# Chapter 14
# Social Responses to Crop Biotechnology: Bt Cotton Cultivation in Gujarat, India

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## 14.1 Introduction

Unlike many other large scale engineering projects, the size of technology in genetically modified (GM) crop biotechnology is miniscule. What makes crop biotechnology a megaengineering project is its spread. According to one survey (James, 2008), the genetically modified seeds were grown in 6 countries in 1996 – the first year of commercialization, which has increased to 13 in 2001, to 18 in 2003, and 25 in 2008. Genetically modified soybean, maize, and cotton constitute substantial part of this spread. Other crops such as canola, squash, alfalfa, papaya, and sugarbeet have been mainly introduced in the U.S. whereas tomato, poplar, petunia, and sweet pepper in China. Recently, genetically modified brinjal (aubergine) is under discussion for the commercial release in India. More than 85% GM crops have been bred for tolerance to specific herbicide and insecticides but almost all the rest are insect resistant varieties. These crops contain the genes controlling the production of a natural insecticide, Bacillus thuringiensis (Bt), which acts specifically on Lepidoptera groups of pests.

The current debates on genetically modified crop-biotechnology are often two-dimensional, pitching benefits against risks, and proponents against opponents (Stone 2002). Most arguments for and against transgenics are about their outcomes and impacts, whether on farmers, on health and the environment, or on economic performance (Narayanamoorthy & Kalamkar, 2006; Peshin, Dhawan, Vatta, & Singh, 2007; Qaim, 2003; Qaim & Janvry, 2005; Qaim & Zilberman, 2003; Ramanjaneyulu & Kurunganti, 2006; Sahai, 2002; Sahai & Rahman, 2003; Sahai & Rehman, 2004). I contend that framing the debate in terms of "back-end risk and impact assessment" is insufficient to evaluate the appropriateness or the social desirability of genetically-engineered crop technology. Instead my aim is to assess the "front-end issues" such as the social and political context of technological

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choice (Scoones, 2003). I first review social response and performance of genetically modified Bt cotton in several parts of the world and then explores, through an anthropological and historical approach, the social context of the choice of Bt cotton seeds in the western Indian state of Gujarat.

More specifically, following four sets of questions are explored.

1. Which farmers in various parts of the world are cultivating genetically-engineered cotton seeds and why? What is the social response and context of Bt cultivation in different parts of the world?
2. Discussing specifically the case of Gujarat, how have agrarian relations and access to land, water, and labor impinged upon the cultivation of Bt cotton and the multiplication of Bt seeds?
3. Arguing that cotton cultivation has become increasingly risky and uncertain in current times, how have farmers from Gujarat dealt with various forms of uncertainity?
4. Why have farmers from Gujarat popularly adopted Bt seeds, and specifically how has this global technology and knowledge become locally appropriated, modified and exchanged?

Ultimately, I seek to explain the cultural, productive, environmental, and cognitive context within which cotton growing farmers in Gujarat adopt, develop and diffuse genetically-engineered crop biotechnology.

## 14.2 Social Responses to Crop Biotechnology

There are only a few studies that have systematically explored the spread of crop biotechnology among different sections of peasantry (cf. Stone, 2007). Who among farmers make a choice of biotechnology and why is a question that has not yet been extensively researched. Based on the available literature, I attempt in this section to provide an overview of GM adoption in some of the major GM cultivating countries. I should note that this survey is by no means exhaustive.

According to one argument the GM crops commercially grown today have been designed for production in regions that already support highly capitalized agro-industry (Tripp, 2001). For instance, the powerful sugarcane producer cooperative in Brazil opted for GMOs to decrease overall pesticide use and maintain production levels, but the association of Western Bahian Farmers and Irrigators, the powerful farmers' group in Brazil's dynamic soybean production regions, explicitly stated its opposition to GM crops (Jepson, 2002). Although at some point GM soya was smuggled across the border from Argentina and used extensively by the large-scale commercial farmers in Brazil (Scoones, 2008). The anti-GM position of the Western Bahain Farmers and Irrigators association, it is argued, may have co-opted the European "green" argument in which different kinds of commercial interests seems to be playing a dominant role. Brazil ships over 80% of its annual soybean exports and 68% of its annual soybean meals export to European markets. It was estimated that Brazil's monopoly over non-GM soybean products for the captive European market that prefers non-GM (green) soya benefitted Brazilian traders US$20 per metric ton more compared to Argentina's GM soybean products (Jepson, 2002). The contrasting positions on GM of sugarcane and soybean growers in Brazil might have been predominantly driven by the common goal of commercial interests. In South Africa, similarly large commercial interests have been the strong advocates of GM maize. They sought to reduce cost of production in response to progressive reduction in farm subsidies given to the white commercial farm sector (Scoones, 2008).

