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Biotechnology and the Political Ecology of Information in India

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The move of crop biotechnology into the south raises issues about effects on cultural agricultural practices. The case of recently introduced genetically modified cotton in India is used to explore how crop biotechnology can affect change in processes underlying local practice. The particular focus is agricultural skilling—acquiring information and adopting management practices derived from that information—based on both environmental learning and cultural transmission. Impediments to skilling include inconsistency, unrecognizability, and overly rapid technological change; these processes may lead to agricultural deskilling, which has similarities to and differences from industrial deskilling. India's first genetically engineered crop, Bt cotton, has recently been released into an unsustainable situation plagued by deskilling, yet biotechnology has brought new disruptions of information flows and thus of the skilling process. The India case shows how susceptible to political manipulation the cultural agricultural practices become when skilling is disrupted.

Key words: political ecology, biotechnology, genetic modification, indigenous knowledge, India

In today's debates on transgenic, or genetically modified (GM), crops for third world farmers, some of the most diverse positions have come from the third world itself. For instance, Indian physicist-cum-activist Vandana Shiva is one of the world's most potent opponents of GM crops, while Kenyan biologist Florence Wambugu is a leading proponent (and practitioner) of crop genetic modification and literally a larger-than-life figure at Monsanto headquarters.[1] What these disparate writers agree on, however, is the importance of indigenous cultural farming practices. Shiva (1996) writes that:

> traditional knowledge, innovations and practices are of importance to the conservation of biological diversity and that indigenous and local communities have a close and traditional dependence on biological resources. Their livelihood and life styles often depends [*sic*] on it and is shaped as it.

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Wambugu's (1999:16) position, oft-quoted in industry media and congressional hearings, is that:

> The great potential of biotechnology to increase agriculture in Africa lies in its "packaged technology in the seed," which ensures technology benefits without changing local cultural practices. In the past, many foreign donors funded high-input projects, which have failed to be sustainable because they have failed to address social and economic issues such as changes in cultural practice.[2]

Monsanto, the global leader in crop genetic modification, takes a different view. Its business is developing technologies to replace current practices, and it targets practices such as plowing, weeding, and seed-saving for replacement.[3] Recent Monsanto literature has even suggested that traditional African hoe cultivation should be replaced by "sustainable" biotechnology. In *Biotechnology: Solutions for Tomorrow's World* (Monsanto 2000), a Sudanic hoe is depicted with the caption: "Farmers in Ghana currently use this tool to till their fields. Through biotechnology, farmers in developing countries such as Ghana will be able to implement sustainable agricultural practices." (Ironically, on the facing page, Florence Wambugu poses in a laboratory.)

The insinuation that the Sudanic hoe is "unsustainable" may strain credulity, yet in one limited but important sense, Monsanto is closer to the truth than Shiva and Wambugu: *cultural agricultural practices change all the time*, as does the indigenous knowledge on which practices are based (Agrawal 1995; Dove 2000; Sillitoe 2000a). Each plot, each year, is an experiment, and practices may change in response to population density; market signals; the arrival of new crops, tools, or neighbors; pests and diseases; government policies; and even new ideas (Stone 2001). The notion of preserving indigenous, and particularly "traditional," cultural agricultural practices is not entirely realistic or, as argued below, necessarily desirable. Traditions are continually being invented, and key aspects of established practices often change even as some of the trappings of tradition seem to be reinforced. In agricultural practice, the stereotype of unchanging peasants is a persistent misunderstanding promoted mainly by those who have not actually studied farm practices through time.[4]

For instance, my coworkers and I have studied changing cultural agricultural practices of Kofyar farmers in Nigeria, who were basically unaffected by NGOs (nongovernmental organizations), government programs, development schemes, and introductions of new technologies. Yet in response to changing demographic and ecological conditions and market opportunities, Kofyar adopted new cash crops and a new set of practices for balancing subsistence and cash-based goods and services (Netting, Stone, and Stone 1989); overhauled their cultivation schedule (Stone, Netting, and Stone 1990), settlement pattern (Stone 1996), and methods of clearing and fertilizing land; and devised a novel set of practices for mobilizing the labor to run the new system (Stone, Netting, and Stone 1990). If such transformations occur without technological change, we can imagine the potential change in cultural agricultural practices where technological change is brisk. Therefore, the real question is not if GM crops may affect otherwise static current agricultural practices, but how they may alter ongoing processes of agricultural change—and in particular the processes of acquiring information and adopting management practices based on that information, which serves as a working definition of *skilling*.

We must first refine our focus, given the enormous variability encompassed by both "indigenous agriculture" and "crop biotechnology." This study is restricted to genetic modification, as opposed to other methods of crop biotechnology, such as tissue culture and marker-assisted breeding that have caused little controversy (for a primer on these technologies, see Stone 2002a). The focus moreover is on small farmers, particularly the intensive smallholders who are most likely to be affected by GM crops. These are the small farms practicing labor-intensive, high-output cultivation on crowded landscapes (Netting 1993), as opposed to the extensive swidden cultivation common under low population densities, or the large-scale industrialized producers common in developed countries. This important distinction is often blurred, perhaps intentionally. For instance, the recent report on rising GM crop use in developing countries by the International Service for the Acquisition of Agri-biotech Applications (ISAAA), which promotes crop biotechnology for developing countries, explicitly equates developing countries with small farmers: "Economic benefits from GM crops are substantial and apply to both small farmers in developing countries and large farmers in industrial countries" (James 2002). Yet the same report shows that 69 percent of the GM acreage in the "developing world" is in Argentina, where the dominant GM crop is Roundup-Ready soybeans, grown on farms averaging close to 500 hectares in size (Lehmann and Pengue 2000; Qaim and Traxler 2003). The heavily capitalized and mechanized megafarms on the Argentine Pampa have little in common with the peasant smallholders invoked in the biotechnology debates.

