AgBioForum, 18(2): 209-220. ©2015 AgBioForum.

Technology Diffusion and Adoption in Cotton Cultivation: Emerging Scenario in Gujarat

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Technology adoption in agriculture depends on the access to information by farmers. This article focuses on the diffusion of seed and pesticide technology among the Bt cotton growers in Gujarat, India. Even though the dealers are supplying two crucial inputs in cotton cultivation, information provided by them appears to be limited. Dealers are aware of hybrid features of the seeds, but have very little knowledge about the Bt traits, use of refuge, and the targeted pests. Farmers seem to select the variety on their own after experimenting with more varieties, and there is very limited extension support. Dependency on the organized seed market seems to be increasing compared to the initial years of introduction of Bt. On the use of pesticide, though, farmers appeared to assess the situation before spraying the chemicals, yet the kind of chemicals used raise health, environmental, and productivity concerns in the long run.

Key words: agriculture Bt cotton diffusion, extension pesticide, seed, technology.

Introduction

Technology adoption by farmers is influenced by information asymmetries, as well as the access and resource constraints at the individual level and checks imposed by natural factors. More access to information either through the traditional extension service through the government or the market channels help in reducing the costly experiments that the farmers have to do by 'learning while doing.' With the sophisticated transgenic seed technology primarily developed and diffused by the private sector, the extension service is likely to be provided by the input providers and their distributive channels through programs such as visits to the demonstration plots. The role of the public sector in such a situation is limited to that of a regulator. Hence, the challenge for the present extension systems in countries adopting a technology is to "meet the information requirements that would allow farmers to develop experience about transgenic varieties and to accommodate credence qualities in their variety choices" (Tripp, 2001. p. 253).

However, in India, information asymmetries are large in the agricultural segment. A detailed review of agricultural extension in India observes (Glendenning, Babu, & Asenso Okyere, 2010) that despite the variety of agricultural extension approaches that operate in parallel and sometimes duplicate one another, the majority of farmers in India do not have access to any sources of information. The recent National Sample Survey Office survey (NSSO, 2014) reveals that only 41% and 35% of the cultivating households accessed any technical advice. This result is not different from the NSSO 2005 survey, where 60% of the farmers had not accessed any information (NSSO, 2005). Even among those who sought technical advice, the two popular sources of information for farmers still included progressive farmers and radio/TV/newspaper/internet. For Bt cotton adoption in India—which seems to be scale neutral and has been adopted by both marginal and large farmers—information on specific farm-management practices is important to derive maximum benefits from the technology. Since both the seeds and the chemical pesticides are bought from market sources, it is of particular interest to know the kind of information provided by the input providers (dealers) to the farmers. The crux of this article is to understand the diffusion issues with seed and pesticide technology among Bt cotton growers in Gujarat by analyzing the farmers' use practices of these inputs.

In order to comment on the diffusion pattern of technology, we have relied on the information gathered from seed dealers in 2007. We also use data from two primary surveys conducted in 2007 and 2010 to discuss the variety choices and pesticide use patterns. The survey in 2007 was conducted in the districts/villages of Rajkot, Bhavnagar, Baroda, Surendranagar, and Ahmedabad and included 200 randomly-chosen cotton growers in these districts. The survey was repeated among the same districts/villages in the 2010 kharif season (the rainy season).[1]

Table 1. Major agricultural companies by revenue (2010-14).

Rank	Company	Revenue in Rs. crore 2013-14	2012-13	2011-12	2010-11	% change over 2010-11
1	Nuziveedu seeds	775	778.13	745	610	27.0
2	Kaveri seeds	647	420			
3	Ajeet seeds	309			87.5	253.1
4	Rasi seeds	266	229	392	371.88	-28.5
5	Mahyco	250	246	314	359	-30.4
6	Ankur seeds	228	341	325	250	-8.8
7	Krushidhan seeds	73	199.81	173.8	276.13	-73.6

Source: Various issues of BioSpectrum

This article presents select features of the bioagriculture business in the country and the cotton scenario in Gujarat. Technology diffusion, Bt cotton adoption by sample farmers, and pesticide use patterns are also discussed.

Status of the Bioagriculture Business in India

Globally, the area planted to biotech crops has increased steadily from a small 1.7 million hectares in 1996 to 175.2 million hectares in 2013 in 27 countries by 18 million farmers (Navarro & Hautea, 2014). Global value of the biotech seed market in 2012 was estimated to be $15 billion. Cotton accounts for 12% of the total biotech crop (soybean, maize, cotton, and canola in order of area).

Genetically modified (GM) cotton is the only crop that has been commercialized in India thus far. It has spread to 10.8 million hectares, or 93% of the total cotton area in 2011-12 (Navarro & Hautea, 2014). A substantial portion of GM seed production is done by the private sector, and India is not an exception to this trend. The approach paper to the 12th Five Year Plan (Government of India, 2011) acknowledges the role of technology in agriculture and also stresses the fact that private sector-research and the seed industry focus on very specific crops that have adequate scale and scope of repeated sales. In India, the birth of agribiotech companies is essentially due to the liberalization of seed policies. Until the 1990s, the Government of India (GOI) had followed a very restrictive seed policy. In the 1970s, strictly adopting the import substitution policy, GOI banned commercial imports of all agricultural inputs that were being produced in India. The seed sector was one of the beneficiaries of the partial liberalization measures introduced in the early 1980s, where GOI gave seed and biotech industries 'core industry' status in the new seeds policy of 1988. Further, this policy allowed seed firms to import commercial vegetable seeds with no quotas in order to import commercial seeds of foreign varieties of coarse grains and oilseeds for a period of two years, after which the firm was expected to produce the seeds in India. It also allowed import of germplasm for research purposes. Transgenic seeds developed locally or imported had to be deposited with the gene bank.