What is the small holders' response to GM crops? The results of a two year survey of smallholders in Makhathini Flats, KwaZulu-Natal in South Africa showed that farmers who adopted Bt cotton in 1999–2000 had higher yields, lower chemical costs, and higher gross margins (Thirtle, Beyers, Ismael, & Piesse, 2003). However, cotton accounts for only about 1% of the total South African agricultural production and small holders form a very low percentage of total cotton producers. Makhathini Flats was a special case as it was a large smallholder development scheme that was created as a showpiece for the international community. As a result, the Makhathini Flats had experimental farm and extension service that was far better than in other areas. Their services would have contributed substantially towards success of Bt cotton among smallholders. Only in India and China, GM crops are primarily smallholder crops where they were adopted on a massive scale even before the regulatory release. The rest of this chapter discusses the case of smallholder adoption of GM cotton in western Indian state of Gujarat to argue that GM seeds were rarely easily afforded by poorer and subsistence oriented farmers. In fact cotton was grown only by landed farmers with easy access to water. The case of China is particularly interesting as the three year survey of Bt cotton adoption in 2000–2001 showed that millions of small holders have been able to increase yield per hectare. It is crucial to point out that these benefits have been accompanied by commercialization of cotton markets in China since the late 1990s. Before 2000, most cotton was purchased by the state owned cotton and jute corporation in 1999 at a price fixed by the government. Since 2000, cotton prices were allowed to be fluctuated with market conditions and cotton mills were allowed to buy cotton directly from growers (Pray, Ma, Huang, & Qiao, 2001). These market friendly developments were crucial for the success of Bt cotton among smallholders.

## 14.3 Popularity of Bt Cotton: Case of Gujarat

Thousands of farmers in India adopting and actively modifying patented Bt cotton seeds provides an additional edge to the debate on the social, economic and environmental appropriateness of genetically engineered crop biotechnology. Bt seeds were supplied by a local seed company called Navbharat in the western Indian state of Gujarat at least 3 years before Monsanto-patented Bt seeds were officially released by the Indian government in 2002. Since then, farmers have produced a number of local brands of Bt seeds by crossing Bt-containing seeds with existing hybrid cotton varieties. These locally produced seeds, including Navbharat seeds, were initially declared illegal. Yielding to pressure from farmers, they are now allowed to be sold inside Gujarat. Locally produced seeds are also popularly believed to be performing better than the government approved Monsanto seeds in Gujarat (Bunsha, 2001; David & Sai, 2002; Sahai & Rahman, 2003; Sahai & Rehman, 2004; Shah, 2005).[1] Given this popularity, the Indian government has now officially released 39 different varieties of Bt seeds, including a second generation of Bt seeds with Cry 1 AB gene (popularly known as Cry II gene). A third generation of Bt seeds with Cry III gene is widely speculated.

The popularity of Bt seeds among Gujarat farmers gives an additional edge to debates about genetically-modified crops in general, and Bt cotton in particular. Those who celebrate biotechnology, however, often go beyond such impact assessment debates to take a moral position. Thousands of farmers actively appropriating, adopting, and modifying genetically-engineered cotton seeds is not only declared a "success" of the technology.[2] Rather it is also linked to an argument that the choice of genetically-engineered seeds should ultimately be left to the farmers themselves. A case such as Gujarat is thus viewed as an undisputable sign of social acceptability and a technological triumph of genetic modification (Taverne, 2005, 2007). Both the tropes, that is, "Bt works" and "it is ultimately farmers' choice," are eventually escalated into an argument for the inevitability of genetic modification in crop biotechnology.

I wish to challenge the framing of debates on crop-biotechnology in terms of "impact assessment" or "success or failure." To evaluate the social desirability of technological choice, I consider socio-anthropologically the cultural, productive, environmental, and cognitive contexts within which the cotton growing farmers in Gujarat adopt, develop and diffuse genetically-engineered crop biotechnology. I show that crop biotechnology represents a technological culture with a specific value framework which is endorsed commonly by both multinational companies and certain cotton growing farmers in Gujarat. The cultivation and multiplication of Bt seeds owe their popularity to the fact that genetically modified seed technology did not make any paradigmatic change in the agricultural practices and agrarian relations shaped by the Green Revolution, which has privileged and consolidated the social power of resource rich farmers. Bt cotton's success is thus part of the successful reproduction of these cotton-growing farmers' historically acquired and culturally consolidated ability to perform with the technology. Thus the appropriateness or social desirability of crop biotechnology should be understood within a wider frame encompassing technological culture and its democratization (which would also entail democratization of social and agrarian relations), rather than considering the issue in the narrow framework of impact or economic performance of the biotechnology itself.

This central concept of technological culture is briefly considered in the next section, before explaining the methodology and findings of the anthropological study in Gujarat.

## 14.4 Engineering the Earth: Explaining Technological Culture

The social, political, environmental, and economic impact of large scale engineering projects are causes of major concern in the recent debates on climate change or discourses on development. This volume aims to engage with one of the most pertinent paradoxes of our times. That is, while debates on climate change and changing discourses on development have on the one hand challenged science and technology-based notions of social and economic progress, on the other hand a plethora of megaengineering projects continue to radically transform the social and natural fabric of our surroundings. This chapter does not intend to solve the paradox, but engages with it by drawing insights from philosophical and sociological discussions on technological culture. Various philosophers and scholars have adopted the notion of technological culture to explain the ways in which characteristic traits of our society have become pervasively technological, including the ways in which science and technology become enabling framework that shape collective activities and societal choices over time. Below is a brief discussion on the various interpretations of concept of technological culture and the way it has been incorporated into social responses to crop biotechnology.

