Agricultural Deskilling and the Spread of Genetically Modified Cotton in Warangal

by Glenn Davis Stone

Warangal District, Andhra Pradesh, India, is a key cotton-growing area in one of the most closely watched arenas of the global struggle over genetically modified crops. In 2005 farmers adopted India's first genetically modified crop, Bt cotton, in numbers that resemble a fad. Various parties, including the biotechnology firm behind the new technology, interpret the spread as the result of farmer experimentation and management skill, alluding to orthodox innovation-diffusion theory. However, a multiyear ethnography of Warangal cotton farmers shows a striking pattern of localized, ephemeral cotton seed fads preceding the spread of the genetically modified seeds. The Bt cotton fad is symptomatic of systematic disruption of the process of experimentation and development of management skill. In fact, Warangal cotton farming offers a case study in agricultural deskilling, a process that differs in fundamental ways from the better-known process of industrial deskilling. In terms of cultural evolutionary theory, deskilling severs a vital link between environmental and social learning, leaving social learning to propagate practices with little or no environmental basis. However, crop genetic modification is not inherently deskilling and, ironically, has played a role in reinvolving farmers in Gujarat in the process of breeding.

Like the adoption of any new technology, people planted it [genetically modified cotton] on smaller acres initially, but the ever-increasing Bollgard plantings demonstrate that the Indian farmer is willing to embrace a technology that delivers consistent benefits in terms of reduced pesticide use and increased income. Clearly the steadily increasing Bollgard acres being planted by increasing numbers of Indian farmers bear testimony to the success of this technology and the benefit that farmers derive from it.

—Ranjana Smetacek,
Director of Corporate Affairs for India, Monsanto[*]

The concept of indigenous knowledge has gone through a sort of developmental cycle . . . [as have other concepts in rural development] which were originally conceived as radical conceptual breakthroughs, but all of which seemed to succumb over time to appropriation by the interests they initially opposed.

—Michael Dove

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[*]. E-mail message to G. D. Stone, November 14, 2005. Monsanto officials have made the same pont in print numerous times (e.g., Srinivasan 2004; *The Hindu* 2002, 2005).

In the global struggles over genetically modified crops, there are few places where the stakes are higher or the questions more urgent than India, with its 600+ million (mostly smallholder) farmers, its alarming problems in agricultural sustainability, its world-class scientific community, its sophisticated media, and its enormous green NGO sector. India released its first genetically modified crop in 2002 after five contentious years of testing and debate. The crop was the same one leading the way into smallholder agriculture elsewhere (notably China): cotton, genetically modified with a gene from the Bt bacterium to produce its own insecticide.[1]

In 2002[2] Bt cotton was available in only three legal commercial seeds, produced through collaboration of Mahyco (the Indian firm providing hybrid cotton seed) and its partner and partial owner, Monsanto (the St. Louis-based biotechnology firm providing the gene construct). The seeds were Bt

1. Bt is *Bacillus thuringiensis*, a soil bacterium that produces crystalline proteins that damage the digestive systems of certain lepidopteran insects, including several moths that are severe cotton pests in their caterpillar stage (generally known as bollworms). The genes expressing the insecticidal proteins are known as Cry genes. As of 2005, all commercial Bt cottons in India contain the same genetic construct, developed by Monsanto, containing the Cry1A(c) gene. For further background on genetic modification of plants see Stone (2002*b*, online version).

2. The cotton season often straddles two calendar years: seeds are typically planted in late June and harvested from October through February or March. To make the discussion less cumbersome, I refer to cotton seasons by the year the crop was planted.

