.

Non-organic farmers had various reasons for rejecting *Bt*. One farmer growing *Shankar* VI regretted his low yields but declined *Bt* seeds because of price. He added that many farmers in his village had grown *Bt* cotton, with good results. However, the *Bt* cotton crop in his village was susceptible to 'American' (green) bollworms. He added that even though F2 seeds of *Bt* cost less, they give less yield and are less pest resistant. Contrary to the general acceptance of gray-market seeds and casual approach to regulatory systems in Gujarat, he felt that:

> . . . we should not oppose any technique, but we should not let any technique come in without proper testing. We don't know the effects of *Bt* on other cotton or other crops. Nobody knows that. We should have given permission to *Bt* only after proper testing. The way it came into Gujarat was wrong. The government also came to know of it later. It shouldn't take place in a democracy. . . . There is difference in the environment of other countries and ours. We have many cotton varieties. Why doesn't the government produce *Bt* itself as has been done in China?

Other reasons for not growing *Bt* cottons in 2002–03 were as varied as are farmers' experiences, but most who did not try *Bt* in the first year of legal growing did plan to try it in the following season. One farmer in Saurashtra was fairly typical: he was planning to experiment with one packet of Bollgard seeds in 2003–04 after asking neighbouring farmers, the government extension agent, and dealers about which Bollgard variety to buy. He said, 'Bollgard variety requires less pesticide, we have seen that with our own eyes', but there is always the question of how well any given variety will do in one's own soil – hence experimentation. A colleague in Saurashtra said, 'I do three to four acres of cotton every year. I put one variety for experience – to see if it does well in my soil. So I use different varieties of cotton for experience. This year I did not do any research varieties because I had found Vikram 5 to be good for my field'. He planned to grow *Bt* cotton on seven acres in 2003–04, and specifically MECH-12 because of its short duration and bollworm resistance. The Bollgard transgenic will allow resuscitating his earlier strategy of crop rotation. He used to grow Mahyco 4, which would be followed by groundnut and wheat, but this variety is no longer used in his area. He said that perhaps he could grow groundnut and wheat after taking a crop of short-duration MECH-12.

In this sample, *Bt*-non-*Bt* adoption derives from agronomic differences across farms, ideological considerations, and differences in knowledge. The 10 farmers who did not grow *Bt* cotton in 2002–03 were somewhat less likely to have irrigation (80 per cent, compared to 91 per cent of the *Bt* cotton farmers). Fewer used both synthetic and non-synthetic fertilisers (60 per cent, compared to 91 per cent of the *Bt* cotton farmers), and fewer combined both chemical and non-chemical pest control measures (10 per cent, compared to 80 per cent of the *Bt* cotton farmers). Almost 63 per cent of the *Bt* growers used market seeds, because they believe that purchasing seeds each year guarantees 'hybrid vigor' in their plants – and better yield. Half of the conventional cotton growers use market seeds, for the same reasons. Conventional cotton growers were all members of cooperative societies, compared to about two-thirds of the *Bt* cotton growers. This outcome may reflect the weakening of the cotton cooperative movement in Gujarat: farmers at the cutting edge of new technology are less likely to be members.

Though seed-saving is often presented as the antithesis of biotechnology, *Bt* cotton farmers *of all sizes* prefer to use a mix of saved and market seeds. *Bt* cotton farmers were almost as likely to use saved seeds as conventional farmers: 34 per cent of the *Bt* farmers used saved seeds, compared to 50 per cent of the conventional cotton farmers. Several farmers used saved 'loose' *Bt* seeds – mostly F_2 seeds derived from NB151, but unmarked and of uncertain lineage – because the illegal but popular *Navbharat* 151 seeds were no longer available in the market. Farmers were using new illegally marketed *Bt* seed varieties as well (with brand names such as *Vaman* and *Rakshak*), along with both Bollgard and non-transgenic cotton varieties from the market. Table 2 presents the cotton choices in this sample

In this sample, loose *Bt* was preferred by more farmers than official *Bt* [Bollgard]. Far from constituting monopoly power over farmers, Monsanto's *Bt* cotton is not winning the competition on the ground in these data. The choice matrix is in part

Table 2. Variety choices of 35 *Bt* and 10 non-*Bt* cotton farmers, 2002–03 growing season