In the classical philosophy of technology the theme of modern culture becoming technological was central. In the accounts of Heidegger, Ellul, Mumford and some scholars of the critical school such as Marcuse and Adorno, technology reduces human beings to what Hiedegger called "technicised animals." These works variously critiqued total domination by *technological society*, reducing human beings to *one dimensional man*. Such classical philosophy provided a powerful critique of technology-society relationships but in an over-deterministic fashion and by interpreting technology and culture as opposed to each other.

In contrast, an emerging focus on technological culture in science and technology studies (STS) emphasises the interplay between technology and culture and even erases the difference by merging the two entities into one. Technological culture in STS is variously interpreted to mean that the characteristic traits of our society are pervasively technological, that is, considering technology as our culture; understanding science and technology from a cultural perspective; presenting technology as a material culture embedded in social processes, and/or acknowledging the fact that the technological and social are inseparable (see Bijker, 2005; Castells, 2000).

There also exist other interpretations. Invoking Wittgenstein and discussing information society, Scott Lash philosophically interrogates technological *forms* of life to mean *ways* of life, or modes of doing thing, that is, culture in an everyday sense. In line with classical philosophers, Lash is also interested in exploring what happens when forms of life go technological, suggesting that we then make sense of the world only through technological systems (Lash, 2001).

These theories of technological culture, however, remain overarching and societal in both classical and contemporary philosophy and even in science and technology studies. A societal analysis of technological culture tends to develop dystopian and apocalyptic overtones as in classical philosophy. In contrast, empirically rich micro-studies of the interplay of technology and culture often lack any meaningful critique of broader directions of technological change (see Keulartz, Schermer, Korthals, & Swierstra, 2004).

None of the entities referred here – society, culture and technology – is monolithic, and ideally the term technological culture may signify not just one but many cultures. Thus, the questions is whether different technologies have different cultural connotations? The discussion on the emergence of technological trajectories or paradigms not only includes social and political contexts both at micro (agency) and macro (structural) levels, but also represent the values, interests, ethics, and choices of those who hold social power and who make technological choices (Russell, 1999). A technological paradigm for Russell is thus not only a new solution to a techno-scientific problem but also an enabling framework that shapes collective activities and the choices of individual actors over time. In STS, what are discussed are not only how technological paradigms/trajectories establish their own momentum, but also how they persist in the global economy over long periods of time (Russell, 1999).

Russell's evaluative concept of technological paradigm is further sharpened here by borrowing from Richards (2004). Richards begins, like Russell, with a Kuhnian concept of "paradigm," viz., the constellation of ideas, values, and techniques that define the course and nature of technological practice. He calls this "culture" based on an interpretation of Durkhemian sociological theory (Richards, 2004). According to Richards, each technological culture has a specific history, collective representation, material framework, shared values and organizational modalities (Richards, 2004). While Russell emphasises the forces of global political economy and social power, he also imparts greater agency to history, representation, values, ethics, and frameworks. The difference between Russell and Richards is the location from which the change is viewed: political economy or culture.

Accordingly, the technological culture of genetically-modified crop biotechnology is critically examined below is with respect to the role of history, political economy, sets of ideas, beliefs, values and attitudes, and the responses and perceptions of those who make technological choices. This reworked notion not only places genetically modified seed technology in the context of global and local political economy, but also provides an opportunity to evaluate how its perceptive and material frameworks configure and constitute the actions of the agents who design and use the technology.

## 14.5 Methodology

A word on methodology is pertinent. The chapter represents an outcome of close ethnographic engagement with a number of actors associated with Bt cotton in Gujarat. These include cotton cultivating and seed plotting farmers, marketing agents, shop owners, seed company owners and employers, owners and employers of seed testing laboratories, office bearers of the cotton-growing farmers' front organization Bharatiya Kisan Union (BKU), and activists of child and migrant labor welfare associations in south Rajasthan and north Gujarat.

The specific case study is focused on the area around Manasa town of Gandhinagar district. Manasa occupies a unique position in Bt cotton cultivation in Gujarat as it is a hub of both seed multiplication and cotton cultivation activities. Most of the seed companies in Gujarat are located close to Manasa, while it has a vibrant market of agricultural products, including a huge cotton market. The industrial enclave where seed companies are located is a hub of everyday discussion about Bt seed multiplication and cotton cultivation. Manasa's cotton seed and product market is supplied through surrounding villages where cotton is a mainstay of agricultural activities. The town thus provides a unique entry point to understand both seed multiplication and cotton cultivation culture which other regions in Gujarat do not provide.