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versions of the Mahyco hybrids MECH-12, MECH-162, and MECH-184. The technology arrived with intense controversy and shrill invective both for and against. Bones of contention have included intellectual property, environmental safety, and ethics. Even the field performance of the new seeds has been hotly disputed, mainly in unpublished studies by organizations with vested interests in the debate.[3] But on sales performance the picture is clear. Sales were 72,000 packs in 2002 and 230,000 in 2003; in 2004, when four Bt hybrids were available, sales jumped to 1.3 million packs, apparently confirming Monsanto's claims of Bt cotton's being the fastest-adopted agricultural technology in history (Dinham 2001) and Indian farmers' being the fastest adopters in the world (Monsanto 2006). But it was in 2005 that the real breakout occurred: with the number of Bt hybrids up to 20, sales jumped to over 3 million packs nationwide.

In some localities, such as Warangal District of Andhra Pradesh (fig. 1), the surge in sales was even more dramatic. Warangal is a pivotal cotton-growing area where I have been studying since 2000 (fig. 2). Cotton cultivation here has been fraught with problems and indeed has even been implicated in a rash of farmer suicides that were used in rhetoric from crusaders on both sides of the Bt cotton divide (Reddy and Rao 1998; Stone 2002*b*). Data collected from Warangal seed vendors shows something remarkable: from 2003 to 2005 the market share held by Bt hybrids climbed from 1% to 20% to 62%. In Gudeppad village, where they are used to having me ask about seed choices, one farmer said with a laugh that my work would be easy this summer: the village was "*motham Bt!*" ("all Bt!"). Surveys showed this to be almost literally true: 90% of Gudeppad's seed choices in 2005 had been for Bt hybrids, including 83% for a single brand. This was more than innovation diffusion and more than a "tipping point" (Gladwell 2000): it was a stampede.

Given the importance of the Third World to the global debate on genetically modified organisms (Stone 2002*b*) and the potential importance of these organisms in the Third World (which is a different matter), understanding this stampede to the first genetically modified crop in this key district in this key country is of great consequence. It is also important

3. That the Bt technology—specifically the MON-531 transformation event using the Cry1A(c) gene—makes the cotton plant express a protein toxic to key species of bollworm is not disputed. What is disputed is what difference this makes agroecologically and economically in actual farm conditions, and on this matter there is great variation and a poverty of sound scientific studies.

The industry-supported International Service for the Acquisition of Agri-Biotech Applications reported yield increases of 90% on test plots in India, although the source was only a personal communication (James 2002, 137). Mahyco-Monsanto's press releases reported on their own studies showing large boosts in yields coupled with lower pesticide costs in 2002, resulting in extraordinary increases in profits (Mahyco-Monsanto 2002). For 2003 the firms commissioned a study of cotton farmers in five states which again showed higher average yields and lower pesticide costs (Krishnakumar 2004; Mahyco-Monsanto 2004).

Qayum and Sakkhari (2003), in a study sponsored by the (anti-GMO) Deccan Development Society, claimed average to poor performance by Mahyco's Bt hybrids. The Delhi-based Gene Campaign has reported two studies with little explanation of sampling or methodology. For the 2002 crop it interviewed 100 farmers in unspecified locations in Maharashtra and Andhra Pradesh, concluding that planters of conventional seeds fared better than planters of Mahyco Bt seeds (Sahai and Rehman 2003). For the 2003 season, Gene Campaign interviewed 136 farmers in four districts of Andhra Pradesh (including Warangal). The researchers reported equivalent yields in Bt and conventional fields and higher profits in the conventional fields, but they wrote off their own findings because "there is chaos in the cotton fields and nobody can say with any guarantee what actually has been cultivated in this cotton season and how much" (Sahai and Rehman 2004). The Gokhale Institute of Politics and Economics found significant problems in Maharashtra in 2004 (*Times of India*, June 4, 2005), as did a study by Greenpeace (Krishnakumar 2003). The Centre for Sustainable Agriculture's survey of 121 farmers concluded that in 2004 Bt growers spent almost seven times as much on pest management as conventional growers (Sharma 2005). Other critical (unrefereed) studies have also been announced by Vandana Shiva's NGO (the Research Foundation for Science, Technology, and Ecology), Greenpeace India, the Center for Resource Education, and the Sarvodaya Youth Organization (*Deccan Chronicle*, March 4, 2003; Padma 2003). Summaries of these and other unpublished studies critical of Bt cotton are provided by the Center for Sustainable Agriculture (2005) and *Frontline* (Krishnakumar 2003).