Three cotton events are in use in India. MON531 (*Cry1Ac*) and MON15985 (*Cry1Ac* and *Cry2Ab2*) —both developed by Mahyco/Monsanto—were commercialized in 2002 and 2006, respectively. JK Seeds sourced the *Cry1Ac* event from IIT Kharagpur. Nath Seeds sourced the fused genes (consisting of *Cry1Ac* and *Cry1Ab*), from China, and both the events were commercialized in 2006. MLS 9124 (synthetic *Cry1c*) developed by Methalix Life Sciences, though approved in 2009, has not been placed in the market yet (Navarro & Hautea, 2014). Both MON531 and MON15985 have been licensed to several other seed companies in India, creating a stiff competition among seed companies in the Bt cotton segment.

The revenue share of the bioagriculture sector increased from 5% in 2006-07 to 13.3% in 2013-14 of total biotech industry revenue (*BioSpectrum*, 2011, 2014). But the bioagriculture sector recorded the slowest growth at 4.27% in 2013-14, which is also reflected in the reduced revenue of some of the major seed companies in 2013-14 (Table 1).

However, the top two places in terms of revenue belong to Nuziveedu and Kaveri Seeds, both from

1. *Due to non-availability of the same farmers at the time of the repeat survey in 2010-11, 67% of the sample consisted of different farmers. Also due to the nearly complete adoption of Bt cotton by the sample farmers, the discussion is restricted to Bt cotton only.*

Table 2. Bt production by state (in lakh bales).

State	2009-10 (revised estimate)	2010-11 (estimate)
Punjab	14.25	16.47
Haryana	14.75	13.84
Rajasthan	11.0	6.46
Gujarat	98.0	106.82
Maharashtra	63.0	77.31
Madhya Pradesh	15.0	18.04
Andhra Pradesh	52.0	65.68
Karnataka	9.0	10.15
Tamil Nadu	5.0	6.71
Orissa		2.0
Others	1.0	2.0
Loose supply	12.0	
Total	295.0	325.48

Source: BioSpectrum (2011, p. 47)

Table 3. Projected sale of BGI and BGII for 2011-12.

	BGI		BGII		Total quantity
State	**Quantity**	**MRP**	**Quantity**	**MRP**	**BGI & BGII**
Maharashtra	40	830	123	930	163
Gujarat	6	830	50	930	55
MP	10	830	12	930	23
Andhra Pradesh	11	830	79	930	90
Karnataka	4	830	16	930	20
Tamil Nadu	1	830	5	930	6
Punjab	11	925	14	1,000	25
Haryana	12	925	14	1,000	26
Rajasthan	4	925	8	1,000	12
All India	103		317		420

Note: Quantity in lakh packets, MRP Rs/packet 450 grams + refugia.
Source: BioSpectrum (2011, p. 47)

Telangana. Nuziveedu has been in the top position for several years, selling about 100 lakh[2] Bt cotton seed packets. However, its market share has declined from 40% in 2012-13 to 24% in 2013-14. This company has introduced a new concept of breeding in which erect plant types are used in Bt cotton hybrids, which reduces the space required between plants and increases the crop density per acre (*BioSpectrum*, 2014, p. 40). Kaveri Seeds, though incorporated in 1986, has become a popular choice in the recent years and commands 20% of the market share and ranks second. All the companies have set up an extensive marketing network. Rasi Seeds, which sold about 42.5 lakh packets of Bt cotton hybrids in nine states during the 2010 kharif season, is estimated to have sold about 35 lakh packets of Bt cotton seeds in 2013. One major development for Rasi in 2013 was the acquisition of the hybrid corn seed business of Bayer Bioscience in India. This should help the company in finding newer market areas. The policy uncertainties over the future of GM crops in India and the stagnation in the area under Bt cotton (Rao, 2013) are two major reasons for this declining trend observed in seed companies.

The central region—which includes Gujarat and Maharashtra—accounts for 66.4% of the total land under Bt cotton, followed by the southern region at 20.5% in the 2010 kharif season (*BioSpectrum*, 2011, p. 47). Gujarat, Maharashtra, and Andhra Pradesh are far ahead of the rest of the states in terms of production (Table 2).

All the companies started with the Bollgard I variety of cotton (which offers protection against bollworms) but now have moved to Bollgard II (which offers protection against bollworm and spodeptra). Except for certain districts of Gujarat, which had reported the pink bollworm's resistance to the Bollgard I variety, no other state had reported resistance issues (*BioSpectrum*, 2011, p. 47). However, the projected sale of Bollgard I and Bollgard II in different states shows (Table 3) that in Andhra Pradesh, Maharastra, and Gujarat, Bollgard II has almost replaced the Bollgard I variety.