My field work was carried out in two parts. I first visited Gujarat in January-February 2005, when illegal seeds were being fiercely debated. In January 2005 the cotton had recently arrived in the market. So had the seeds; they were being sorted and packed. I again visited Gujarat in April 2007 when a new season of cotton cultivation was being readied, and when seeds were being sold, bought, and debated. In both periods, the focus of my study was not cotton fields as such, but on the various spaces where actors assemble to perform their cotton related activities. In addition to engaging with cotton market and seed companies in Manasa, I conducted group meetings with farmers from 10 villages in Gandhinagar district, most of these I visited and revisited in 2005 and 2007. I met my respondents – farmers, seed agents, shop owners and market agents – in their regular haunts, at markets, shops and the offices and shops of cooperative societies. My approach was to engage with them in a group, to begin by asking simple questions about Bt cotton, and then to engage in serious discussion, with an idea to debate and provoke. In Gujarat, each village usually has two or three different types of cooperative society. In some villages I started a discussion impromptu with already present farmers at one of the offices or shops of the cooperative society. At other times I asked a known farmer to invite other cotton growing farmers, and at yet others for discussions. I had discussions with both individual key farmers or BKU leaders. The gatherings usually included 7–12 farmers present, but sometimes 20–25 farmers participated at some point. The discussions usually lasted for an hour or two, while several of the most vibrant discussions lasted into an entire evening. Through these ethnographic methods, the study has thus focused on the cotton enclave of Manasa but has also mapped farmers' perceptions and practices across a wider spectrum of villages.

## 14.6 The Technological Culture of Biotechnology and the Agency of Global

Crop-biotechnology found its roots in Gujarat by way of the successful cross-pollination of two separate parental lines of Bt seeds, viz., the Bt male line genetically modified by global multinational companies such as Monsanto and a female line originated from distinctly local hybrid cotton varieties.[3]

The genetically-modified seed technology has a crucial implication for Monsanto which has pivotally shaped the technological culture in Gujarat. Bt technology is different from its predecessor, hybrid seed technology, in one important way. Two distinct parental lines are needed to produce hybrid seeds; only the breeder who has those two parental lines can produce hybrids. Replanting or self-multiplying saved seeds will not grow into a crop resembling the previous hybrid plant but rather perform in an irregular and unpredictable way. Hybrids thus force farmers to buy new seeds every season from the seed companies. The technology of hybrids thus is non-textually scripted to have a built-in patent. In contradistinction, Bt cotton varieties are produced by crossing a genetically modified male line with a hybrid female line. Once the gene is inserted, the Bt male lines can be replicated well by controlled self-pollination. Farmers thus have access to both parental lines needed to produce hybrid Bt seeds. That means that genetically-modified crop biotechnology does not have the built-in patent. It therefore requires an external regulatory system to protect the market-interest of the seed companies. This crucial (lack of) script of genetically-modified seed technology has triggered a labyrinth of discussions and controversies all over the world around the issues related to the nature of patents and regulatory systems. A technological script could have made these "textual instructions" for ordering and guarding moral or ethical behavior redundant, as it was in the case of hybrid seed technology (Shah, 2003).

This non-scripting of genetically-modified technology has given birth to Gujarat's own "Robin Hood," a fond media ascription for Dr. D. B. Desai, the executive director of Navbharat Seeds Company. Navbharat first produced N-151 seeds by crossing a Monsanto designed Bt male line with the GujCot 8 female line. Owing to the non-scripting of the genetically-modified Bt male line, only a handful of seeds was technologically needed for the massive expansion of cultivation of locally produced Bt seeds in Gujarat. Tracing the genealogy of N-151 is less important for this paper; the more important question is to understand what makes the global and local cross pollinate for the biotechnology to find its roots (Shah, 2008).

## 14.7 The Technological Culture of Bt Cotton in Gujarat

### *14.7.1 Who can Grow Cotton in Gujarat?*

Succeeding the green revolution, the technological culture of crop biotechnology has flourished in Gujarat at the interface of the "nature of work" and the "work of nature" including both nature's subsidy and nature's unpredictability (Gidwani, 2001).[4] I argue here that nature's agency makes cotton cultivation a risky and uncertain enterprise, to the extent that the nature of work needed to compensate could potentially be afforded only by those who have the necessary cultural capacity, both social and material. The technological culture of crop biotechnology in Gujarat is thus chosen, shaped, and perpetuated by those who hold social power.

Cotton is one of the oldest crops cultivated in Gujarat, grown for centuries and especially since colonial times. The native variety of cotton (called Desi) was largely grown in Gujarat before the American variety was introduced in the late 18th and the early 19th centuries. It is a well known chapter in the history of cotton that the American varieties had longer filaments and hence were more suited to the machinery in Europe and they were encouraged by the British even though American cotton was highly susceptible to pest attack compared to Desi varieties (Prasad, 1999). However, it was only in the 1960s and 1970s with the introduction of the green revolution that the hybrid varieties developed from the American family (hirsutums) of cotton made pure Desi (arboreum and herbaceum) varieties uneconomical and obsolete due to their unresponsiveness to fertilizers.