We will further focus on India with special attention to Warangal District of Andhra Pradesh (Figure 1). Of the developing countries involved in the global biotechnology debate, probably none are as important and hotly contested as India. This country is home to what will eventually be the world's largest population of farmers, to a vast and talented scientific establishment, to a vigorous biotech-entrepreneurial sector (Scoones 2002), and to some of the world's most savvy green activists. Thus, India offers enormous markets for crop biotechnology products along with capacities to develop its own biotechnology and to marshal opposition. India approved the sale of its first GM crop in March 2002. It was the crop that has led the march of GM into the developing world—cotton, modified with a gene from the Bt bacterium that causes the plant to express a protein fatal to some lepidopteran insects.[5] Marketed under the trade name of Bollgard, this GM cotton was developed through a collaboration of St. Louis-based Monsanto, which provided the gene construct, and the Indian seed company Mahyco, which provided the cotton varieties. The approval followed five years of testing and acrimonious debate, with extremely divergent predictions on the product's effects: while some claimed it would lead the Indian farmer to early death and suicide (RFSTE 2002; Shiva et al. 2000), others proclaimed it would prevent suicide (Vidal 1999) and make the farmer "rich beyond his wildest dreams" (Das, quoted in Rameesh 2002). Warangal District is a cotton-growing area where the controversy is being acted out with singular urgency, with destruction of Bollgard test plots, aggressive marketing by Mahyco-Monsanto, and a recent suicide epidemic that has been used by both sides to validate their position (Stone 2002b).

The actual performance of India's first legal GM crop in the 2002 season, and the lessons to be learned from this national experiment, have been the subjects of heated controversy, conducted without benefit of refereed scientific studies:

> 1) A study by Vandana Shiva's NGO (The Research Foundation for Science, Technology, and Ecology, located in New Delhi) was quoted in *Nature* as having uncovered "a drastic failure of transgenic Bt cotton" in two states (Whitfield 2003). Other NGOs, including Greenpeace India, Center for Resource Education, and Sarvodaya Youth Organization announced data showing that farmers lost money on Bollgard (Deccan Chronicle 2003; Padma 2003). Meetings were held by a coalition of NGOs in Andhra Pradesh (Qayum and Sakkhari 2003; Venkateshwarlu 2002a) and by the Delhi-based NGO Gene Campaign (AgBioIndia 2003) to announce separate studies documenting lower economic returns to Bollgard planters: both meetings are discussed below. In Andhra Pradesh, Agriculture Minister V. S. Rao (Sun Network

Figure 1. India and Location of Warangal

> 2003) and the joint director of the Agriculture Department (Ramu 2003) confirmed that the first GM crop had performed poorly, and the state government promised to recompense farmers for their losses (Hindu 2003).
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> 2) Indian Environmental Minister T. R. Baalu insisted that the crop's performance had been "good," while a Mahyco spokesman admitted to failure only "in a few pockets" (Hindu 2002). Monsanto India's public affairs director claimed Bollgard had "done very well in all the five states where it was planted" (AP 2003), and a Mahyco-Monsanto press release claimed a sample of the nearly 55,000 cotton farmers showed increased yields and lowered pesticide usage (Mahyco-Monsanto n.d.). In the midst of this contretemps, an analysis of Mahyco's 2001 test-plot data appeared in *Science*, showing surprisingly high benefits over conventional varieties (Qaim and Zilberman 2003); the report was instantly mistaken as a positive verdict on the just-harvested 2002 commercial crop (AP 2003; Padma 2003). (For another summary of the competing claims on the first year of Bollgard, see Scoones 2003.)

Many would dismiss all this as a tempest in a teapot because the new technology should—and will—be adopted if and only if it benefits farmers, who will pursue their own economic interests independently of NGO and industry studies. On the surface this position may seem obvious, and it reflects the orthodoxies in American agricultural circles that technology adoption is driven by anticipated profitability (Fernandez-Cornejo and McBride 2002) and that the farmer is in the best position to judge the overall benefit of a given technology. It is a position espoused by Monsanto (Hindu 2002) and by pro-industry agricultural leaders like P. Chengal Reddy, who was quoted approvingly by Pinstrup-Anderson and Schioler (2001:108): "we should leave the choice of selecting modern agricultural technologies to the wisdom of Indian farmers."[6] It was espoused by some Indian officials like V. S. Rao himself: "let the farmers finally decide on the usefulness of Bt cotton…farmers are wise enough to adopt anything good and discard things that do not work" (Venkateswarlu 2002b). In other words, the fate of Bollgard should and will be decided in the field, by individual farmers on the basis of their own balance sheets, and if they really "think so much of this technology, they will steal it," to quote ISAAA's Clive James (Barboza 2003).

The intent here is not to make predictions about the commercial success of Bollgard or other varieties of Bt cotton in the pipeline, nor to make a case for or against the product on agronomic, environmental, or ethical grounds. It is rather to use the Bt cotton controversy in India to examine how adoption of new technologies involves vital cultural and political dimensions beyond simple balance sheet calculations by individual neoclassical actors. I argue that this new seed must be considered as part of the larger process of agricultural skilling, which plays a special role in smallholder farming, and that skilling is a largely cultural process that may be significantly affected even by this technology, which is being billed as leaving cultural agricultural processes intact. My primary interest here is contributing to scientific understanding of how third world agriculture works as an ecological, social, and political process, an understanding that takes on new importance as crop biotechnology "goes south" (Moffat 1999). As a practical implication I will show, at the risk of encouraging the propaganda machines of which I have elsewhere been critical (Stone 2002c), that media wars and lobbying could have a significant impact on the fate of biotechnology.