The few refereed studies on the performance of Bt cotton in India have had a variety of limitations and problems. Qaim and Zilberman 2002 analyzed 2001 test plot data supplied by Mahyco-Monsanto, showing that the Bt seeds gave an astonishing 80% yield increase. The article has been heralded by biotechnology companies (e.g., MonsantoIndia 2003), but its extrapolations set off a "firestorm" (Herring 2005*a*; Scoones 2003). It has been pointed out that 2001 was an unusually bad year for bollworm outbreaks, exaggerating the value of Bt (Herring 2005*b*), and that the source of the data was suspect. Even defenders of genetically modified crops complained that the study "used selective data sets from just one season when they had access to five years worth of data sets . . . This kind of astonishing yield increase due to a single gene trait was never going to be true" (Shantharam 2005).

A farmer-participatory field trial in Maharashtra in 2002 compared MECH-162 Bt grown under integrated pest management with MECH-162 non-Bt and conventional cotton grown with and without it (Bambawale et al. 2004). This study suffered from scale problems (the area of MECH-162 non-Bt was only 1.44 ha), and its results were equivocal: it showed far less bollworm damage to MECH-162 Bt than to MECH-162 non-Bt, but when seed cost was taken into account the benefit:cost ratios were almost identical. (Biotechnology proponents still proclaimed that the study showed MECH-162 Bt cotton to be a "hands-down winner" [Shantharam 2004].) These findings agreed with another independent but unrefereed study on 100 Karnataka farmers in 2002: in that study, Orphal (2005) reported higher yields for Bt seeds only with irrigation and no significant difference in gross margins.

While far from exhaustive, this summary provides a sense of the discrepancies in assessment of the field performance of Bt; further discussions of the controversy are provided by Stone (2004), Scoones (2003), and Herring (2005*a*, 2005*b*). At present the only safe conclusions seem to be that "an urgent need is obvious for further rigorous scientific evaluation of Bt cotton in India before deciding its further promotion" (Arunachalam 2004) and that this further research needs to address the enormous variation in the impact of Bt cotton (Qaim et al. 2006).

A recent study of eight Bt cottons in test plots by India's Central Institute for Cotton Research showed that, although the gene construct was the same, Bt effectiveness varied markedly among hybrids; expression was also highly seasonal and imperfectly matched to the seasonality of Indian bollworms (Kranthi et al. 2005).