The transition from Desi to American cotton has proven disastrous for the balance of organisms in the local environment. With the American cotton came American Bollworm, whose menace became rampant after hybridization and the large scale introduction of pesticides. The history of cotton cultivation in Gujarat is replete with cotton varieties appearing and disappearing at high speed mainly in order to compensate, among other things for pest attack and so keep yields high.

Since the 1970s, several hybrid varieties have been introduced mainly to improve crop yield, which many farmers claim would slack after cultivation for 5–7 years. A hybrid variety called GujCot 4 or H-4 (popularly known among farmers as Sankar 4 – Sankar literally means hybrid) was introduced in the early 1970s. It gave, as farmers described, bumper yields, but was not preferred because of its long duration. Meanwhile, a short term variety GujCot 8 (Sankar 8) was introduced, which could be reaped in 4 months time (instead of the 6 month duration of Sankar 4) making it possible to cultivate 3 crops a year or to cultivate one more food crop after the harvest of cotton. GujCot 8 however became heavily infested with pests, and was also susceptible to early dropping. It was followed by GujCot 9 and 10. "And so it goes on," my informant farmers optimistically concluded. Even after the introduction of GujCot 8 and 9, the short term variety of GujCot 8 remained popular until the late 1990s when it was repeatedly and massively attacked by American Bollworms. The series of hybrid seeds was also accompanied by the introduction of a series of new pesticides. At the heart of the technological culture of the green revolution is such a continuous interplay between the artefacts, new cotton varieties and pesticides, and nature's agency, that is, worms.

Throughout the history of cotton hybridization, pests showed the capacity to develop resistance within a few years. In fact, a leading entomologist argues that pest resistance increased with the increased consumption of pesticides (Kranthi, 2005). The cotton plant has been infested by various types of pest throughout the last 150 years. The entomology of cotton pests has shown their highly dynamic nature; several pests have become major from being minor and vice versa. Although at present, the most devastating pest is American Bollworm (*Heliothis* and *Helicoverpa armigera*), others have dominated at different times, including tobacco caterpillar (*Spodoptera litura*), whitefly (*Bemisia tabaci*), pink bollworm (*Pectinophora gossypiella*) and spotted bollworm (*Earias vitella*) (Shetty, 2004). It is widely reported that the threat of American Bollworms reached catastrophic level in the late 1990s causing several farmers in Andhra Pradesh and Punjab to take their lives (Prasad, 1999; Bose, 2000). Some farmers in Gujarat have used a cocktail of pesticides to control different types of pest and have even targeted pests at different stages of development, but often with no result. Usually 10–12 sprayings and a maximum of 15 sprayings of pesticides are recommended, but farmers claim that since 1996 pests seem not affected even after 30 sprayings a season. This has been corroborated by reports from other parts of the country (Shetty, 2004). By the mid to late 1990s, pesticides started to account for 40–50% or even more of the total cost of cotton production. The new brands of pesticides have become exorbitantly costly even for wealthy farmers. Moreover, nearly half of the country's total pesticide consumption is said to be used for the protection of cotton (Editorial, 2001). In fact, pests have not just become resistant to pesticides, but have been mounting militant resurgence (technically known as abnormal increases in pest populations), requiring even stronger pesticides.

Worms are one type of actors in nature's drama. Access to land and water also crucially shape the nature of work. To a large extent, access to land in Gujarat is historically determined. Due to the historical advantage received during the colonial period, the Patels are now economically and socially a dominant agrarian caste in Gujarat.[5] Even after a socially significant trend of migration to the U.S. and U.K., cotton cultivation still remains an important identity marker for the Patel community.

While access to land is historically determined, access to water in north and central Gujarat where cotton is a dominant cash crop is determined through control over tubewell technology. Hardiman shows how the history of ground water extraction has favoured capital-rich farmers. Although the British considered cotton as a non-irrigated crop, Hardiman argues that in the past cotton was always watered with wells to raise the yield (Hardiman, 1998). Current varieties of cotton also need at least 8–15 irrigations for good yield. A large part of mainland and north Gujarat, the cotton growing tract, has an arid and semi-arid climate; surface irrigation concentrated in southern Gujarat is dependent on ground water (Prakash, 2005). The British policy on ground water extraction was so designed that only wealthier cultivators could afford to dig a well in the first place, and then pay the exorbitant taxes levied on it. Later, the policy gave tax exemptions to deeper wells; this policy also favored capital-rich farmers who could afford to dig deeper (Hardiman, 1998).

Prakash (2005) takes Hardiman's argument further to show that the current scenario also favors the wealthier sections of agrarian society in access to ground water. The dominant mode of access is currently through shared ownership of tubewells. In Prakash's study village, Patels own 53% of the total village land and 67% of the tube wells (Prakash 2005). Although a majority of Patel farmers in Prakash's study village fall into the categories of marginal, small and medium farmers, their capital share in tube wells (65–67% of the total number of tube wells in the village) give them a much larger share of the ground water now available at more than 1000 ft (305 m). Prakash further shows that the water market that enabled non-tube well owners to access ground water in the past has declined since the late 1990s as a result of electricity supply failures. When water is insufficient even for the shareholders of tube wells, there is little left to sell it to the non-shareholders. No ownership of water sources thus means no cotton cultivation.