In December 2010, the Genetic Engineering Approval Committee (GEAC) gave permission for field trials of Bt corn developed by Monsanto at five locations for the 2011 rabi (dry season) in Bihar (two locations), Tamil Nadu, Karnataka, and Andhra Pradesh; and at 9 locations for kharif 2011 in Bihar (two locations), Tamil Nadu, Karnataka, Andhra Pradesh, Uttar Pradesh, Rajasthan, Gujarat, and Madhya Pradesh. In March 2011, the Union Environment and Forests Minister Jairam Ramesh asked the GEAC to immediately withdraw its permission to Monsanto for field trials of Bt maize in Bihar. With two independent committees of the GOI recommending a moratorium on GM food crops, it is not clear whether the GM brinjal and corn would be released, even though considerable work has gone into it. If approved, the Biotech Regulatory Authority of India (BRAI) bill would be one approach

2. *A unit in the Indian numbering system equal to 100,000.*

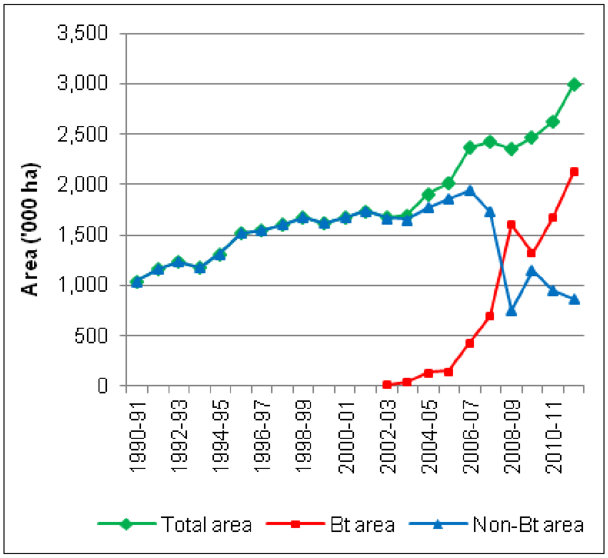

Figure 1. Area under cotton in Gujarat.

Source: Data provided by Directorate of Agriculture, Government of Gujarat, August 2012.

to regulation of biotech products. Commercialization of agricultural and health biotech products would nevertheless be left to the central and state governments. Since the BRAI bill that was introduced in the 15th Loksabha has already lapsed, a decision on this would be taken by the current government. Hence, it appears that Bt cotton will be the only commercialized GM crop for years to come; therefore, lessons learned from the spread of this crop should be useful in the case of crops that are yet to be adopted.

In the following paragraphs, adoption and diffusion of GM cotton is discussed in the context of Gujarat.

The Cotton Scenario in Gujarat

Gujarat has the credit of developing the first cotton hybrid in the 1970s. With the introduction of Bt cotton in the year 2002-03, total area under hybrids and varieties that occupied 99% of the total area in 2002-03 declined to 28.9% in 2011-12 (Figure 1). By the time the approved varieties were planted in Gujarat in 2002, it came to light that the farmers were also planting on a large scale another Bt variety that was not commercially approved by the GOI. The widespread adoption could not be prevented, as farmers found the yield difference between the approved and unapproved variety to be negligible (Lalitha & Ramaswami, 2007; Lalitha, Ramaswami, & Viswanathan, 2009). But, it has nevertheless contributed to increasing the area under Bt cotton cultivation from a mere 8,000 hectares in 2002-03 to 21.3 lakh hectares in 2011-12 in the state.

Diffusion of Technology

In India, as the Bt technology has been introduced in popular cotton hybrids, widespread adoption has taken place in a short time. As farmers easily recognize the newer variety from the same company, and 'Bt' is used either as a prefix or suffix of the popular hybrids, Bt adoption has been faster, thus reducing the learning costs that discourage adoption of new technologies. As a business strategy it has worked well with companies.

Bt cotton farmers in the state and in the country face a complex seed market that offers many choices, as there are nearly 1,128 hybrids that have been approved for sale in India. It may be noted that the private seed companies as well as public-sector corporations sell through a network of distributors and dealers. The distributor/dealer indents seed with the companies well in advance. But not all seeds sold by the dealers are certified. Under the Indian seed laws, a private seed company could sell seeds either as certified or a 'truthfully labeled' seed. Hence, an unscrupulous seed dealer could push a particularly poor quality seed to a farmer at the same price as the good-quality seed.

Seed Diffusion through Dealers

A total of 82 dealers were contacted for the study, in the same districts and talukas (administrative division or sub-district) where the farmer survey was conducted in 2007. Thus, we contacted 19 dealers in Rajkot, 14 in Bhavnagar, 16 each in Vadodara and Ahmedabad, and 17 in Surendranagar. The primary objective of the survey was to understand the information available through the dealers about the seeds and pesticides that they were selling, and how much of this information has been accurately passed on to the farmers.

Selling cotton seed and pesticides is the main business activity for a majority of the dealers, and 77% of the dealers also deal with other seeds. Seventy-seven percent of the dealers have their shop in the taluka headquarters, and 16% of the dealers have their shop in a village. A small 7% operate in both villages and talukas. Hence, it can be said that the diffusion point is not geographically very far for the farmers to reach. Forty-five of the dealers started their seed business after 2002, and as many as 14.6% of the dealers came into the business in 2005, which essentially coincides with the government's approval for more companies to sell Bt cotton seeds.