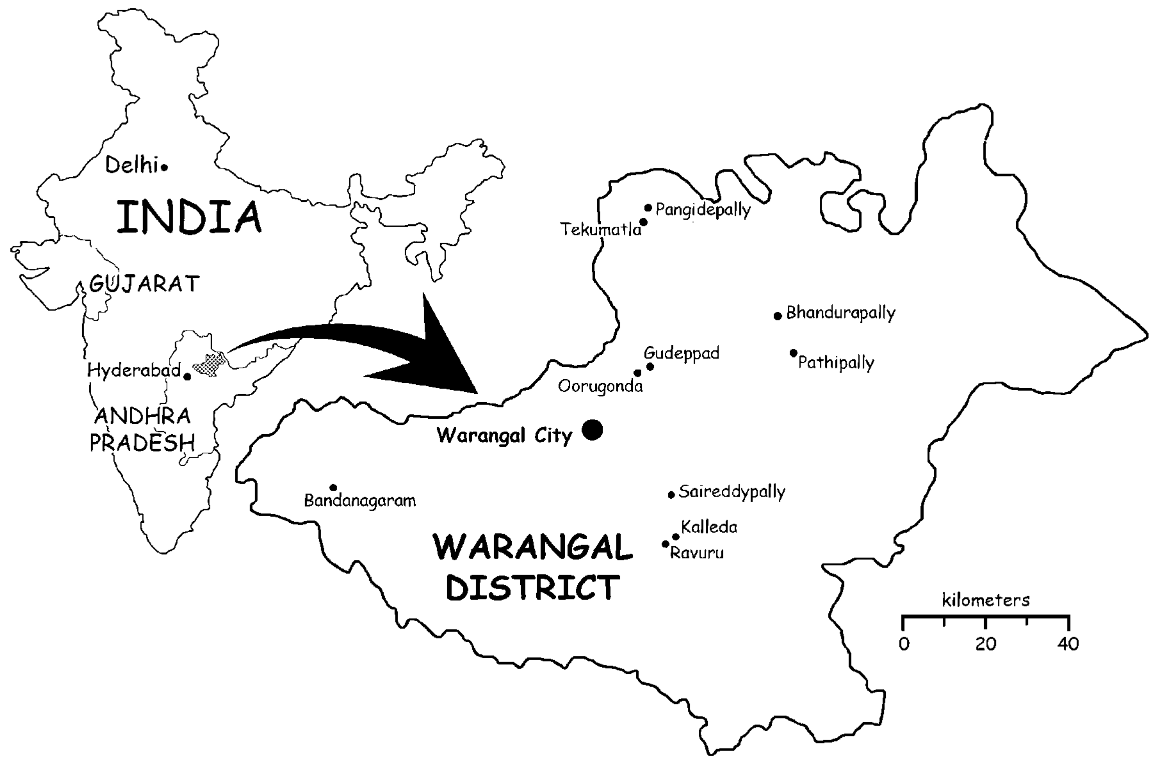

Figure 1. Warangal District, showing census villages.

because the pattern of adoption is highly inconsistent with theoretical predictions; for instance, the adoption curve looks nothing like the S-curve seen for agricultural (and other) innovations, and the highly diverse social environment in Warangal is hardly one in which theory predicts accelerated adoption to occur.

Monsanto, the purveyor of the genetic technology and also much of the public discourse surrounding it, attributes the spread to farmer knowledge and wisdom, alluding to classic models of experimentation and adoption. However, the results of a multiyear study of Warangal cotton cultivators show a very different context for the spread of Bt cotton. While these results indicate that adoption has been even greater than Monsanto has claimed, they also point to a completely different explanation for it—an explanation with surprising implications for our understanding of innovation diffusion and of the nature and fragility of indigenous knowledge systems. These data show that the 2005 Bt cotton craze fits into a strange and disquieting pattern of localized cotton fads; 2005 was really only different in that local fads were synchronized. Farmer experimentation and evaluation play a much smaller role in seed choices than innovation-diffusion theorists and seed companies have claimed; instead, the seed fads result from *agricultural deskilling*, in which farmers fail to experiment and evaluate because of the unpredictability of key variables in cotton cultivation. At present, Warangal farmers have more to teach us about the social nature of decision making in unpredictable and unstable environments than about the benefits of genetically modified crops.

Innovation-Diffusion Theory

Bt cotton is a classic example of an innovation, and the field of innovation-diffusion research, which has always centered on agricultural technologies (Rogers 2003), has much to say on the topic. Innovation-diffusion research was jump-started by Ryan and Gross's (1943) study of the adoption of hybrid maize in Iowa.[4] Their interpretation, which has shaped much research on innovation since, focused on how farmers evaluated the new seeds and acted on the evaluations. They showed the adoptions following the S-curve that results from plotting a normal curve distribution cumulatively. The S-

4. Hybrid crops, which are produced by crossing inbred lines, characteristically exhibit "hybrid vigor," which increases yield for a generation. Replanting second-generation hybrid seeds leads to genetic segregation and, in most cases, depression of yield. Since this obligates the farmer to purchase new seeds every year, it has provided the basis of the modern seed industry (Kloppenburg 2005).