The risks involved in cotton cultivation due to nature's agency, pests and water, are thus substantial, and in need of considerable social and material resources to be mitigated. The past historical policies and culture of the green revolution have thus pivotally configured social relations of power, and thereby the cotton cultivation capabilities.

### *14.7.2 Cognitive Aspects of Technological Culture of Crop Biotechnology*

Farmers' perceptions and practices have mutually shaped each other and the technological culture of Bt cultivation. As cotton growing farmers counteract the double attack of nature, viz., rapidly resistance-developing pests and a rapidly declining water table. Thus farmers' perceptions shape agrarian practices. Such agrarian practices and perceptions in turn further shape access to natural resources and determine who cultivates cotton and who does not.

The Patel farmers have been able to retain their hold on cotton cultivation through three key means: (1) access to labor surpluses, (2) a well developed social network that also functions as both a credit and knowledge network, and (3) diversification of livelihoods through migration first to east Africa and now to Britain and the U.S. The outmigration of the Patel community is not discussed in detail here, but see Rutten and Patel (2002) for a detailed discussion. Access to labor and social networks are discussed below.

Gandhinagar has long been a key district for the plotting, exchange, and selling of hybrid cotton seeds, and now also for Bt seeds. This exchange takes place through two main channels. Firstly, many seed companies (of which there are about 500 in Gujarat) give contracts to farmers to multiply seeds.[6] Many of the seeds thus bought back by the seed companies are sold to other parts of India (currently and illegally). A sizable number of Punjabi farmers visit seed companies located in the Gandhinagar district in the months of April and May to purchase Bt seeds. One seed company owner speculated that 70% of the seeds purchased by the seed companies are sold to other parts of India and only 30% are diverted to the local Gujarat market. Informally, I was told that a considerable part of the seeds thus sold outside of Gujarat are generation F2, that is, they are also mixed with other spurious material. Cotton-growing farmers from Gujarat are not among the important clientele of the seed companies. In Gandhinagar district, much of the seed multiplication and selling for local consumption is done by farmers themselves.

Cotton growing farmers in Gujarat have developed a number of new varieties by crossing the Bt gene-inserted male line (with Cry 1 AC gene and later Cry II gene released by Monsanto-Mahyco) with a number of local hybrid female lines. The first such experiment was reportedly conducted by the CEO of Navbharat company, Dr. D. B. Desai, when he crossed the Bt male produced by Monsanto with the GujCot 8 female line to produce a progeny that is resistant to a number of pests including American and spotted and pink Bollworms. At the same time it is suitable for local agro-climatic conditions. Dr. D. B. Desai is often described as a genius breeder, including by a leading entomologist Dr. K. Kranthi at Central Institute of

Cotton Research at Nagpur, India. Without access to any institutional knowledge on breeding, farmers in Gujarat have now crossed 60–70 different varieties with the Bt male line (first containing Cry I and later Cry II genes) to produce Bt seeds with varied sets of locally suitable traits. Farmers have even attempted to cross Bt male with Bt female to produce ultimate Bt progeny, and have experimented with crossing Cry I gene lines with Cry II gene lines. These locally produced Bt varieties are then declared as “indigenous” (*swadeshi*) Bt.

Local knowledge about seed crossing has gained significant ground through constant experimentation over the last 5 years. For these experimentations, social networks function as conduits for the exchange of knowledge. It is part of the common repository of popular knowledge that for producing new seeds, the Bt male parental line is essential but not the key. Rather it is the female parental line that determines the performance and stability of the new seeds in the specific agro-ecological conditions in Gujarat. Following D. B. Desai’s experiment, Bt male was popularly crossed with the female of GujCot 8 for a couple of years. Popularly known as generic N-151, this cross is still commonly cultivated, but also discredited in some circles for its short staple length, for small boll size, and for causing difficulty in harvesting. Subsequent crosses with Vikram 5 and GujCot 4 are preferred for their long staple length and large boll size despite their long duration. Currently, different territories are divided among different crosses: Farmers in Punjab and north Gujarat tend to prefer Vikram 5 and GujCot 8, whereas GujCot 4 is popular in Maharashtra and Saurashtra.

What usually takes several years for breeders to achieve in a controlled environment, cotton-growing farmers in Gujarat have achieved through experimentation in a few seasons. This rapid multiplication and experimentation has largely been possible because of access to cheap and skilled labour. Seed plotting of hybrid varieties is traditionally and widely carried out in central and north Guajarat. For the seed plotting, seasonally migrating Adivasi laborers and now young female and child labourers are preferred, a legacy of the green revolution. Adivasis entered the settled village agrarian economy more prominently from the 1970s, especially after the intensification of agriculture linked to the green revolution (Patel, 1992). Adivasis now perform a variety of seasonal agricultural tasks. The easy availability of migrant labor from south Rajasthan helps consolidate highly commercialised and intensive agriculture in the north and central Gujarat. This practice has made it possible for cotton-growing farmers to invest in the development of stable and well performing Bt seeds in relatively short periods of time. The social spread of Bt cotton is thus yet another legacy of green revolution-shaped agrarian relations.