The Indian case material presented here is based on six periods of fieldwork between 2000-2003, principally in Warangal District (both Warangal City and its rural hinterland) and secondarily in Hyderabad and Delhi. Quantitative information on agricultural practices came from daily records kept by a group of 12 cotton farmers in Parvagathiri mandal. Further information on agricultural knowledge and practice was collected in approximately 50 semistructured interviews with a nonprobabilistic sample of farmers, merchants, industrialists, and scientists, and from observation of farmer meetings and agricultural activities.

Ecology of Smallholder Skilling

Skill obviously plays a role in all farming, but its importance in third world agriculture is often underestimated. Synthesizing a lifetime of studying agrodiversity, Brookfield (2001:9, 43) lays particular stress on indigenous management strategies and even defines agrodiversity in terms of management practices based on local knowledge. Extensive farming surely involves experimentation and innovation

(Richards 1985), but it is in intensive agricultural systems that management skill becomes most crucial. As population density, market demands, and other factors force agricultural intensification, reliance drops on the manipulated natural processes of fire and fallow, and farmers' work necessarily becomes more complex, less forgiving, and more demanding of detailed knowledge and finely tuned tactics. In intensive smallholder farming, as Netting (1993:9) put it, "skill replaces scale." For instance, the distinctive feature of the evolution of Asian rice economies—the example par excellence of intensive nonindustrial cultivation—is the "increase in the use of skilled manual labor accompanied by the development of managerial skills," as compared to the trend in western industrial intensive farming of replacing labor with machinery (Bray 1986:113). The skill at the heart of smallholder farming is not simply knowledge of plants and agronomic processes, or proficiency at agricultural tasks, but more generally the farmer's ability to execute a *performance* based on agronomic knowledge, farm management strategy, prediction of a range of factors, and manipulation of socially mediated resources (Richards 1989).

Skill is, according to analysts such as Marglin (1996), qualitatively different from formal agronomic knowledge in being more experiential and implicit, less decomposable and articulatable. It is not simply objective information that exists sui generis; skill is largely generated, maintained, and implemented socially. Farmers are often "skilled" through observing, discussing, and often participating in each other's operations. They acquire seeds from each other, and information expressed in locally meaningful concepts moves along with seeds between farmers and communities (Brush 1993, 1997; Richards 1989; Sillitoe 2000b). Agroecological processes become embedded in cultural concepts (Brodt 2001; Thrupp 1989), and communal skills requiring coordination across multiple farms (e.g., for pest control and irrigation management) may be embedded in cultural institutions that individuals may not fully understand (Lansing 1991; Netting 1974). It is vital, then, to move beyond the study of static indigenous taxonomies of "what the farmer knows" (Brush 2003) to consider how information and technology become incorporated into systems of management skill. We can provide an initial approximation of the skilling process by focusing on two different sets of processes particularly relevant to the effects of Bollgard on Indian smallholders, each with a major social component.

The first is what is often termed "environmental learning," defined simply as "payoff information provided by the environment" (Henrich 2001:994), but for cash crops this should include the economic environment (cost and availability of inputs, market prices). Such learning is as much a social process as a simple interaction of the individual farmer with the environment. The presence of other farms in the community increases the number of "experiments" each farmer can observe; farmers may have detailed knowledge of local practices that allow them to "harvest" information from each others' operations, although this varies among agricultural systems. Environmental learning involves not only acquiring primary payoff information, but interpreting it, and there is an important social component to this as well. Acts of cultivation under actual conditions are always imperfect experiments—the farmer cannot control rainfall, fluctuating pest populations, or soil fertility. Consider, for example, Conelly's (1987) description of Kenyan maize fields beset with stemborers, striga, maize streak virus, infertility, and drought. Raw payoff information from the field requires interpretation, and this process may be strongly shaped by discussion among community members, application of local conceptual frameworks (Brodt 2001), and deference to key individuals.

A second set of processes underlying skilling has been illuminated in recent years by cultural evolutionary theorists (Boyd and Richerson 1985). Humans' long history of adaptation to diverse environments has left a legacy of coping with incomplete and ambiguous environmental information. Since humans adapt not as individuals but as groups, individuals have to adapt to their social group as well as to their environment. Decisions about strategies for environmental interaction, including adopting technologies, cannot be based purely on payoff information, but also on:

> "transmission biases" that allow humans to effectively and efficiently acquire beliefs, ideas, and behaviors from the immense amount of confusing and often contradictory information presented by the external world. Evolutionary considerations suggest that our cognitive abilities consist of learning rules that preferentially select and evaluate sensory data from prescribed subsets of externally produced information. These learning mechanisms provide "rules of thumb" that bias humans towards acquiring certain beliefs and behaviors without exhaustively examining and processing the immense amount of available social and environmental information (Henrich and Boyd 1998:218-219).

Transmission biases include *direct bias*, for traits favored by social learning psychology even if unrelated to performance, and *prestige bias*, for traits associated with successful actors even if the trait did not contribute to that success (Boyd and Richerson 1985:9-10; Henrich 2001). Particularly important in adoption of agricultural technology is *conformist*, or *frequency-dependent*, *bias*. This refers to the tendency to adopt traits because they are widely adopted by others; once a strategy becomes sufficiently pervasive, it becomes the default value, and actors tend to follow that strategy in the absence of a compelling reason not to. This means that the social matrix is providing proxy information about the adaptiveness of a trait (Henrich and Boyd 1998:218-219), potentially overriding flawed information acquired through environmental learning.