Varieties	Number of farmers
Farmers growing *Bt* cotton	
Official *Bt* (i.e., Bollgard varieties) only	7
Loose *Bt* only	11
Official *Bt** + Loose *Bt*	6
Branded but illegal *Bt* (*Vaman Bt*) + Official *Bt*	1
Loose *Bt* + non-*Bt* varieties	6
Loose *Bt* + one *Bt* official + one non-*Bt* variety	1
Official *Bt* + non-*Bt* varieties	3
Farmers not growing *Bt* cotton	
Lalsanthi (using organic techniques)	4
PAC 135	1
Shankar-VI	1
JK Durga + Banni	1
JK Durga + Banni + Shankar-VIII + 555	1
Shankar-VI + Sanju	1
Vikram 5	1

Note: 'Official *Bt*' is defined as growing at least one Bollgard variety.

clear: the cheapest seeds are 'loose *Bt*': the F_2 generation of *Navbharat* 151. Though the government has banned the sale of NB 151, the F_2 seeds were available at the rate of Rs. 50 to Rs. 100 per kilogram. 'Loose' varieties were sold or traded informally among farmers. Though cheaper, they may give weaker expression of the *Bt* toxin lethal to bollworms. Moreover, there is no authentication of the seeds: they may be of low quality – or even fraudulent in their *Bt* claim. What stands out is the experimentation among these farmers, and the mix of *Bt* and non-*Bt* in cropping strategies.

IV. Elements of the Decision Matrix

Coping with risk begins with information. How did farmers find out about seed options? All 45 farmers in the sample were informed about *Bt* cotton and its claim to mitigate bollworm attacks. Further, they knew that both legal and illegal varieties of *Bt* cotton were available in Gujarat. Most farmers said that they depended on their own experience when deciding which varieties of seeds to purchase. A second important factor was the experience of other farmers (often those belonging to the same cooperative society). Farmers also paid attention to the news from articles in newspapers such as *Gujarat Samachar* and articles in farming magazines such as *Krushi Jeevan* and *Krushi Gauvidya*. A fourth important source was radio and television programs (for example, *Annadata*). Some farmers also mentioned that government extension agents were important sources of information about the qualities of different seed varieties, while others said they depended on private company extension agents, demonstrations and literature to inform their choices; others cited agro-dealers as important sources of information. Trust in the brand name and company were important. Some said they went to agricultural fairs to get more information about seed varieties. Others learned about varieties from their cooperative societies or from NGOs. NGOs were especially important for organic farmers. A few farmers went to the agricultural universities in Gujarat to get more information about seed varieties.

There is nothing passive about this behaviour. These farmers were actively experimental, continually testing different varieties to see how well they would grow in their particular soil and water conditions.

After collecting information about different seed varieties from various sources, farmers faced two decisions: (1) whether to grow *Bt* cotton or not; (2) if yes, whether to grow legal varieties of *Bt* cotton or not. Those who decided to grow *Bt* cotton (whether legal varieties or illegal varieties) considered water and electricity to be necessary conditions. Most farmers believed that all *Bt* cotton varieties (whether legal or illegal) needed more water compared to non-*Bt* varieties: both opinions and experience varied on this dimension.

If farmers chose to grow *Bt* cotton, they then had to decide whether to grow legal or illegal varieties. Again water came first. Many farmers believed that the water requirement of *Navbharat* 151 was less than that of Bollgard varieties. Several believed that pesticide costs of *Navbharat* 151 for bollworms and sucking pests were less than those required for Bollgard varieties; they preferred F_2 offspring of NB 151 to Bollgard. Pest-resistance management also figured into the decision of some farmers: they believed that there were no refuges required when growing

Navbharat 151, while those planting Bollgard had to grow refuges. These farmers did not wish to grow refuges, considering it a waste of land. The result of these multiple considerations was the predominance of loose seeds in Table 2. Farmers who rejected loose seeds despite their low cost cited loss of hybrid vigour in F_2 or F_3 seeds. Reinforcing this logic was a feeling of some farmers that seeds available in the open market were preferable to black-market seeds; they chose Bollgard varieties precisely because of their official, government-approved status. One farmer chose a Bollgard variety because of its comparatively long staple length. These preferences by their nature are unstable; all are subject to testing in the field. For example, several farmers who grew MECH-184 in 2002–03 found it requires early watering to avoid wilting and thus is inappropriate for their farms.

Supply influences choice as well. Some farmers said that in 2002–03, their agro-dealers had few packets of particular *Bt* varieties; they were not able to sow *Bt* seeds according to their choice. These farmers said that the government should give permission to many companies, including Navbharat, to sell *Bt* cotton seed legally, to ensure availability of multiple varieties of *Bt* seeds.