In seed technology dissemination, it emerged from our survey that 50% of the dealers recommended a particular variety and others simply sold what the farmers requested.

As many as 92 names of Bt seeds were given by the dealers that were sold in 2007, which also included some of the unapproved variety. This was also confirmed by the fact that 5.4% of the responses on price of Bt sold per packet ranged from Rs 100 to 600, while as many as 80% of the responses indicated selling the seeds at Rs 750; this was the official price of the approved Bt seeds in 2007.

In 2007, more varieties of Bt cotton were available in the market; when dealers listed their top-five-selling varieties that year, it elicited as many as 354 responses. The numbers reported for 2005 and 2006 were 106 and 188, respectively. Interestingly, only two varieites (Rasi and Ankur) remained in the top positions in all three years of the dealers' ranking of the varieties according to their sales; this is irrespective of the fact that the number of varieties sold by the dealers had increased in the three years.

When we collectively look at all Bt varieties sold by dealers during 2005-2007, 88.7% of the sales have been approved varieties. More than 80% of dealers were aware of the important characteristics of the prominent varieties that they sold; these characteristics include 1) effect on yield, 2) time to maturity, 3) number of bolls, 4) boll size, 5) staple variety, 6) production expected in irrigated and unirrigated conditions, and 7) amount of watering required.

Eighty-four percent of dealers said that the top varieties sold by them offer good resistance to bollworms; 11% considered them to have medium resistance and 2% considered them to have poor resistance. More than 92% of dealers could not name the types of bollworms or sucking pests. Further, 14% of the dealers said that the varieties offer good resistance to sucking pests, while 46.3% categorized them as poor.

It was also evident from the dealers' response that not many of them are aware of the fact that the Bt seed packet also consists of refuge seeds—only 25.7% of the dealers said that the Bt seed packet includes refuge seeds.

We were also interested in knowing the kind of extension service offered by the seed dealers. Eighty-nine percent of the dealers said that they do provide extension services. Thirty-nine percent of dealers provided information on insecticide use to the farmers, while the remainder considered that their recommendation of the services provided by the seed companies counted as their extension service.

It may be noted that all the seed sales were paid with cash, and credit was limited to a short period of two weeks only. Short-term credit was made available only if the dealer had known the farmer for a long period of time. Forty-four percent of the dealers said that they provide credit for the purchase of seeds, which included both Bt and hybrid varieties. While 11% of the dealers said that they provide credit on certain brands only, 33% said that they provide credit on all brands.

Theory suggests that—in the case of experience goods such as seeds—firms will invest in advertisements and outreach to the farmers (Murugukar, Ramaswami, & Shelar, 2006); however, in our survey, only 11% of dealers said they had company-specific schemes promoting sales, which included both cash and gifts. Thirty-three percent of the dealers said that they give small gifts (i.e., bags and calendars) to the farmers. But not all companies provide compensation to farmers when the seeds fail to germinate, the plants wilt, etc. (perhaps they are not supposed to be failing). Only three seed companies had instances of compensating the farmer by providing new packets of seeds.

Thus, an important point that emerges from this description is that, while the dealers are aware of the qualities pertaining to the hybrid features of the seed, they have limited information about the Bt trait introduced in the hybrids.

Farmer Adoption of Seed Technology

It should be noted that when a newer seed technology is introduced, adoption may not be faster.

> "Larger farms will start with experimentation by applying the new technology on part of the land and using the traditional techniques of cultivation on the rest of the land. With the passage of time, those who have already adopted the innovation on part of their land expand their use of it or switch completely to the innovation while new adopters join from the ranks of smaller farms. It is shown that those who join late may not need to experiment, since the level of uncertainty will be quite low for laggards. The aggregate rate of adoption, measured by the ratio of land cultivated using the new technology relative to total cultivated land, demonstrates an S-shaped pattern over time as observed in reality for many

Table 4. Bt cotton adoption trend among sample farmers.

Year	Total cotton land (in ha)	Bt cotton land (in ha)	Area under Bt cotton (%)
2010-11	853.22	707.87	82.97
2009-10	780.70	636.61	81.54
2008-09	767.97	625.99	81.51
2007-08	1016.00	906.55	89.23
2006-07	967.20	832.62	86.09
2005-06	879.66	704.72	80.11
2004-05	781.84	522.18	66.79
2003-04	737.43	397.83	53.95

Source: Authors' farm household survey, 2007-08 and 2010-11

innovation diffusion processes" (Feder & Mara, 1981, p. 46).

We find this trend to reflect Bt adoption among the sample farmers; adoption rapidly increased up to 2006-07 and, after a small decline, appears to have stabilized at around 80% of the total cotton area (Table 4), with 89% of the chosen farmers cultivating only Bt hybrids by 2010-11.