Figure 2. Early adopters of Mahyco Bt cotton in Parvathagiri Mandal, Warangal District.

curve has since been shown in adoptions of antibiotics and various other innovations (Rogers 2003). Ryan and Gross identified stages in the farmer's adoption process, which (after some modification by later researchers) are initial knowledge (farmer learns of innovation), persuasion (farmer forms attitude toward innovation), decision (farmer evaluates innovation), implementation (farmer adopts innovation), and confirmation (farmers evaluates performance of innovation) (Rogers 2003, 168–218; see Ryan and Gross 1943 and Beal, Rogers, and Bohlen 1957 for different stage schemes). Their interest in characteristics of early versus late adopters led to a typology of innovators, early adopters, early majority, late majority, and laggards. Coleman, Katz, and Menzel's (1966) study of the adoption of tetracycline in the 1950s found striking parallels with Ryan and Gross's study, including the S-curve and some of the key traits of early versus late adopters.

Buried deep in the paradigm for innovation-diffusion research was the assumption that the "innovation" is somehow a better mousetrap: after all, hybrid corn gave greater yields, and tetracycline had fewer side effects. Such relative advantages were what was confirmed in the decision phase, either through conducting one's own trials or by accessing information on trials by others (Rogers 2003, 177). For farmers, the mainstay of this process was planting a small experimental plot. Farmers in the Iowa study planted a median of 30% of their total maize acreage to hybrid seed when they first tried it (Ryan and Gross 1943, 18). This assumption of relative advantage was reflected in the use of judgmental terms like "innovators" and "laggards," and subsequent research used blunter terms such as "winners" and "losers." Everett Rogers, the sociologist whose successive editions of *Diffusion of Innovations* (1962, 1983, 2003) encapsulate the history of the field, attributes some of this bias to funding sources; he asks how diffusion research might have been different if the maize study had been sponsored by a farmers' organization rather than by the Iowa Agricultural Experiment Station which developed the hybrid or if the drug study had been sponsored by the American Medical Association instead of Pfizer (Rogers 2003, 118).

From the beginning, innovation-diffusion research has also been overtly concerned with the social component of adoption. Social variables such as education and social connectivity were first used to explain how individuals sorted out into the adopter types rather than to explain whether particular innovations spread at all. Subsequent work has retained the emphasis on experimentation and assessments (in both industrialized and nonindustrialized agricultural systems [Chibnik 1981; Johnson 1972]) but has also reconsidered the assumption that adoption is ultimately driven by relative merit by recognizing social processes that override or replace empirical evaluations. Diffusion research now stresses *perceived* advantages of innovations, and it has documented numerous cases in which local cultural practices and beliefs exert control over which innovations are adopted. In some cases, medical innovations (such as water-boiling in disease-ridden villages) that were not only "better mousetraps" but potentially matters of life and death were rejected on cultural grounds (Rogers 2003). Comparative studies of contraceptive use in both Korea and Thailand showed that whole villages adopted one form of contraceptive even if it offered no particular advantage over methods used by other villages (Rogers and Kincaid 1981; Entwhistle et al. 1996). A more relevant recent example is the Perales, Benz, and Brush (2005) study of maize diversity in Chiapas, Mexico: neighboring Maya communities used distinct landraces of maize not for reasons of agronomic performance but because of the channeling of information within social networks. Various researchers have concluded that social system homogeneity is a major determinant of innovation diffusion (Rogers 2003; Perkins and Neumayer 2005), and new technologies have been shown to diffuse more slowly in countries with socially heterogeneous populations (Takada and Jain 1991; Dekimpe, Parker, and Sarvary 1998).