Simulations even show that the famous S-curve of innovation adoption is better explained by these cultural transmission biases than by environmental learning (Henrich 2001). This would mean that the central role of the environmental learning implied in the claim that "farmers will adopt if it benefits them" may be overrated. Acquisition and interpretation of environmental payoff information is partly a social process, and agricultural decision making is governed not only by direct payoff information, but by social processes only indirectly related to payoff information.

Adopting a practice for social reasons like conformance, even if the practice appears to be suboptimal from a strictly agronomic perspective, may be advantageous when we consider the overall context of agricultural performance. Smallholder agriculture is partly a social enterprise, in which the farmer may rely on the community to ensure land tenure, labor, and other inputs (Stone 1997). Following agricultural strategies compatible with one's neighbors may well have a payoff even when the strategy would not be optimal for a purely independent operator. Thus, this vital process of "skilling" has both ecological and social components; knowledge and management practices arise both from environmental learning, which has an important social component, and social phenomena only loosely related to environmental payoff information.

Agricultural Deskilling?

The indigenous management skill that results from these processes may be in many ways quite sophisticated, but some romanticized depictions of it obscure the fact that it is hardly flawless (e.g., Shiva 1997:8). Numerous factors significantly impede acquiring and interpreting the information that is a crucial component in skilling. For instance, Bentley's (1991, 1992) studies of Honduran farmers' management of insects concluded that farmer knowledge varied widely, depending on conspicuousness of the insect activity and the amount of cultural importance (including lore attached to the pest). Social insects, as well as weeds, which were readily observable and rich in lore, were well classified and understood by farmers. Insects that figured less in cultural lore, like earwigs or spiders, were classified with less taxonomic specificity; parasitic wasps, which not only lacked cultural lore but were difficult to see, were largely unknown despite playing a key role in agroecology.

To Bentley's criteria of observability and cultural importance, I will add three factors. First is the *consistency* of a technology's effect on management practices. Seeds and other technologies may have "credence qualities" that only become apparent over time or under special circumstances (Tripp 2001a). A technology's effects may also change through time as a result of factors that are difficult or impossible for the farmer to monitor (Sillitoe 1998:225): insecticidal sprays are the example par excellence, as effects can vary sharply from year to year in their direct impacts on target species and indirect impacts on predator species. Insecticide sprays tend to open a self-widening information gap: the less the farmer knows about insect ecology, the more insecticide is used (Thrupp 1990; Vandeman 1995). This often leads to insecticide resistance and chaotic fluctuations in insect populations (Brogdon and McAllister 1998), exacerbating the problem of inconsistency. Inconsistency has impeded skilling in pre-Bollgard cotton cultivation in India, but we will also ask whether Bollgard presents its own problems in consistency.

Second is the *recognizability* of a technology. While the skilling process is challenged by the latent or variable effects discussed above, an even more fundamental obstacle may be that the farmer is unsure of what is being planted. The problem is often exacerbated as reliance on marketed seed replaces replanted seed, but it is not a problem exclusive to marketed seeds; farmers have encountered "identity confusion" with the second generation of replantable modern varieties (Tripp 2001b). For instance, farmers easily recognized first-generation Green Revolution seeds, but the more subtle changes bred into subsequent generations caused greater confusion and slower rates of adoption (Byerlee 1994). Lack of recognizability impeded skilling. The recognizability problem is particularly relevant to crop genetic modification:

> The precision of genetic engineering, avoiding the trade-offs characteristic of conventional plant breeding by providing, for instance, disease resistance without any other changes in a variety's appearance or performance, is a double-edged sword. If a new transgenic variety is not immediately distinguishable from conventional varieties, what are the chances that farmers will recognize and demand it? The answer in this case depends on the distribution and severity of the particular disease, but farmers may not be able to draw causal inferences from the variety's performance in fields where many other yield-limiting factors are probably in evidence (Tripp 2001b).

So the very characteristic of genetic modification that some biologists applaud, because it may allow changing seeds without affecting cultural agricultural practices, may impede the skilling process that is at the center of smallholder agricultural performance.

Third, we need to draw attention to the *rate of introduced technological change* as a factor affecting agricultural skilling. Skilling takes time. Even if a technology avoids the other impediments to skilling—it is unambiguously recognizable at the time of acquisition, it displays a reasonable consistency, its action is readily observable, and even if there is cultural lore to guide its interpretation—the skilling process may fail to keep up with overly rapid technological change. Skeptics of GM for third world farmers have been accused of advocating a museum-like preservation of indigenous practices. This was the same false choice that arose in the planning stages of the Green Revolution, which led the Rockefeller Foundation to ignore agricultural geographer Carl Sauer's prescient warnings about revolutionizing peasant Mexican agriculture. Rockefeller officials thought he saw "Mexico as a kind of glorified ant hill which they are in the process of studying…[he] resent[s] any effort to 'improve' the ants" (Marglin 1996:217). For Sauer the issue was not change versus stasis, but the speed and type of change; he advocated that peasants "build on the preservation and rationalization of their own experience with slow and careful additions from the outside" (ibid.).

The notion that the value of technological change may hinge on it appearing at a rate that allows it to be integrated slowly and carefully into local practice is not a familiar one in Western circles. Farmers in industrialized countries may enjoy a rapid flow of information from government agencies, seed companies, and consultants, but third world extension systems are typically weak, and the information they have to provide is often inappropriate. This is certainly the case in India (Sulaiman and Holt 2002). Rapid technological change may open information gaps. They should be closed through the skilling process, but information from the formal sector may help. It certainly does in industrialized countries, but it may be of little help or may even obstruct skilling, as the following case shows.