We do not claim that complete matching with the trade names of the seeds was done, because as Tripp (2001, p. 255) observes, "modern variety names are often complicated letter-number codes that anyone would have trouble remembering," but often instead identify with local names. A look at the names of the seed reported by farmers and matching it with the company brand name reveals a conservative estimate that 7.5% and 9%, of the seeds could belong to the desi (hybrid) and approved Bt varieties in 2007-08, respectively. The rest perhaps are all different names of the unapproved variety that has circulated among the farmers.

In 2007-08, seeds purchased from the organized sector (Table 5; shops, cooperatives, university, research centers, etc.) comprised 35% of the total seed purchase. The substantial presence of the unorganized sector can be associated with the sales of the unapproved seeds through the 'farmer-to-farmer' sale. The geographical perspective of diffusion of technology (discussed in Basant, 1988) highlights two stages of the diffusion: 1) the establishment of diffusion agencies or outlets through which the innovation or information about the innovation is distributed to the population at large, and 2) the implementation of a strategy by each agency to induce adoption among the population in its service area. Hence, unless some institution makes the innovation available at or near the potential adopter's location, seeds was through the well-organized informal seed network among farmers and seed producers, which created faster adoption of the technology in the state.

Table 5. Farmer distribution by source of seed purchase.

Source of seed purchase (%)	2007-08	2010-11
Organized sector	35.13	90.92
Unorganized sector	54.76	8.07
Both organized + unorganized	10.11	1.01

Source: Authors' farm household survey, 2007-08 and 2010-11

We find that the number of farmers reporting buying seeds from the seed shop increased from 2007-08 to 2010-11 (Table 5), implying a reduction of unorganized sources and convergence with the organized market.

Farmers buy the seeds on cash payment, which is reported by 73% and 78% of the farmers during 2007-08 and 2010-11, respectively. Also, just 1% of the farmers in 2007-08 reported getting some benefits from the shopkeeper for their purchase, while none in 2010-11 received any benefits on their purchase. However, only 63% of the farmers said that they were properly billed for their purchases in 2010-11, while in 2007-08, this percentage was 40%. In 84% of the cases, it is the farmer who made the choice about seeds, though 50% of the dealers said that they have actually recommended a particular variety to the farmers. Less than 3% of the farmers said they have bought a dealer-recommended variety.

In total, the farmers cultivated 191 and 172 varieties in 2007 and 2010. Two major points emerge from Table 6. The total number of varieties and land under cotton cultivation by sample farmers declined in 2010. While the percentage of farmers and the land under single variety has grown substantially in 2010, percentage of land under more than one variety has declined overall. Does that mean farmers are experimenting with more varieties or does the trend point out that the "seed choices are either based on environmental learning or social learning" (Stone, 2007, p. 211) and often guided by the yield perception? We also find that farmers with experience learn how practices and technologies perform together under variable conditions (Stone, 2007). This is reflected in Table 7, where the farmers' response indicate that their own experience with the seed is equally important in deciding on a particular seed, along with other considerations.

A farmer's decision to choose a particular variety depended primarily on the high-yielding nature of the variety in 2007-08 (Table 7). In 2010, while it was still important (28%), factors such as a farmer's own experi-

Table 6. Distribution of farmers by number of varieties grown and percentage change in land cultivated.

	2007-08			2010-11			
Number of varieties	Number of farmers	% of farmers	Total cotton land (in ha)	Number of farmers	% of farmers	Total cotton land (in ha)	% change in land over 2007
1	47	23.5	123.72	77	38.5	258.20	108.70
2	64	32	307.19	52	26	195.51	-36.35
3	40	20	196.65	34	17	163.96	-16.62
4	23	11.5	132.39	25	12.5	152.70	15.34
5	13	6.5	132.35	6	3	38.08	-71.23
6	5	2.5	36.28	3	1.5	17.24	-52.47
7	3	1.5	37.73	3	1.5	27.53	-27.04
8	3	1.5	25.72				
9	1	0.5	6.48				
10	1	0.5	17.51				
Total	200	100	1,016.00	200	100	853.22	16.0

Source: Authors' farm household survey, 2007-08 and 2010-11

Table 7. Factors considered by farmers in seed choice.

Details	2007	2010
High-yielding variety	73.3	28.23
Bigger bolls and quality of cotton	7.2	10.2
Own experience		20.2
Resistance to pests	4.8	5.02
Suitability to unirrigated conditions	0.96	10.29
Experience of neighborhood farmer	0.48	9.81
Other factors	13.2	16.2
Total	99.94	99.95

Source: Authors' farm household survey, 2007-08 and 2010-11

ence with the seed as well as fellow farmers' experience and the suitability of the seed to marginal environment also mattered.

In disseminating transgenic seed technology, the extension service needs to educate adopters about the recommended biosafety measures in addition to the requirements regarding the salient features of the seed, nature of planting, requirement of fertilizer, timing of pesticides application, etc. But there is good evidence that resource poor-farmers often do not have even the most basic information about the crop varieties they are growing (Tripp, 2009).

It was evident during the field visits that only a small percentage of farmers (18% and 17% in 2007 and 2010, respectively) were aware of the purpose of refuge requirements and was actually using the non-Bt seeds provided with the Bt packet. A majority of the farmers considered that using the non-Bt seeds would increase pests in the field. This misconception could be because of the fact that the dealers, who are the farmers' diffusion point, themselves have limited knowledge about the Bt traits and need for refuge practices.