V. Selected Farmers' Experiences with Yields and Income

In this sample, there were only two farmers (both from Junagadh district) who had planted Bollgard MECH-12 (hereafter Bollgard will be assumed; MECH is Mahyco's name for their hybrid varieties). S. B. Patel of Junagadh district cultivated MECH-12 on five acres in 2002–03 and obtained a yield of 14 quintals per acre. He approves of MECH-12 because of its yield, and because the boll size was good and the staple length was 32 mm. The other farmer, J. V. Barot, reported a significantly lower yield of seven-and-a-half quintals per acre. Mr. Barot had also grown a branded unofficial *Bt* variety called *Vaman Bt*, which gave the same yield. He reported that MECH-12 had some problems from sucking pests and American bollworm, while there were no such problems with *Vaman Bt*. For this farmer, MECH-12 had certain disadvantages compared to the gray-market transgenic competitor.

Another farmer in the Junagadh district, J. Chauhan, reported that he had grown Mahyco 1 (which is non-transgenic) on six acres, MECH-184 on one acre, and loose *Bt* on one acre. His yield was five quintals per acre from Mahyco-1, 5 quintals per acre from MECH-184, and 10 quintals per acre from loose *Bt*, though he gave the same irrigation to all three varieties. Sucking pest attacked all three varieties. MECH-184 suffered the least sucking-pest attack. Mahyco 1 had the most serious bollworm attack; MECH-184 had few bollworms, whereas loose *Bt* had none. On all counts, for this farmer, the loose-seed transgenic proved superior, even leaving aside the seed cost differential, which is huge.

Mahyco–Monstanto's MECH-184 also had problems with wilting, as mentioned by a number of farmers from different parts of Gujarat, including S. B. Patel of Junagadh. In addition to being a farmer, S. B. Patel is a seed trader. He said he did not sell much MECH-184 because it is an early-maturing variety, and thus prone to wilting. He concluded that this variety must get water and fertiliser in its early stages or the crop can fail. Patel compared MECH-184 to a small baby that should be carefully fed milk during the early stages of life. He believed that farmers had problems with this variety because they did not know this critical agronomic fact. In a similar vein, S. J. Jamod of Vadodara said that MECH-162 was successful in his area, but not MECH-184. He obtained 14 quintals per acre from MECH-162, but 11 quintals per acre from MECH-184. He had chosen not to grow NB151 in 2002–03 because only F_2 and F_3 generations were available to him, and he believed these seeds do not yield well. But he maintained that NB151 was better than official varieties because it grows faster and needs less water than MECH-184. He was advised by the representative of Monsanto to water MECH-184 every 10 to 15 days. As he had no water source of his own and had to buy water from others, 184 was an inferior choice to 162. Not trusting F_2 and F_3 generation seeds, Mr. Jamod was willing to invest in costly Bollgard seeds, but found only one variety appropriate for his circumstances.

L. Savjibhai of Junagadh experimented with all available transgenics: he had grown MECH-184 on two acres, MECH-162 on three acres and *Navbharat* 151 (F_2) on one acre. He owns 25 acres of land and a tractor and irrigates from his own well. Savjibhai reported a yield of seven-and-a-half quintals per acre with MECH-184, six quintals per acre with MECH-162, and only three quintals per acre with F_2 seeds. Water figured in his understanding of differences: Bollgard plants needed more water than NB151, and MECH-184 needed more water than MECH-162. He felt that NB151 had less sucking pest attacks and fewer bollworms than MECH-184 and MECH-162. Despite some pest attacks, Savjibhai thought that there was a 'difference of earth and sky' (*zamin aasman no farak chhe*) when comparing *Bt* cotton with non-*Bt* cotton; *Bt* cotton was profitable because it lowered the incidence of pest attack. Because Gujarati farmers generally face a shortage of water and NB151 required less water than MECH varieties, and handled pest attacks with less expenditure, Savjibhai preferred NB151. The conclusion of this farmer and seed merchant has negative aggregate consequences: Savjibhai prefers a variety that gives less than half the yield of the best MECH variety, but the upfront costs of seeds are a fraction of those of MECH seeds and water requirements are less. The profit margin may be higher, but cotton yield suffers and labourers who are paid by the kilogram picked have less income than would be the case with higher yields. Moreover, his preferred variety is illegal.