One of the most interesting ideas about the systemic effects of these impediments is that farmers may become "deskilled." Vandeman (1995) claims deskilling is a byproduct of pesticide use; Fitzgerald (1993) sees it as a result of large-scale hybrid maize breeding. Some observers of Indian agriculture have predicted it as a sure concomitant of GM crops there (Harwick 2000:53). However, the application of "deskilling" to agriculture is not straightforward. The deskilling concept as currently used was primarily developed by Braverman (1974:205); it is an industrial process leading to separation of "intellectual work from work of execution." Using somewhat different terminology, both Adam Smith and Karl Marx described the same process (Marglin 1996:194-195). Braverman emphasizes the replacement of skilled workers, who are more expensive and less controllable, by machines and less-skilled workers. Yet, what might be called deskilling in agriculture is in some ways different, more variable, and certainly less understood.[7]

Braverman's deskilling is an intentional process that benefits management at the expense of the most skilled workers. In contrast, the developers and vendors of pesticides are likely to view their products as benefiting the farmer; they are also trying to turn the farmer into a regular customer. The use of pesticides does, however, "transfer skill and exercise of judgment from the agricultural labor process, where the farmer exercises control, to the chemical manufacturer" (Vandeman 1995:55). The pesticide industry then benefits from the farmer's lack of information, because of the inconsistency in pesticide's effects, and because the less the farmer knows about pesticides the more are used (Vandeman 1995:49). Fitzgerald (1993) sees the deskilling of American farmers by hybrid corn as lacking the "malice" of the factory floor, yet the change in management skill was profound. Only 20 years after substantial yield increases had been achieved by a USDA program encouraging farmers to take *greater* control over corn breeding, farmers were cautioned by seed companies against even trying to choose which seeds to purchase.[8] Ziegenhorn (2000) shows how U.S. farmers were for years systematically misled on the nature of the seeds they were buying.

Thus commodification of pest management and seed production have the potential to make serious inroads into management skill. This points to a key difference between Braverman's industrial deskilling and agricultural deskilling. Industrial deskilling does not so much eliminate skill as it relocates it. According to Braverman (1974:112), basing his analysis on Taylor (1911), the process must begin with management assuming "the burden of gathering together all the traditional knowledge which in the past has been possessed by the workmen" and codifying it so it may be embedded in higher levels of operation. Compare this to smallholder agriculture, which must always retain its quality of a performance, and in which erosion of management skill is likely to obstruct the adaptation and improvisation that performance requires. In other words, unlike in the factory, the apparent replacement of skill is an illusion for which the farmer may pay a price when problems arise—as they invariably do in agriculture. This perspective on information flow, skilling, and deskilling provides a basis for examining the case of GM cotton in India.

Indian Cotton Farming

Cotton cultivation has a deep history on the Indian subcontinent. The earliest known cotton textiles are from the Indus Valley, and for centuries Indian calicos and muslins were widely traded luxury goods. These were woven of the indigenous (*deshi* or *desi*) species *Gossypium arboreum*, which had a short staple, low water requirements, and resistance to indigenous pests. During the 19th century, the British crushed the Indian textile industry and established the classic colonial pattern of mass production of raw cotton to be woven in England. During the late 19th and early 20th centuries, there were repeated attempts to replace desi cottons with New World species, principally *G. hirsutum*. *Hirsutum's* longer staple was better suited to British textile mills (Prasad 1999) and could produce higher yields if enough water and fertilizer were available. It was also vulnerable to Indian pests and was not widely adopted until pesticide sprays were available in the mid-20th century (Prasad 1999; Sauer 1993). The 1970s brought the introduction and rapid spread of hybrid cotton varieties. As of 1998, just over 80 percent of the Indian cotton crop was *G. hirsutum*, and around half of the crop was hybrid (Hindu 2001). This switch to hybrids had inevitable effects on the skilling process by reducing both the recognizability of seed and the consistency of its performance.

The early 1990s brought important changes in cotton cultivation in Warangal District of Andhra Pradesh: strong cotton prices coupled with government promotional campaigns induced local farmers with little background in cotton cultivation to take it up. Around the same time, the pesticide treadmill moved ahead a notch with the arrival of fourth-generation synthetic pyrethroids, which were effective on the bollworms that had been showing resistance to organophosphate and earlier pyrethroids. But by later in the 1990s, this generation of sprays began to lose effectiveness against the rapidly evolving "American bollworm" (*Helicoverpa ameriga*, actually an Old World species), and populations of previously minor pests like whitefly began to explode as their natural predators were decimated by the spraying. To make matters worse, the fluctuations in various insect populations were erratic and thus increasingly inimical to farmer skilling. Good harvests were at least frequent enough to lead many farmers to continue to risk it, and the combined effect of erratic but generally worsening insect predations led to a desperate cycle of debt and to increased—indeed, often indiscriminate—spraying. My interviews and agricultural monitoring studies in 2000-2002 revealed many farmers applying up to eight different insecticides, often in inexplicable combinations, in up to 20 sprayings per season.

The full range of impediments to environmental learning are present. The insect pests are not inconspicuous, but most of the Warangal farmers lack cultural lore on cotton pests to guide the social process of skilling and certainly have little lore on insecticide sprays. More importantly, the pesticide treadmill entails severe problems in consistency and rate of change and even sometimes in recognizability, since the products may be diluted or mislabeled. Regardless of the state of indigenous management skill in rice, grams, and other crops, Warangal smallholders were largely deskilled in cotton cultivation by the mid-1990s. When 1997 brought a particularly bad year for cotton pests, it triggered the Warangal suicide epidemic that took a disproportionate number of marginal and poorly educated farmers (Reddy and Rao 1998; see also Stone 2002b). Most farmers in Warangal recognize their own deskilling in cotton cultivation. I attended a recent meeting of farmers and NGOs in late 2002, called primarily to discuss Bt cotton, but when the farmers held a subgroup meeting their discussion immediately turned to the need for a "guide" in each village to assist them in managing cotton inputs.