Pesticide Spray Decisions

Regarding pesticide use in India, Alagh (2004, p.125) observes that

> "while the alternative methods of biological control, homemade formulations and environment friendly alternatives have had a low usage as well as a low awareness, the awareness about chemical pesticides is 100% in all the states. Most of the farmers in Andhra Pradesh, Punjab, and Gujarat use chemical methods. All these farmers also consider chemical pesticides to be effective. The differences in the percentage of adopters and usage of pesticides between small holders and the total do not appear to be significant. Pesticide use levels were determined significantly by the extent of irrigation, presence of cotton and wheat in the cropping pattern, increased use of high yielding varieties and agricultural wage rates. Once the farmer accepted pesticides as necessary, his demand for pesticides seemed to be inelastic."

One of the intended benefits of Bt cotton seeds is to reduce pesticide use, particularly for bollworm, which is the major pest in cotton. It has been reported that subsequent to the introduction of Bt cotton in India, insecticide use expenditures for cotton has decreased to 21% in

Table 8. Insecticide expenditure in cotton (Rs. in crores).

Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
% Bt cotton				0.38	1.2	5.59	11.51	41.42	67.1	80.8	82.43	90.67
Cotton insecticide	879	839	1,052	597	925	1,032	649	579	733	791	834	880
Cotton fungicide	11	10	6	3	8	6	8	11	25	31	52	67
Cotton herbicide	2	1	1	1	3	4	8	12	22	26	45	87
Total insecticides in agrl.	2,128	2,052	2,268	1,683	2,146	2,455	2,086	2,223	2,880	3,282	3,909	4,283
% share of cotton	41	41	46	35	43	42	31	26	25	25	21	21
Total pesticides in agrl.	3,004	2,972	3,207	2,622	3,147	3,581	2,439	3,396	4,697	5,293	6,999	7,684

Source: Down to Earth (n.d.)

2010 as compared to the 41% share of cotton in 1999 (Table 8). Bollgard II—based on the pyramid technology—offers protection against bollworm and *Spodoptera*. Hence, because of the in-built protection against these pests in cotton, it is expected that pesticide use on Bt cotton farms would decline due to wider adoption of Bollgard II in 2010-11.

As many as 49 names of pesticides were reported by dealers to have been sold in 2006 and 2007. We received 258 and 215 responses on the top three pesticides sold by dealers in 2007 and 2006, respectively. Of these pesticides, names like monocrotophos, acephate, acetamapride, and imidachloride figure prominently; these are also the preferred pesticides of the farmers. The expenditure on pesticides reported by the farmers ranged from Rs 200 to more than a lakh in both years. It is evident that while pesticide use has declined, farmers have shifted to more expensive pesticides to control pests. The average number of sprays per hectare has been reduced from 5.4 in 2003-04 to 3.7 in 2010-11.

Information provided by the farmers on pesticide use yielded more than 150 names in both the years. It should be mentioned here that most often farmers could not report the actual ingredient of the insecticide—only the trade and the local names. Hence, it is possible that actually only a few generics are used but are known by many trade names. In a few cases, we were able to gather more information about the pesticides from the pesticide packets that the farmers had with them. Farmers used both liquid and powder forms of insecticides in their field. In both years, more than 95% of the farmers reported the names (generic, local, or trade) of the pesticides they used.

The salient features that emerge from pesticide use (Table 9) in both years include the following.

1. Overall quantity of pesticide used in 2010-11 was reduced by 27%, and hence, the per-hectare use of pesticides also reduced from 6.04 in 2007-08 to 4.94 in 2010-11.
2. In both years, the number of liquid pesticides remained almost the same.
3. There is a significant jump in the quantity of insecticide used in the >500 liter category, which consists of monocrotophos. Monocrotophos belong to the organophosphate category and are classified by the World Health Organization in the highly hazardous category. One known limitation of the organophosphate category of pesticides is that they are more toxic to parasitoids and predators than to insect pests, which results in pest resurgence of secondary pests (Kumar et al., 2010). This insecticide alone accounted for 31% in 2007-08 and 42% in 2010-2011 of the total quantity used because farmers reported using this to control sucking pests, bollworms, and other plant diseases as well.
4. We also note that a large number of pesticides have been reported in the <10 liter category, but the actual quantity reported in this segment is actually only 15% in 2007-08 and 10% in 2010-11.
5. In the case of insecticides in powder form, a particular insecticide known by the name parathion accounted for 48% of the total quantity reported in 2007-08. Interestingly, in 2010-11, the quantity of the same reduced to 33.19 kg, which is just 1.2% of the total quantity in powder form. It is possible that this product—which is a generic—is also sold in another brand name.
6. Also, the total quantity of insecticides in powder form reduced by 54%. This reduction could make a significant difference to both human beings and the environment.

Table 9. Pesticide use pattern among sample farmers.