A separate stream of research, principally by anthropologists, has in recent years shed new light on social dynamics affecting innovation adoption. Cultural evolutionary theorists working in the tradition of Boyd and Richerson's (1985) *Culture and the Evolutionary Process* make a fundamental distinction between environmental (or individual) learning, which is based on individual evaluations of payoffs from various practices, and social learning, in which adoption decisions are based on teaching or imitation (Boyd and Richerson 1985 40; Henrich 2001).[5] Henrich argues that the predominant force in behavioral change is the biases that characterize social learning. One of these is prestige bias, in which a farmer emulates another on the basis of prestige, regardless of that farmer's actual success with the trait being copied. Another is conformist bias, in which a farmer adopts a practice when (and because) it has been adopted by many others.[6] Writers in this tradition have given much attention to the conditions under which behavioral change should be driven by environmental versus social learning. In general, reliance on "pure social learning" should be high when environmental learning is costly and/or inaccurate (Richerson and Boyd 2005, 13–14; McElreath 2004). Social learning may lead to the spread of maladaptive beliefs (Richerson and Boyd 2005, 166), especially when the environment changes very rapidly (p. 118).

This distinction between environmental and social learning is useful in building a formal body of theory, but from an ethnographic standpoint it is contrived because the two forms of learning contribute to each other to varying degrees. Even a direct environmental observation made on one's own crop ("Brahma cotton yielded 6 quintals/acre for me last year") is likely to be interpreted or contextualized through a form of social learning ("which was much more than my neighbor said he got with the same seed"). Even a classic case of conformist adoption ("I am planting Brahma because my neighbors are") assumes at least an indirect environmental basis ("and they wouldn't all be planting it unless someone had an indication it would do well"). This variation in the realm of social learning in crucial. It is not social learning per se that may spread maladaptive beliefs and practices (Richerson and Boyd 2005, 166) but social learning with relatively little grounding in environmental learning. When the flow of environmental payoff information is disrupted or rendered inaccurate or expensive, social learning may run largely on transmission biases and other factors weakly connected to payoff evaluations.

Agricultural Skilling and Deskilling

Producers of Bt cotton have been quick to attribute its adoption to farmer wisdom based purely on environmental learning. Monsanto cites small-plot experimentation, consistent results, and the development of "faith in the seed" (BBC 2005); the biotech industry's public relations consortium explains the Indian adoptions as a response to doubling in yield gains (CBI 2005). Pro-industry agricultural leaders such as P. Chengal Reddy insist that "we should leave the choice of selecting modern agricultural technologies to the wisdom of Indian farmers" (Pinstrup-Anderson and Schioler 2001, 108). Government officials such as the Andhra Pradesh agriculture minister stress the need to "let the farmers finally decide on

5. This is a brief distillation of a large and nuanced body of theory that is principally concerned with longer-term phenomena or "stable behavioral dispositions" (Boyd and Richerson 1985, 40). What I am summarizing as "environmental (individual) learning" is a sketch of what Boyd and Richerson (pp. 95–97) call "guided variation" and Henrich (2001) calls "the environmental learning model." This usage of "social learning" differs from that in agricultural development circles, where it often refers to group training like that offered in farmer field schools (Tripp, Wijeratne, and Piyadasa 2005; Tripp 2006, 39).

6. Henrich (2001) shows that that adoptions based purely on environmental learning produce not S-curves but R-curves, which are less common in reality. What does produce S-curves, according to Henrich, is environmental learning combined with biased (especially conformist) transmission. This concept of conformity differs from the innovation-diffusion theorists' parallel concept of critical mass, which refers to the point at which further diffusion is self-sustaining. Critical mass is based on actual payoffs for adoption, and it mainly applies to interactive technologies like phones and faxes, in which the value increases as more people adopt them. In contrast, conformist bias is identified by evolutionary theorists as a purely social phenomenon

the usefulness of Bt cotton. Farmers are wise enough to adopt anything good and discard things that do not work" (Venkateswarlu 2002).