India has numerous GM crops in the pipeline and each may play different roles in farming systems; but this first crop, Bt cotton, was released into a troubled situation plagued by problems that were more systemic than simple pesticide resistance by one species of caterpillar. It is rather a situation in which the most fundamental resource of intensive smallholder farming—management skill—has been corrupted. The warnings of activists that GM crops will bring about "deskilling" (Harwick 2000:53) are too late; calls to preserve "cultural practices" become meaningless when the practices are crippled by an unfillable information gap and thus are unsustainable. But if cultural agricultural practices change all the time anyway, the question is how practices and the flows of information underlying them may change with this new technology. Potential effects of even apparently subtle changes in agricultural technology on dynamics of smallholder farming are routinely ignored in the scientific literature on crop biotechnology, even in studies of "social consequences" of transgenics (e.g., Edge et al. 2001; Shelton, Zhao, and Roush 2002). But they are in serious need of attention as these technologies move into developing countries. Although the technology is still quite new in India, some preliminary observations on how information flows have been changing with the introduction of Bt cotton are possible.

Information Flows

Bollgard cotton demands a considerable amount of new information for skilling, and it brings a novel set of potential impediments to information flow and skilling. Even before the first harvest had commenced, there were reports from "both government sources and NGOs . . . that local farmers are not meeting the many technical specifications" (Jayaraman 2002b:1069), and new relations within the production system that we may call "relations of information" had been established.

The first of these concerns field testing. Farmers take a keen interest in field tests in general, whether it is anecdotal evidence from observing a nearby test plot or the summary results of field trials. In Warangal, there has been particular interest in test results on a high-stakes product like Bollgard, which came with a high cost and also high promises. Mahyco-Monsanto began contained field trials of Bollgard in 1997. Despite a succession of difficulties, including the torching of test plots in 1998 and controversies over the integrity of testing procedures (Shiva, Emani, and Jafri 1999), tests continued through 2001, when 395 trials were conducted in seven states. To the exasperation of many scientists, including many who are generally supportive of biotechnology in India, data from the field trials have never been released (Jayaraman 2002b). Many biotechnologists I have interviewed are concerned that the approvals process has been corrupted. Others blame the secrecy on green critics: one member of the Genetic Engineering Approvals Committee (GEAC) claims that because of public interest litigation filed by Vandana Shiva's NGO, the Department of Biotechnology would risk contempt of court by publishing data from field trials (Khurana 2001).

What has been released is a study of a subset of Mahyco's test plot data (Qaim and Zilberman 2003). The data provided by Mahyco show that in 2001—a very heavy year for the American bollworm to which Bollgard is supposed to be resistant—Bollgard performed well, astonishingly well, with yields 80 percent greater than non-Bt versions of the same hybrid variety. What the study did not make clear, however, was the inconsistency that is vital to the skilling process: between 1998 and 2001 differences between Bollgard and its non-Bt counterpart ranged from 37 to 80 percent (Matin Qaim, agricultural economist, Center for Development Research, e-mail to author, March 4, 2003). This also assumes that the data are to be taken at face value. The confusion caused by this paper being mistaken for a vindication of the controversial 2002 harvest (Padma 2003; Srinivasan 2003) constitutes another disruption of information flow.

Whereas the Bollgard test plot data have brought passive restrictions of information flow, its commercial release in 2002 has apparently brought active disruptions. In April 2003 the Delhi-based NGO Gene Campaign held a meeting to report results of a study comparing Bollgard and conventional cotton in Andhra Pradesh. The findings reflected poorly on Bollgard.

The meeting was reportedly disrupted by a group of farmers hired and brought in an air-conditioned bus by Monsanto (AgBioIndia 2003). Monsanto has reportedly used tactics of "information espionage" in biotechnology campaigns before, including hiring African American churches to demonstrate for crop biotechnology (Petersen 1999) and having its public relations firm create imaginary citizen biotechnology experts and organizations to conduct "viral marketing" (Monbiot 2002).

Second are changed relations of information concerning crop management. Bollgard requires novel management practices based on principles unfamiliar to the farmers. GEAC approval stipulates that each Bollgard field must be surrounded by a refuge of the non-Bt version of the same cotton variety, the amount being the larger of five rows or 20 percent of the field area. Controversies in the underlying logic for these procedures have significant implications for the skilling process.

The refuge model was developed in the United States as a hypothetical means of retarding the evolution of Bt-resistant pests in large monocultural fields. Non-Bt plants located within or around Bt fields are intended to provide refuge habitat for Bt-sensitive insects that will breed with Bt-resistant insects. The effects of refuges on insect populations are far from clear due to several complicating factors. Disagreement continues on the optimal refuge sizes (Levidow 1999). There is an obvious free-rider problem in resistance management by refuge, and even in the U.S. many farmers are breaking the rules for some Bt crops (ABSTC 2001). Insects in other areas have already developed worrisome resistance to Bt (e.g., Gahan, Gould, and Heckel 2001). On the other hand, studies of Bt cotton in Arizona show that the threat of resistance may be exaggerated (Tabashnik et al. 2000), and that large expanses of Bt cotton actually reduce regional populations of pink bollworm (Carriere et al. 2003).