	2007-08		2010-11	
Range (in liters)	Number of pesticides	Quantity reported in liters	Number of pesticides	Quantity reported in liters
Pesticides in liquid form				
>500	1	715.5 (31.1)	1	1,039.153
>100 < 500	5	593.6 (25.9)	3	636.6
>10 < 100	21	638.5 (27.8)	21	539.57
<10	136	346 (15.1)	141	255.27
Total	163	2,293.6 (100.0)	166	2,470.593
% change in quantity over 2007-08		7.7		
Pesticides in powder form				
Range (in kg)	Number of pesticides	Quantity reported in kg	Number of pesticides	Quantity reported in kg
>1,000	1	1,365.8 (48.3)		
>500	1	669 (23.7)	1	617
>100	1	256 (9.1)	1	165
>10 < 100	12	412.5 (14.6)	14	403.4
<10	55	123.9 (4.4)	48	102.8
Total	70	2,827.2 (100.0)	64	1,288.2
% change in quantity over 2007-08		-54.4		
Total pesticides (liquids and powder form)				
Total insecticide used in liters*		5,238.6		3,812.468
% change in quantity over 2007-08		-27.2		
Per hectare use		6.04		4.94

Note: Figures in parentheses indicate percentages
Source: Authors' farm household survey, 2007-08 and 2010-11
** Indicates that the figures in KGs have been converted to liters.*

Information gathered from the farmers indicates that the spray decisions were taken after inspecting the field. Sixty-one percent and 45% of the spray decisions during the study years were taken because of the high intensity of pests observed in the field. However, a small 3% of the spray decisions were based on the fellow farmers' decision to spray. A majority of the pesticide sprays were aimed at controlling sucking pests. The relatively small percent of sprays targeted for bollworms and *Spodoptera* in 2007-08 perhaps indicates that these were not a major issue for the farmers (Table 10). But, in 2010-11, while the sprays aimed at sucking pests decreased, those intended for bollworm and 'others' (which includes reasons such as growth and nourishment) show an increase compared to 2007-08. The probable reason could be that

> "intensive cultivation of Bt hybrids without the use of refugia has been hastening resistance in bollworms. Excessive use of imidacloprid as seed treatment and foliar sprays on Bt hybrids has resulted in insecticide-resistant leaf hoppers and is causing more damage. Threats from new insect pests such as mealybugs, mirid bugs, jassids, thrips, pink bollworm and diseases such as cotton leaf curl virus and wilt are increasing" (Jishnu, 2011).

Table 10. Percentage of insecticide sprays by target pests.

	2007-08	2010-11
Sucking pest	75.94	63.52
Bollworm	7.32	11.01
Spodoptera	3.68	
Others	1.95	21.57
Unknown	11.11	3.90
Total	100.00	100.00

Source: Authors' farm household survey, 2007-08 and 2010-11

During field surveys, it was not uncommon to find the combinations other than those suggested by the Cen-

Table 11. Pesticide combination used by farmers.

Major pesticide	Combinations used
Monocrotophos*	Endosulfan**[+], Confidor**, Tatamida**, Acephate***, Acetamypride, Prophanophos**, DDVP, Imidaclorolpride**, Computer**, , Quinalphos**, Astafpowder, Cypermethrin, Ethion**, Tarthin***
Acephate* **	Monocrotophos*, Endosulfan**, confidor, Tatamida**, Prophenophos, computer**, Ethion, Confidor

Note: A few of the local names as reported by farmers have also been mentioned.

+ Many civil society organizations have been actively demanding a ban on endosulfan at the national level in India due to its adverse impacts, as reported from few states, viz., Kerala and Karnataka. In early June 2011, the Government of Gujarat had banned the use, production and sale of endosulfan.

, ** and * indicate the pesticides that belong to the WHO classification of most hazardous, moderately hazardous and slightly hazardous category.*

Source: Authors' farm household survey, 2007-08 and 2010-11

tral Insecticide Board and Registration Committee (CIBRC; see Appendix 1) and different combinations that involve highly hazardous and slightly hazardous chemicals (Table 11); this could be detrimental to the soil and the crop and may even affect the yield. For instance, farmers reported using monocrotophos with as many as six other chemicals in 2007-08 and at least four other chemicals in 2010-11. The apprehension here is that when newer neonicotinoids (which are slightly or least hazardous in nature) are mixed with an extremely toxic organochlorine or organophosphate such as monocrotophos, it could end up with the same fate of pyrethroids, for which all the major cotton pests have developed resistance. It is not out of place to cite the recent European Union's decision taken in spring this year where a partial ban on three neonicotinoids suspected of having adverse impact on bees, butterflies, and other non-target species (Martin et al., 2013) was imposed.

Likely Impact of Pesticide Use

The severity of any adverse effects of exposure to pesticides on humans depends on the dosage, the route of exposure, how easily the pesticide is absorbed, its accumulation, and persistence in the body (Mukhopadhyay, 2003). Farmers' exposure to pesticide can happen in four possible ways—a) dermal exposure, b) ingestion, c) inhalation, and d) absorption through eyes. Use of personal protective gear such as goggles, gumboots, protective clothing, and face masks prevent such exposure. Our survey revealed that farmers do not use any such precautions while spraying pesticides. Very few farmers reported using handkerchiefs as a face mask to prevent direct inhalation. A small number of farmers also reported practices such as not smoking during the spraying operation to prevent direct ingestion of chemicals. A safe re-entry period after spraying pesticide is unheard of among the farmers. In contrast, it was revealed by the farmers that none of them had serious health problems after spraying, and whatever little symptoms that were reported were not serious enough to receive medical attention immediately. Hence, there was no medical expense reported or man-days lost due to sickness. Similarly, none of the farmers reported any visible adverse impact on the environment due to continued pesticide use. It must be added here that all the farmers in our panel have been cultivating cotton for many years. Therefore, they have been exposed to pesticide applications for a long time, so separating the effects of pesticide sprays due to Bt cotton on soil and farmers' health would call for a completely different scientific enquiry. Nevertheless, we cannot totally rule out the possibility of potential damage to the environment and soil productivity because pesticides "harm the soil structure and soil aeration, reduce the water holding capacity of the soil, making more prone to soil erosion by water and wind" (Mukhopadhyay, 2003, p. 35).