The social relations of power also configure social networks and social relations of knowledge exchange. Locally multiplied seeds are diffused through existing channels in social networks which also traditionally function as credit channels. During my discussions, farmers repeatedly invoked the channels of trustworthiness and known people through which all transactions for the sale and purchase of seeds happen. That the seller does not go out looking for buyers, but the buyers come looking for a known and trusted seller, is the operating philosophy that seems to underlie the market of locally multiplied seeds. Questions such as “where do you buy your seeds from?” and “whom do you sell your seeds to?” were uniformly answered "to and from known and trusted people". To be known is a pre-requisite to be trusted and to be known largely means to come from the same caste group and social network. One farmer explained the logic of cotton cultivation and market as "*je vyapari chhe te ja agent cche ane te ja khedut cche*" (the merchant, agent and farmer mean all the same). This aphorism accurately represents an overlapping of agrarian and market relations which are primarily caste relations with respect to cotton. The merchants and agents dealing with the marketing of cotton and farmers growing cotton not only overlap each other's space professionally, but also share caste and kinship relations. Being trusted and known in the community thus goes far in generating not only a creditworthy market reputation, but also an acceptable social identity with further bearing upon marriage and other customs. Markets thus function not through impersonal contractual relations, but through relations of kin and caste. In the absence of an open market space when locally multiplied seeds were declared illegal, and when the market is saturated with spurious and F2 and F3 seeds, this social/credit/market network is the only trustworthy conduit for the exchange of locally multiplied Bt seeds. This social/credit network in the service of diffusion of Bt seeds seems to be thriving on an effervescent sense of solidarity and communitarianism, sustained through a common language of representation and understanding. It was no surprise that many cotton-growing farmers in the periphery of 50 km (31 mi) spoke the same language with the same idiom and expressed similar opinions.

Such social solidarity is also manifested in the way cotton-growing farmers perceive the possible implications of widespread Bt cultivation on the environment and accordingly develop agricultural practices. In terms of the efficient utilization of land and water, the resource rich farmers follow various practices. It has been commonly acknowledged that the cultivation of Bt cotton extracts substantial nutrition from the soil and that continuous cultivation for 4–5 years is likely to leave the soil unfit for any other cultivation. Farmers compensate the loss of soil nutrition by rotating cotton with wheat and pulses. Approximately four tractor loads of green manure are ploughed into the field after each crop of cotton, and in addition, a crop of wheat or pulse is cultivated on the same piece to allow the green manure to weather sufficiently. Only in the third season is cotton cultivated again on the same piece of land. This means that for the continuous cultivation of at least a few acres of cotton to maintain a profitable standing in the market, a cotton-growing farmer needs to be holding 7–8 bigha of land (1 bigha = 0.6 acres) – one more reason why only land rich farmers in Gujarat grow cotton profitably.

That Bt cotton needs more water than hybrid varieties is also commonly acknowledged. Many farmers acknowledged that when hybrid cotton seeds need water once in 15–17 days, Cry I and II seeds should be watered once in 10–12 or even 5–7 days. Ground water in central and north Gujarat is now mined to a depth of 1000 ft (305 m) and pumps have to be fitted at 600 ft (183 m) to gain sufficient pressure. In cotton-growing farmers' view, ground water would be unpalatable with a very high fluoride content should levels plummet below 1200 ft (459 m), yet many speculate that this will happen within 5 years. One farmer described the water conserved at 1200 ft as five generations' old water. "In a decade we have consumed thousand years' old water" was how one of the farmers dramatically described the state of ground water consumption and its relationship with cotton.

## 14.8 Conclusion

In this paper, I address the central paradox of this volume, that is, the contrasting way in which the megaengineering projects continue to dominate our social and environmental surroundings and the way in which these are accompanied by discourses on climate change, environmental degradation, and negative social impact. I do so by explaining the way in which the technological culture underlying one of the most discussed and opposed megaengineering projects – genetically modified crop biotechnology – frame and configure actors' rationality. A few observations based on the discussion on cultural, cognitive, and productive aspects of the spread of GM cotton in the western Indian state of Gujarat are summarized below that I wish would throw some light on why and how megaengineering projects find global and local acceptance.

First, the preceding discussion makes it clear that the knowledge development pertaining to Bt cotton technology in the globalized world has been multipolar. The cross-pollination of the global and local components have enabled Bt cotton to find its roots in Gujarat soil. Thus, multiple global and local actors have joined hands in developing and diffusing the knowledge on Bt cotton seeds. However, multipolarity of knowledge generation does not necessarily entail technological multiculturalism as the case of Bt technology explains. Neither does it ensure automatic democratization as a result of involvement of the political agency of the local. Multipolar development and diffusion of knowledge and local political agency can co-exist with monoculturalism of technology. The popularity of Bt cultivation in Gujarat shows the triumph of a technology supported by both global and local elites (Shah, 2005).