N. Patel of Vadodara had grown MECH-162 on about three acres and loose *Bt* on 45 acres in 2002–03. He obtained similar yields (about 10 quintals per acre) for both varieties. Attacks of bollworms and other pests had been so severe in his area that yields had not exceeded 7.5 quintals per acre during the previous five years. He attributed his highest yield in five years specifically to transgenic cotton. Nevertheless, N. Patel said that he would not be growing MECH in 2003–04 because the seeds were costly and the yields of loose *Bt* were comparable. In contrast, K. Bhatt of Vadodara had been growing *Navbharat* 151 for the previous three years. But it was only in September 2001 that he realised that he had been growing a transgenic crop. In 2002–03, he planted NB151 on 11 acres and MECH-184 on one acre. The weather was good in 2002–03 and there was less incidence of pests; attacks of sucking pests were less on NB151 compared to MECH. He obtained a high yield of 13.6 quintals per acre from MECH-184 and a yield of 10 quintals per acre from NB151. B.R. Patel of Vadodara grew NB151 in 2001–02 and obtained yields of eight quintals per acre. In 2002–03, he obtained yields of 13 quintals per acre from NB151. Most cotton farmers reported that 2002–03 was a lower pest-incidence year. Still, he noted an attack of sucking pests on NB151, but no bollworm attack. A similar conclusion on pests was reached by A.R. Bhanderi of Vadodara district. He grew *Gujarat 23* (an indigenous variety) and a loose *Bt* variety. He obtained a yield of 2.3 quintals per acre for Gujarat 23 and 4.5 quintals per acre for loose *Bt*. Loose *Bt* seeds did better than *Gujarat 23* in terms of yield, but required two sprayings for sucking insects.

VI. Small Farmers' *Bt*

Are small farmers experiencing the introduction of transgenics in any systematically different way when compared to their larger neighbours? In general, the answer is no. The 14 smallest farmers in the sample split between *Bt* and non-*Bt* in ways similar to the larger farmers. Six of these farmers chose not to plant *Bt* in 2002–03, but of these, four said they would plant *Bt* in 2003–04. The other two farmers preferred organic farming and ruled out *Bt*.[14] Of the four planning to plant *Bt* in 2003–04, three said they would plant MECH while one said he would plant loose *Bt*. Of the smallest 14 farmers, eight planted *Bt* cotton in 2002–03: a combination of loose *Bt* F_1, loose *Bt* F_2, MECH-184, MECH-162 and MECH-12. All eight said they would plant *Bt* cotton (either loose or official) in 2003–04.

An example may help illustrate their logic. M. D. Patel, from Saurashtra, owned five acres of land; he two acres to *Navbharat* 151 F_2 seeds and obtained a yield of 300 kg per acre. He sowed MECH-184 seeds on 1.3 acres but he did not get good results. He said, 'Sucking pest attack and bollworm attack was more on MECH-184 compared to NB151. I sprayed Confidor (for sucking pests) one time on NB151 and I had to spray Confidor six times on MECH-184'. He said he would sow NB151 in 2003–04. Another small farmer from Central Gujarat who owns 5.5 acres of land said he grew MECH-162 and MECH-184 in 2002–03.

> I decided that since no other company has permission to sell *Bt*, I will buy Monsanto's seeds. The seeds were costly – Rs 1600 for 450 grams, but I got enough yield, so MECH-162 suited me. MECH-162 is a success for our soil but MECH-184 has not suited the farmers at all.

He obtained a yield of 1439 kg per acre for MECH-162 in 2002–03. His yield of 1136 kg per acre for MECH-184 was termed a 'failure'. He planed to sow MECH-162 in 2003–04. This farmer did not use NB151 F_2 because he claims that yields decrease by 50 per cent with the second generation of hybrids. He used to spray pesticides 15 to 17 times on *Shankar-VIII* and *Shankar-X*; with MECH he sprays pesticides only four to five times.

The smallest farmer in this sample – Mr Barot – owns four acres of land and grew cotton on three acres in 2003–04. He has been practicing organic farming for seven years. He grew an indigenous variety of cotton (*Lalsanthi*) in 2002–03, as he had for the previous three years; its yield is only 150 kg per acre. Despite this performance, the benefits of *Lalsanthi* are many in this farmer's mind: it is immune to pests, it gives 'good yields', it is early maturing – ready in 160–80 days like the hybrid varieties – and picking is easy because the bolls open well, though they are small.