The situation for Indian smallholders is less resolved yet. Monsanto has given assurances that if the refuges fail to prevent resistance, new Bt genes can be brought into service, thus replacing the pesticide treadmill with the genetic treadmill. Yet according to some proponents of Bt cotton, including some at Monsanto India, the 20 percent refuges mandated by GEAC are unnecessary because American bollworms feed on many crops other than cotton, growing in scattered small fields (Jayaraman 2002a). In this view, the refuge requirement is essentially a sop to environmentalists. (The theory is plausible but unstudied. It is also unknown how a lack of refuges would affect pink bollworm, a Bt target pest that has a much narrower diet than American bollworm.) But GEAC envisions another refuge function as well: the refuges may serve as pollen sinks, preventing outcrossing with non-Bt varieties (Rao 2002). Exacerbating the contradictions in information were sharp disagreements over the economics of refuge planting, with Monsanto oddly agreeing with Bollgard critic Suman Sahai on the claim that small farmers could not afford to plant refuges (Scoones 2003:9).

The contradictions in the rationale behind refuges raises the question of how, and if, farmers can be made to understand refuges so the practice can be incorporated into indigenous management, or if they will follow practices they do not understand and so devise their own explanations.

The instructions in the pamphlet and audiotape accompanying the seed in Andhra Pradesh (both in Telugu) are mute on the rationale of refuges: farmers are simply told to plant five rows of the non-Bollgard seeds (provided in a separate packet in the Bollgard box) around the edge of the Bollgard. Much of the responsibility of explanation falls to the vendors. Mayhco-Monsanto brought its approved vendors to a workshop where they were taught to answer farmers' questions and instruct them on the importance of the refuges. Vendors were also told to sell Bollgard only to groups of ten farmers, supposedly to invoke peer pressure to follow the stewardship plan. Purchasers had to sign a statement affirming their intention to plant the 20 percent refuge.

No quantitative indicators of the efficacy of these information management strategies are yet available, but anecdotal evidence shows some serious problems. Not surprisingly, many farmers neither read the directions nor listened to the tape. In Warangal, the policy of selling to groups has not been followed, and I encountered several farmers who bought their Bollgard from other farmers. It is not surprising that farmers' understandings of refuges varied considerably. Meeting with a group of 20 Bollgard planters in Warangal in December 2002, I asked why, according to their understanding, refuges were needed. Three salient explanations emerged: 1) that it would act as a barrier to bollworms; 2) that it would concentrate bollworms so they could be sprayed; 3) and that it would keep Bt from harming the environment. Several farmers responded in terms of obedience rather than function: some noted that it was a government rule, others that they would be punished for noncompliance, stating that "If you don't plant a refuge, you are liable for contamination of the environment," and "If you don't, the government will uproot your crop."

Explanations by seed dealers, who normally serve as a principal conduit for crop management information, included the rationales noted above, as well as the rationale that refuges are intended to demonstrate the superior qualities of Bt cotton. Many dealers flatly stated that they had no idea what the refuges were for. Management advice from dealers will likely fall into disrepute as farmers come to recognize that the refuges neither act as bollworm barriers nor serve any other comprehensible function.

The most unsatisfactory aspect of information flow from the formal sector has been in agricultural extension (Sulaiman and Holt 2002). Government extension programs can never provide the complete package of "skill" as it is being discussed here, but they should be able to contribute basic information on new technologies that is important in the skilling process. Far from offering a self-contained solution to an agronomic problem, technologies offering credence qualities require a higher level of extension, especially extension rooted in agroecology suitable to smallholder conditions in India rather than large scale monocultures (Tripp 2001a).

Rethinking Information Flows in Skilling: The Role of Lobbying

Given the central role the third world has assumed in the biotechnology debate (Stone 2002c), and the importance of cultural agricultural practices in the third world, there would seem to be some urgency in arriving at a sound understanding of the smallholder skilling process. The case of Warangal cotton farmers certainly dramatizes this need. Social science has shed light on the key role of management skill in smallholder farming; it has also made progress in understanding the two sets of formative processes in skilling described above: environmental learning and biased cultural transmission. What social science has been slower to come to terms with has been the separate set of processes that have often been overbearing on the Indian agricultural scene: professional rhetoric, or lobbying of the farmer. There is reason to believe that with India's first GM crop, lobbying may be able to override both environmental learning and cultural transmission.

Information and argumentation reach Warangal farmers from outside the formal positions of regulating or selling farm products, or teaching farm practices. Two Telugu-language dailies in Warangal, along with one weekly and one monthly publication, emphasize agricultural issues, and there are radio and TV shows dealing with agriculture. Over one-third of the Warangal farmers read newspapers and magazines, and well over half get agricultural information from radio and television. Various NGOs also call farmer meetings: between August and November of 2002, 14 such meetings were called in Warangal District. These all are important conduits for new forms of lobbying.

The public flows of information on Bollgard in India began with generally low-profile and technical articles in the mid 1990s. When Bollgard field tests began, there was a dramatic upsurge in articles in mass media and in lobbying activities of government, civil society, industry, and scientists (Yamaguchi, Harris, and Busch 2003). This was certainly not the first time campaigns had been directed at farmers: one of the reasons so many in Warangal were growing cotton in the first place was a government-sponsored campaign of a few years before, complete with posters and loudspeakers on vans blaring exhortations to move into cash cropping. One of the factors that has started them on the pesticide treadmill had been advertising. Yet the lobbying on Bollgard that began in 1998 has been qualitatively different from previous endeavors to influence opinion and farmer practices. There is much more rhetoric, since rather than being an India-specific agricultural issue it is a global struggle in which India is a key battleground. Considerable funding is available from outside sources. The topic of GM cotton now engages the interest of a substantial portion of Indian society, partly because of rising interest in larger issues of the role of crop plants in first-third world relations following controversial patents on neem, tumeric, and basmati rice.