These perspectives may ignore the social aspects of agricultural decision making, but Indian newspapers do not, often taking a dim view of it in articles such as "Farmers Turn to Other Farmers" (*Deccan Chronicle*, July 4, 2005) and "Farmers Ape Neighbors, Pay Price" (*Deccan Chronicle*, June 6, 2003). Indian seed companies also are well aware of the social component of adoption and go to lengths to manipulate it even as their public rhetoric dismisses it. For instance, companies often donate seeds to selected farmers for demonstration plots; the seed is typically new and the farmer always a *pedda rytu (*pl. *rytulu)* —literally "big farmer" in Telugu but connoting opinion leaders who tend to be emulated. The company may then bus in farmers to inspect the field, enticing them with a spread of food.

Demonstration plots may have real impact on seed adoption. Viewing these plots would seem to be a clear case of environmental learning, since farmers actually see the crop growing, but this is not well sustained in interviews. Asked about influences on their cotton seed choices, farmers routinely recall other farmers who grew the seed (especially *pedda rytulu*) but rarely recall agronomic details beyond the ubiquitous and generic phase *manci digubatu*, "good yield." This is not simply a local discourse on crops that centers on general performance rather than agronomic specifics: there are reasons that farmers really do tend to be surprisingly ignorant of crop traits. The demonstration value of a cotton field is diminished by the enormous local variation in pest outbreaks and access to irrigation which override subtle differences attributable to seed traits; a seed may give very different yields even within one village area. Thus, in their approach to crop observation, farmers straddle the categories of environmental and social learning; if observations were true environmental learning, farmers would be engaged in empirical evaluation, and it would not matter who the planter was. Yet demonstrations are virtually always on *pedda rytu* farms, and farmer interviews show that they were swayed by who was growing the seed more than by assessment of the crop.

This reduced role of environmental learning may seem discordant with the accumulated wisdom in anthropology extolling indigenous technical knowledge that results from environmental learning. This tradition may be traced from Conklin's (1954) seminal study of Hanunóo cultivators to a wide literature since (e.g., Brokensha, Warpen, and Werver 1980; Richards 1985; Brosius, Lovelace, and Marten 1989; Chambers, Pacey, and Thrupp 1989; Hobart 1993; Brush 1993, 2005; Scoones and Thompson 1994; DeWalt 1994; Warren, Slikkerveer, and Brokensha 1995; Brush and Stabinsky 1995; Sillitoe 1998; Ellen, Perkes, and Bicker 2000). Some research has moved well beyond indigenous classification and knowledge of static details of plants and agronomic processes to analyze relationships between knowledge and practice (Soleri and Cleveland 2001, 108) and the response of farmers to various scenarios (Soleri and Cleveland 2005; see also Ingold's [2000, 2001] exploration of knowledge as skill). A key conceptual contribution was Richards's account of the farmer's need to execute a "performance" based on agronomic knowledge, prediction of a range of factors, and manipulation of socially mediated resources (Richards 1989, 1993). This conceptualization of agricultural practice goes beyond individual technologies and stratagems to consider how these fit together into a system. Numerous studies have highlighted the systemic nature of agricultural practice and the often intricate fit between agroecology and a range of cultural systems (e.g., Lansing 1993; Stone, Netting, and Stone 1990). Therefore we must think not of farmers simply acquiring information on a seed or other technology but of farmers developing the ability to perform with a technology under variable conditions; this will serve as a definition of agricultural skilling (Stone 2004). Skilling obviously must incorporate environmental learning, but it is a highly social process as well.