VII. Conclusion: Risk, Transgenics and Gujarati Cotton

Gujarati farmers use an array of information points and risk assumptions in deciding which cotton seeds to combine in their fields. The pattern was similar for large farmers and small farmers in field interviews. Most are comfortable with transgenic seed materials as part of their familiar risk-aversion strategies. *Bt* cotton varieties, if accessible and affordable, contribute to risk management. Cotton farmers in Gujarat are wary of dependence on a single variety: even if *Bt* cotton monocultures have a reputation for high yields, the dominant ground strategy is continual experimentation and mixing of varieties. These farmers say that even though *Bt* varieties reduce pesticide costs substantially and improve protection from bollworms, they are not without risk. Seed traders can be unscrupulous, passing along adulterated seeds of uncertain parentage. Risky seeds include the inexpensive 'loose' seeds (unpackaged, unlabeled transgenic varieties) with which farmers continue to experiment.

But if loose seeds entail risk, farmers also feel that it is risky to incur the very high cost of transgenic seeds officially approved by the government. *Navbharat* 151 had given good results in the preceding year (September–October 2001), when the bollworm infestation was particularly heavy, motivating farmers to try filial generations of NB151 in 2002–03.

Seed cost alone cannot be the determining factor in choice, however. There is considerable risk in tying up land and resources in any seeds, inexpensive or dear. Most important, farmers' experiences with *Bt* cotton cultivars were quite variable – contrary to the claims of public intellectuals claiming *Bt* cotton to have been a disaster.[15] Experientially, *Bt* cotton has done well for most farmers in both data sources used in this study, but there are many choices to be made within the *Bt* frame and across other cotton varieties:

(a) *Seed price*: For critics of transgenic technologies, the potential of monopoly and price-gouging from dependency makes the new seeds unattractive for the poor. In Gujarat, something like the obverse of monopoly is evident in the fields – a rare competitive market. Some farmers complained about the high cost of Bollgard varieties, but demand for official seeds continues to grow. The price of *Bt* seeds can be considered an insurance cost; buying bollworm insurance in 2002–03 would have been a far less wise investment than in 2001, but farmers could not know this in advance. For many farmers in 2001, the choice to stick with tried and true traditional varieties resulted in disaster. In the ACNielsen survey, smaller farmers benefited more from *Bt* than large in revenue enhancement per acre. Yet limited-resource farmers, for whom the higher cost of official seeds must be subjectively set against their insurance value, have not coalesced on any particular strategy.

(b) *Legal risk*: Both official and loose *Bt* seeds performed reasonably well in 2002–03. Farmers who preferred the cheaper grey-market seeds perceived no legal risk in buying them.

(c) *Yields*: There was no general pattern; agronomic variation is telling. Some farmers obtained higher yields with loose-seed transgenics, others with Mahyco–Monsanto MECH varieties. If there is any conclusion, it is that *Navbharat* 151 – the 'Robin Hood' seed[16] – may have been the best variety, though it has been officially banned. MECH-184 seems to be the most finicky about water timing. All *Bt* seeds proved capable of producing profits under typical conditions.

(d) *Safe seeds*: Though yields achieved with unofficial seeds were high, there is risk in buying loose seeds. Farmers feel their choices would improve if the government legalised NB151; they would then have better assurances of unadulterated seeds from licensed firms. Most farmers felt that the government should allow Navbharat and other companies to sell *Bt* cotton, providing wider varietal selection and competition to reduce prices.

(e) *Sucking pests and bollworms*: *Bt* cottons provided a fairly high degree of protection from the American bollworm, the spotted bollworm and the pink bollworm in Gujarat; sucking pests such as aphids, jassids and whiteflies remain a threat. Farmers would like to see new technology for protection against sucking pests and complete protection against bollworms to reduce pesticide spraying further.

(f) *Pest insurance*: On some farms, pest incidence was much lower in 2002–03 compared to 2001–02. Therefore the performance difference between *Bt* cotton and non-*Bt* cotton declined somewhat in 2002–03. Most *Bt* farmers saved money by reducing pesticide application. If *Bt* seeds command a premium price, the value of implicit insurance purchased thereby is difficult to calculate, as farmers cannot predict pest incidence. This uncertainty helps explain the widespread preference for loose *Bt* seeds: the insurance is cheap and works reasonably well. It is more a satisficing than an optimising strategy.

(g) *Wilting and agronomic knowledge*: Farmers who cultivated MECH-184 reported problems with wilting. Some lacked knowledge of agronomic characteristics of the variety: they were not aware that more water was required early in the growing cycle. Others simply could not supply enough water. Nevertheless, some farmers had excellent yields from this most problematic of the MECH varieties.