Secondly, I suggest that while the communicative rationality of the public sphere is "textually" debating the good and bad of genetic engineering, the technological culture, with its non-textually inscribed rationality, is ideologically conditioning and shaping the direction of action. Genetically-modified crop technology, that is, its rationality inscribed with ideas, values, perceptions, practices, and frameworks – belongs to the technological culture of the green revolution. This technological culture promoted and consolidated the interests of a historically advantaged group of farmers with access to land, water and labor by shaping their perceptions and agrarian practices. The resource rich farmers on the forefront of cotton cultivation in Gujarat have experimented with genetically-modified technology owning to their green revolution-determined access to skilled and cheap tribal, migrant, child and female labor from south Rajasthan. The knowledge generated through these experimentations has been diffused and consolidated through caste-based social and market networks. The social power of cotton farmers in Gujarat has constituted and configured the technological culture of crop biotechnology by responding collectively to the risk and uncertainty of nature's agency with the social organization of work and technology and by buttressing it through cognitive solidarity.

Thirdly, and lastly, the answer to the question of why Bt seeds are popular among farmers and why other technological options to deal with insects are not popularly adopted has only partially to do with the traits of the technological artefact as such. The choice of technology is hardly about "what works and what does not work." Purely going by traits, a number of technological options would have been possible to solve the pest problems of cotton. Technological rationality in that sense is indeterminate until it is inserted into social space. In this sense, the success of Bt is a performance. It is a core argument of this paper that the artifact is just one component in the success of technological performance. Bt cotton's success belongs to the successful reproduction of the cotton-growing farmers' historically acquired and culturally consolidated ability to perform with the technology. This successful performance is not only social but also collective and historical. This centrality challenges the notion of a smart, rational farmer taking a correct decision in favor of his/her private and largely economic interests.

Bt may not have given the same performance in Andhra Pradesh and Vidarbha region of Maharashtra where the technological culture may not combine comparable historical and social resources. But I argue that the enabling conditions for social and environmental learning involve a combination of a range of social, historical, and technological factors, which are culturally linked to reproduce a successful agricultural performance. The absence of such technological culture can result in the lack of such performance, even when the artefact in question is same.

## Notes

1. According to the Gujarat agricultural department's data, although the area under cotton in Gujarat marginally grew from 1.615 million ha in 2000–2001 to 1.628 million ha in 2003–2004, both total production and yield more than tripled in 2003–2004. The production increased from 1161 thousand bags in 2000–2001 to 5400 thousand bags in 2004–2005 and yield increased from 122 to 483 kg/ha (Mehta & Patel, 2004). However, these claims, especially of the yield difference between the local and officially released seeds, are contested. For example, a survey of 363 farmers in Gujarat reported that the officially released Monsanto-patented Bt seeds gave the highest yield (Gupta & Chandak, 2004). Others attribute the increase in yield to good rainfall since 2001 (Sahai & Rehman, 2004). What is being claimed widely is that locally multiplied seeds, first generic Navbharat and later other locally multiplied varieties, have been cultivated in 60–80% of the total area under cotton in Gujarat since 2000–2001. I do not intend to take a conclusive side in this dichotomised debate. I provide these figures merely to give a flavor of the ongoing debate.
2. Ranjana Smetacek, the Director of Corporate Affairs of India, Monsanto, expressed similar views speaking at the Development Studies Association's conference on science, technology, development organized at University of Sussex, 18–20 September 2007. It is also referred to by Stone (2007).
3. The separate and monolithic spaces of global and local are increasingly challenged in social sciences. Responding to a closely intertwined interplay between global and local spaces, some scholars instead prefer to use the term glocal. In contradistinction, I have retained the separate identities of global and local precisely to understand the culture of interplay between them.
4. Gidwani employs these mechanisms to account for agrarian change that combines pure determinism and pure contingency variances of history of agrarian change. Unfortunately, Gidwani's mechanisms have a prominent space for nature, but technology appears peripherally in his conception. He has subsumed all aspects belonging to the physical landscape under the category of "nature" and thus has obliterated the role of technology to transform nature through work.

5. During the colonial period, the Kanabis (a peasant caste/community of sedentary cultivators), as against Kolis (shifting cultivators) were elevated into a category of landowners called Patidars. Through changes in the land tenure system during the colonial period, Kanabis encroached upon the land until then cultivated by Kolis and tribals. Since the early to mid 19th century Kanabis, who were eventually re-caste into Patel, ascended in economic and political power. "Patel" was originally a title given to a village officer in charge of tax collection and law and order, but it was now adopted by all members of the Kanabi alia Patidar caste/community. For further discussion (see Rutten & Patel, 2002; Gidwani, 2001; Shah & Rutten, 2002)
6. The two types of seeds known as foundation seeds, 240 g of Bt male and 600 g of hybrid female (usually GujCot 8), are supplied for one acre. One acre can produce anywhere between 100 and 300 kg of seeds. Seeds are planated in May or June and after usually 45–60 days hand-crossing starts, which continues until 120 days.

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