Aggressive lobbying reaches virtually all farmers. It may play a much larger role in the skilling process than those who take the "farmers will adopt if it benefits them" perspective are willing to admit, and it certainly plays a larger role than recognized in the social science models of adoption described above. Lobbying may have particular potency in this case because of the deskilling in cotton farming. Moreover, the special property Bollgard offers cannot necessarily be gauged from short-term results, and long-term results are unavailable (and the five years of test data are not available even to agricultural scientists). We do not know how this product will eventually fare in India, but there are grounds for anticipating that the aggressive lobbying, both pro and con, may shape agricultural practice along with environmental learning and cultural transmission.

Figure 2. Farmers' Meeting

Photo copyright G. D. Stone, 2002

Note: Farmers' meeting called by coalition of NGOs in Andhra Pradesh opposing genetically modified cotton, December 2002. The program featured presentations of results of a study showing poor performance by Bt cotton in its first year of commercial release. There was also a procession of farmers who described their experiences with Bt cotton, including the man facing the crowd.

Yet politicized flows of information are not completely independent of environmental learning or cultural transmission. The current activities of the Andhra Pradesh Coalition in Defence of Diversity provide a case in point. This coalition sponsored the study showing lower economic returns to Bt cotton in Warangal (Qayum and Sakkhari 2003). This study was released to the press (Venkateshwarlu 2002a) and was presented at a public farmers' meeting in Warangal in December 2002 (Figure 2). It was, in effect, an organized political forum for carrying out the social function of environmental learning—the "harvesting of information from each others' operations" discussed above.

Interestingly, the meeting was also designed to manipulate cultural transmission biases, including the conformist transmission described above. The main focus of the agenda was a procession of Bt planters who gave critical accounts of their experience (Figure 2). I asked several farmers if they felt the testimonies had been orchestrated to impeach Bt cotton; the consensus was that the program had been genuinely open to any Bt planters, but satisfied planters were probably less inclined to testify. A few did give positive testimonies, encountering skeptical questioning from organizers as to why they would have had experiences so divergent from the majority. Near the end of the meeting, I asked how many of the 20 farmers present intended to plant Bt cotton again—only one raised his hand. The meeting was, among other things, a formal attempt to promote conformist transmission. (Industry too attempts to invoke conformist transmission. For instance, the Monsanto India Web site posted an article [Monsanto 1999] exclaiming how 92 percent of farmers interviewed "think that biotechnology is useful," although the article appeared in 1999, three years before the farmers would have even seen a GM plant.)

Conclusions: Information in the Seed and in Society

The third world smallholders who are central to global biotechnology debates have been the subject of numerous social scientific studies, including detailed ethnographies and synthetic overviews (e.g., Bray 1986; Brookfield 2001; Netting 1993; Richards 1985; Turner and Brush 1987). Each study has underscored the pivotal importance of management skill in smallholder farming. In these agricultural systems, skill is much more than information control; it is better characterized as *performance* based on the process of skilling. It is important to consider the nature of the skilling process in addressing the pressing question of effects of transgenic crops.

I have argued that cultural agricultural practices change all the time, and that skilling is a dynamic process, which means that GM crops' purported ability to leave local cultural practices unchanged is off the mark. In India, some local cultural practices in cotton cultivation are manifestly unsustainable, which has been a justification for the first commercialized GM crop. It is overly simplistic, however, to presume that Bollgard is a "solution" to the problem that will be adopted if farmers find that it benefits them. Some phenomena pose special challenges to the "environmental learning" component of skilling, and some of these, such as consistency, recognizability, and rate of technological change, may make Bollgard partly incompatible with skilling. Information flows from the formal sector might in theory mitigate the problem, but in practice, they have not and probably will not. Skilling is also in many important ways a social process and may turn out to be significantly influenced by new politicized information flows.

Notes

[1]The visitors entry at Monsanto's Chesterfield, Missouri, facility has been dominated by an enormous photograph of Wambugu.

[2]The point is made widely about GM crops. Other recent examples include this from an Aventis scientist: "The quality/technology resides in the seed itself—farmers do not even have to change their traditional farming methods in order to achieve better yields" (Kern 2002:3), and this from an agricultural consultant: "the benefit to the farmer is embedded in every seed. Therefore, any farmer that uses this technology would benefit from it just as equally" (Jayaraman 2002a).

[3]Monsanto has long promoted its Roundup herbicide as a preferable alternative to hand weeding and as the basis of "no-till" cultivation. It has also championed seed that is nonreplantable (because of either biological limitation in the seed or contractual agreement) as important to attracting investment to agricultural technological development.

[4]For instance, Goossens (1996) describes African farmers who scorn improved seeds and chemical inputs on the grounds that soil fertility comes from their ancestors, who expect "traditional" cultivation practices. I too have heard African farmers attribute soil fertility to ancestors; however, I have also heard American farmers use similar terms in attributing productivity to God. In both cases, the statements reflect discourse more than agroecological knowledge. It is significant that, following his description of tradition-bound Africans, Goossens admits that the farm inputs are expensive and not dependably available.

[5]"Bt" is *Bacillus thuringiensis*. Bt cotton is now grown in South Africa, Mexico, and China (Ismael, Bennett, and Morse 2001; Pray et al. 2001; Traxler et al. 2001).

[6]Pinstrup-Anderson was head of the International Food Policy Research Institute and a strong advocate of crop genetic modification. The rationale in this quote has been used to justify the controversial "terminator" technology (Bailey 2001).

[7]Indeed, as is made clear in the extensive "Bravermania" literature (Littler and Salaman 1982), the basic concept of deskilling oversimplifies the transformations within industry (Cohen 1987; Thompson 1989a, 1989b).

[8]"You may not know which strain to order. Just order FUNK'S HYBRID CORN. We will supply you with the hybrid best adapted to your locality" (Funk Bros. 1936 Seed Catalog, quoted in Fitzgerald 1993:339).

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