(h) *Resistance management*: The *Cry1Ac* toxin is a public good. If *Bt* crops speed development of resistance to this natural pesticide, there is enhanced collective risk. *Refugia* are the proposed remedy. All farmers growing MECH varieties in the small sample claimed to have planted refuges, but those cultivating unofficial *Bt* varieties did not. It is unknown whether bollworms will develop resistance more quickly in Gujarat because of lack of refuges or if the combination of small farms and polycultural practices, as well as alternative hosts for bollworms provided by India's specific plant diversity, are sufficient to offset poor refuge management.[17] Most farmers were unconcerned with this long-term public good in their seed choices.

The conclusion of the national study by ACNielsen – that Indian farmers will prosper if they adopt Bollgard seeds due to remarkably high net returns – is not contradicted by this analysis, but caveats are introduced. Likewise, the structure of decisions is consistent with the model and outcomes suggested by Zilberman et al. (this issue), though with more complexity of choice. Specific MECH varieties may not prosper in specific fields. It was highly unlikely that three officially approved varieties of *Bt* cotton could serve the quite variable agronomic conditions Indian farmers face; complaints a bout Mahyco–Monsanto followed. Moreover, the official seeds carry a high cost that must be borne upfront, with the possibility of indebtedness if the crop fails. This cost could deter poorer farmers if credit institutions are not effective. Despite national-level rhetoric, Gujarati farmers see transgenic cotton varieties not as 'miracle seeds or suicide seeds', but as useful additions to strategies of adapting to adverse biotic and abiotic risks. Unlike lumpy capital investments that systematically favour wealthy farmers, transgenic seeds – both in theory and on the ground – exhibit what Rogers (1995) calls 'trialability' – defined as the degree to which experimentation with an innovation may be done on a limited basis. Trial and error experimentation is consistent with the way Gujarati farmers approach cotton.

Despite globalisation and industrialising pressures in agriculture, Gujarati farmers are empirical and experimental in their struggle with the cotton economy and its risks. Their attitude is essentially empirical: what works? Larger ideological constructions of transgenics are missing in the fields (Herring, forthcoming b). Large and small farmers alike used saved and 'loose' seeds, officially approved and illegal transgenic seeds in 2002–03. The high price of official seeds distressed many; the uncertain quality of loose seeds worried others. Accordingly, they mixed and matched seeds according to their needs, not all of which were economic.[18] Ongoing experimentation is an elemental part of their risk-management strategies; transgenics have simply added new possibilities to the mix. It is in this sense that most Gujarati cotton farmers have naturalized transgenics, fitting them into traditional strategies of conceptualizing and managing risk and assuring a livelihood.

Most discussion of agricultural risk centres around capital: who has put up money and may lose it? But there are many at risk in an agrarian economy who have no voice in technology choice. As in much of the world, the most precarious poor in Gujarat are the rural landless labourers. The ACNielsen study reports very large aggregate benefits for agricultural labour.[19] This finding is consistent with the agronomic findings in those agrarian settings in which labourers are paid by the weight of the harvested crop. As yields increase, so too does the harvest wage bill, assuming farmers cannot exert sufficient power to capture all the benefits of technical change. There is some support for the ACNielsen findings in Gujarat: some labourers interviewed in summer 2004 found *Bt* cotton beneficial, as they could pick more in a given day.[20] Though they lacked knowledge of the different varieties, they did not fear displacement by the reduction of pesticide applications, as this happened at a time of year in which other employment was available. There can be no firm conclusion here, but it is important to note that not all risk is borne by farmers: in the event of crop failure, such as the bollworm rampage of 2001, there is no cotton to harvest, and hence no income for cotton workers. In bumper crop years, labourers have a somewhat easier time making subsistence. Labour has a stake in the risk strategies of farmers.

It is widely recognised in the development community, at least rhetorically, that for both pragmatic and ethical reasons, farmers should have a say in agricultural developments that affect their welfare (Toennissen, 2004). We would add other elements of rural society, including farm workers. The views and voices of real agriculturalists have frequently been drowned out in the largely metropolitan conflict over biotechnology – more often a discourse of cities than of villages. *Bt* cotton is already altering the landscape and risk calculus of rural India. What we learn from farmers of Gujarat should help understand both policy challenges of a technology rapidly spreading across India and the complexity of decision-making among farmers facing new options.