Essentially, the potential environmental implications emerging from the use of pesticides need more empirical investigations based on information/data generated from micro-level monitoring and surveillance; this is virtually lacking in the current context. Equally important is the health of the farmers and farm workers engaged in spraying pesticides. It appears from the pesticide-use pattern that farmers are more concerned with the higher yield that a variety could be associated with than a specific issue such as pest or disease resistance that the variety may acquire due to improper farm practices (such as lack of refuge criteria) since they may not be immediately obvious. Such practices may affect not only the particular farm that lacks such practices but also the neighboring farms. It is in this context, extension activities should move from solely on-farm activities to focusing on larger issues (for instance, the impact of inappropriate use of chemical inputs).

It should be remembered that "a transgenic insect-control technology is most likely to be used effectively if it is part of a broader pest-management strategy involving a range of technologies and, crucially, farmer management skills" (Tripp, 2009, p. 242). Presently, this is not happening, which particularly calls for focused extension services among Bt cotton adopters. Global impact studies of farmer field schools show reduced use of toxic pesticides; in the context of rice in Sri Lanka, 4-14% higher yields were found for farmer field school graduates who cultivated cotton compared to the control group (Glendenning et al., 2010; Tripp, Wijeratne, & Piyadasa, 2005). The importance of farmer field school is that it runs through the entire crop season and—through collective action—builds social capital among farmers. Though there are new initiatives on extension service by the public and private sectors, the impact is not widely spread.

Summary and Conclusion

This article focused on the diffusion of seed and pesticide technology among Bt cotton growers in Gujarat. Though the dealers are supplying two crucial inputs in cotton cultivation, information provided by them appears to be limited. Dealers are aware of hybrid features of the seeds but have little knowledge about the Bt traits, use of refuge, and the targeted pests. Farmers seem to select the variety on their own after experimenting with several varieties, and there is very limited extension support. Dependency on the organized seed market seems to be increasing compared to the initial years after introduction of Bt. Even though farmers appear to assess the situation before spraying pesticides, the kind of chemicals used raise health, environmental, and productivity concerns in the long run. Developed countries have banned harmful organophosphates, which are widely used in India without any safety precautions. Use of pesticides targeted on sucking pests continues to be high. The information about refuge is limited to a small percentage of farmers.

Bt cotton is the only GM crop in India, though there are a number of promising products that are undergoing field trials; these may be released in the future if they clear all the policy hurdles. In the future, if GM crops have to be adopted, then the entire extension system needs to be reformed so that biosafety measures are effectively followed. Reforms require—among other things—active involvement of farmers through user groups/associations and building gender concerns into the system by manning the extension services predominantly by women (Dev, 2008). Lack of extension service results in inappropriate and misuse of technology, and ultimately technology becomes redundant due to misuse even within its limited lifetime. Extension based on user groups, farmer associations, or farmer field schools need to be strengthened in all the cotton-growing states among cotton cultivators. Prevalence of such collective action and more interaction among the farmers about their experience in adopting a particular technology would increase the learning experience, reduce stress, and even help in reducing farmer suicides.

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Acknowledgement

The authors thank Prof.Chandraekara Rao for his comments on the earlier draft. The usual disclaimers apply.

Appendix 1. Insecticide combinations approved by CIBRC.

A.	Insecticides
1	Carbaryl 4% + Gamma BHC 4% Gr.
2	Deltamethrin 1% + Triazophos 35% EC
3	Profenofos 40% + Cypermethrin 4% EC
4	Chlorpyriphos 50% + Cypermethrin 5% EC
5	Cypermethrin 3% + Quinalphos 20% EC
6	Chloropyriphos 16% + Alphacypermethrin 1% EC
7	Acephate 25% + Fenvalerate 3% EC
8	Phosalone 24% + Cypermethrin 5% EC
9	Ethion 40% + Cypermethrin 5% EC
10	Deltamethrin 0.75% + Endosulfan 29.75% EC
11	Cymoxanil 8% + Mencozeb 64% WP
12	Methyl bromide 98% + chlorpicrin 2%
13	Propoxur 0.25% + cyfluthrin 0.025% Aerosal
14	Cyfluthrin 0.025% + Tranfluthrin 0.04%
15	Imiprothrin 0.1% + Cyphendthrin 0.15%
16	Propoxur 0.5% + Cyfluthrin 0.025% Spray, Propoxur 0.5% + Cyfluthrin 0.015% Spray
17	Acephate 5% + Imidacloprid 1.1%

Source: http://www.cibrc.nic.in/pesticides.doc accessed on 13th May 2011.