Notes

1. Vasavi (1999), Stone (2002), Parmar and Visvanathan (2003). Reports of a suicide epidemic have not involved Gujarat.
2. In 1998, the Indian firm Maharashtra Hybrid Seeds Company Ltd (Mahyco) partnered with Monsanto to produce a joint venture – Mahyco–Monsanto Biotech Ltd (MMB). Breeders back-crossed Monsanto germplasm with local cultivars to obtain varieties that would suit Indian agronomic conditions. On *Bt* biology and agronomics, see Thies/Devare, forthcoming.
3. Clive James (2002a: 19) reports that 'In China the economic gain for resource-poor *Bt* cotton farmers [in 2001] was $500 per hectare. . . . In South Africa, where 50 per cent of cotton farmers are women, cultivation of *Bt* cotton allows them more time to care for children, the sick, and/or generate additional income from other activities'.
4. Navbharat did not market NB 151 as a transgenic, only as a hybrid especially resistant to bollworms. It resulted from a cross of plants containing the *Cry1Ac* gene (the origin of which is disputed) with a local variety (Gujarat Cotton 10). Navbharat still faces charges for biosafety violations in selling un-approved transgenic seeds, but there is no patent protection for the Monsanto gene in India. (See Herring, forthcoming a).
5. Joshi (2001), Parmar and Vishvanathan (2003), Herring (2005: 210–7); Herring (forthcoming a).
6. The English word is in use locally; farmers also call these seeds *lodhavela biyaran* ('ginned seeds' in Gujarati) to designate non-Bollgard *Bt* seeds. These are sold loose – unpackaged and unbranded – by farmers to each other or by traders to farmers. Gupta and Chandak (2005) report widespread crossing of hybrids with *Bt* varieties by farmers for informal sale among neighbours.
7. The authors thank researchers at ACNielsen ORG-MARG for sharing unpublished information on their research findings. Their study interviewed 1672 Bollgard cotton farmers and 1391 conventional cotton farmers in five states. For research design, ACNielsen (2004).
8. Using size categories standard for India, the following net revenue *changes* [in Rs/acre] for *Bt* adoption are reported (ACNielsen 2004b): marginal farmers: 11,000 to 12,000; small farmers: 7000 to 8000; medium farmers: 6000 to 7000; large farmers: approximately 5000.
9. The reason for a premium is that bolls are less damaged. Raju Barwale, MMBL, 2004, personal communication to Herring described the same result, of somewhat lower magnitude; the small Gujarat sample discussed below finds no premium, nor did Herring's interviews with cotton farmers in Gujarat in 2005.
10. An estimate of Rs. 75,00,000 ($1.67 million). This payment practice is not universal. Given differential class power, it is uncertain that labourers can count on sharing gains in labour productivity from technological change.
11. Even if not tainted by MMB funding the ACNielsen data face potential validity and reliability problems in their size categories, imputed labour values and other issues. Farmer responses to questions about acres farmed often confuse operational and owned holdings and variable interpretations of joint-family versus nuclear-family holdings. Rented land takes many different form. Not all rented lands involve cash leases and may mix elements of lease and mortgage. In the field study discussed below, 8 of 45 farmers (17 per cent of the sample), had leased land. Finally, there is a problem of comparing isogenic varieties for scientific assessment of the *Bt* added value.
12. The 45 farmers are part of a larger snowball sample of 120 farmers for Devparna Roy's dissertation (Roy, 2006). Non-random snowball sampling was used to identify respondents, based initially on information of local extension agents. All farmers' names used in this paper have been changed to protect their privacy.
13. When two different parent lines (whether pure lines or not) are crossed, the first generation of seeds is called F_1. When resultant seeds are sown again, that generation is called F_2; the third generation, F_3, and so on.
14. Organic cultivation of cotton has emerged as an alternative, but biopesticides account for a small fraction of the market – about 3000 tonnes of the 0.1 million tonnes of annual pesticide trade in India (Singh, 2002).

15. For example, Krishnakumar (2004) reports that a six-member panel set up by the Gujarat government to evaluate the performance of *Bt* cotton concluded that Bollgard is unfit for cultivation and should be banned in Gujarat. Gupta and Chandak's (2005) survey of Gujarat's farmers found that Mahyco–Monsanto Biotech (MMB) cotton gave higher yields than *Navbharat* 151, but their preference remains the latter because of its ability to yield for longer duration, earliness in flowering and lower seed costs.
16. On farmer organisations' role in resisting official orders to destroy the crop (Herring, forthcoming a).
17. See Thies and Devare (forthcoming) for explanation of why the effects of *refugia* on resistance development in *Lepidoptera* are unknown.
18. Though not part of the sample under discussion, Roy has discussed seed choice with farmers who prefer traditional values of agriculture, including organic methods. There is in India a distinctive Gandhian undertone to preference for established over novel technologies.
19. But their methodology prevents a necessary disaggregation: 'labor' is imputed a value in their findings whether performed by the farmer or by hired wage labourers.
20. Laborers said that they could pick more cotton because of the shape of the boll. The *Bt* gene should do nothing to the morphology of the boll; this must be a varietal characteristic, perhaps more common in the varieties to which the *Bt* technology has been applied, but not a *Bt* trait. Gupta and Chandak (2005) report that several farmers have crossed (illegal) Navbharat 151 with local hybrids and produced economically beneficial results, extending the life of cotton in the field from six to nine months to take advantage of continuous flowering and thus higher yield.

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Appendix 1. Details of varietal mixes in cotton farming, 2002–03

No.	Region	Total acres	Acres of cotton	Variety1	Variety2	Variety3	Variety4	Variety5	Variety6
1	1	55.00	5.00	lalsanthi					
2	1	30.00	20.00	**loose Bt**					
3	1	55.00	5.00	lalsanthi					
4	1	22.00	8.00	lalsanthi					
5	1	15.00	1.00	**loose Bt**					
6	1	33.00	9.00	**loose Bt**					
7	1	4.00	3.00	lalsanthi					
8	1	25.00	1.00	**Mech162**					
9	1	13.20	4.00	S-VI					
10	1	20.00	1.00	**Mech184**					
11	1	20.00	2.00	PAC135					
12	1	20.00	2.00	**Mech162**					
13	1	8.00	1.48	**loose Bt**					
14	1	18.00	1.00	**loose Bt**					
15	1	10.00	1.00	**Mech12**					
16	2	30.00	15.00	**loose Bt**					
17	2	25.00	10.00	**loose Bt**	S-VIII				
18	2	16.50	15.80	**loose Bt**	S-X				
19	2	10.50	6.00	**loose Bt**					
20	2	11.90	8.00	JKDurga	Banni	555	S-VIII		
21	2	13.20	6.00	JKDurga	Banni				
22	2	21.00	12.00	**loose Bt**	**Mech184**				
23	2	55.00	12.00	**loose Bt**					
24	2	5.50	5.5	**Mech162**	**Mech184**				
25	2	20.00	20.00	**loose Bt**	S-VIII	VCH9			
26	2	15.00	10.00	**loose Bt**					
27	2	75.00	45.00	**loose Bt**	**Mech162**	**Mech184**	S-VIII	VCH9	Guj.23
28	2	115.00	40.00	**Mech162**	**Mech184**	S-VI	S-VIII	**LooseBt**	
29	2	138.00	48.00	**loose Bt**	**Mech162**				

(*continued*)

Appendix 1. (*Continued*)

No.	Region	Total acres	Acres of cotton	Variety1	Variety2	Variety3	Variety4	Variety5	Variety6
30	2	50.00	8.00	**loose Bt**					
31	3	9.9	2.50	S-VI	Sanju				
32	3	66.00	6.00	**loose Bt**	Sandrocot	Ajeet9	JK99		
33	3	40.00	5.00	**Mech12**					
34	3	59.00	18.80	**Mech12**	**VamanBt**				
35	3	10.00	8.00	**loose Bt**	**Mech184**	Mahyco1			
36	3	25.00	6.00	**loose Bt**	**Mech184**	**Mech162**			
37	3	5.00	3.30	**loose Bt**	**Mech184**				
38	3	13.20	4.00	**Mech162**	Rasi 2				
39	3	10.00	3.00	Vikram5					
40	3	13.20	5.00	**loose Bt**					
41	3	28.50	6.50	Mech162	Mech184				
42	3	29.70	4.00	**Mech184**	Sanju				
43	3	33.00	12.50	**Mech184**	Sanju	S-VI	Dhanno		
44	3	26.40	18.00	**loose Bt**	**Mech184**	Vikram9			
45	3	33.00	10.00	**loose Bt**	**Mech162**	Vikram9	Vikram11		

Note: Transgenic varieties in **bold type.** (a) Region 1: north Gujarat; Region 2: central Gujarat; Region 3: Saurashtra; (b) S-VI = Shankar-VI; S-VIII = Shankar-VIII; S-X stands for Shankar-X; Guj. 23 = Gujarat 23; (c) Mech 12, Mech 162 and Mech 184 are the three Bollgard varieties legally approved for use in Gujarat during 2002–03. Loose *Bt* includes the technically illegal *Navbharat* 151 and other unbranded varieties of *Bt* cotton.