Yet as adaptive as this environmental-social skilling process may be, it is susceptible to obstruction. If an ethnography of agricultural performance skills is important (Richards 1993, 62), so too is an ethnography of the degradation of the skilling process. What research exists on such degradation has tied it to specific agricultural technologies such as hybrid seeds and pesticide sprays. In her history of maize breeding in the United States, Fitzgerald (1993) argued that adoption of hybrids led to "deskilling" of American farmers, turning farmers into passive customers of seed firms. Within a few years of the spread of hybrid corn, farmers who had previously been developing landraces and collaborating with public-sector breeders were told, "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). With her claim of deskilling, Fitzgerald invoked a process described in Braverman's (1974) *Labour and Monopoly Capital*, in which capitalism was constantly degrading the role of laborers by separating mental from manual work. (Adam Smith and Karl Marx described the same process, albeit in somewhat different terminology [Marglin 1996, 194–95]). To Braverman, the crux of deskilling was the replacement of skilled workers, who were more expensive and less controllable, by machines and less-skilled workers. Fitzgerald did not probe the nature of agricultural deskilling thoroughly, noting mainly that it lacked the "malice" inherent in the industrial process. Synthetic pesticides have also been blamed for deskilling farmers. Vandeman (1995) has argued that pesticides commodify farm pest management in a destructive and self-perpetuating cycle: the less farmers know about insect ecology, the more insecticide they use (Vandeman 1995; also Thrupp 1990 and Pems, Waibel, and Gutierrez 2005), producing intractable problems of environmental contamination and pesticide resistance.

These technology-specific cases show vulnerabilities of environmental learning, but what they describe is hardly the same as mechanization and compartmentalization on the factory floor; Braverman's deskilling serves more as a metaphor than as a theoretical model of technology-induced changes in agricultural production. Expanding an analysis begun in a previous study (Stone 2004), I would argue that agricultural deskilling differs from Braverman's process in three key respects. First, agricultural practice is much more dynamic than factory work. Farming constantly changes in response to population density, market signals, the arrival of new crops, tools, or neighbors, pests and diseases, government policies, and even new ideas. Therefore farming does not consist of mechanical application of knowledge or the making of binary decisions (e.g., adopt versus don't adopt); if it is a performance, then the role of each technology in the performance must constantly be in play. Therefore agricultural deskilling is not the displacement of a static set of skills but rather *the disruption of an ongoing process of skilling.*

Second, agricultural skilling is a hybrid process involving both environmental and social learning, in which farmers observe, discuss, and often participate in each other's operations. When technology passes between farmers, information normally does too (Brush 1993, 1997; Richards 1989; Sillitoe 2000; Cleveland and Soleri 2002). The presence of neighboring farms increases the amount of payoff information available, and neighboring farmers normally participate in the process of interpreting it. Agroecological skill may become embedded in cultural concepts (Brodt 2001; Thrupp 1989) and even in institutions that individuals may not fully understand (Lansing 1993; Netting 1974). Pálsson [1994] makes the same point regarding "enskilment" of sailors, which is a necessarily collective enterprise involving whole persons, social relations, and communities of practice. More generally, Baltes and Staudinger [2000, 127] argue that "wisdom is fundamentally a cultural and collective product in which individuals participate. Individuals are only some of the carriers and outcomes of wisdom.") Factory workers may learn some aspects of their jobs from fellow workers, but this plays a much smaller role in their training, and they are not responsible for overall production strategy as the farmer is. Agricultural deskilling is *the disruption of the balance between social and environmental learning that is instrumental in farm production.*

Finally, in contrast to industrial workers, farmers still need the skill that is degraded. That slaughterhouse workers do not know a sirloin from a filet or that McDonald's staff lacks culinary skills is no problem: the process of turning an animal into discrete food products has been compartmentalized and the process of cooking fries automated so that workers have no use for the displaced skills. In contrast, farmers still have to make decisions about the use of technologies even if they have not been able properly to "skill on" them. There is a crucial difference between an industrial situation in which skill has no place and an agricultural situation in which skill is needed but cannot be acquired. Agricultural deskilling is not simply the automation of farm tasks; it is *the degradation of the farmer's ability to perform* or, as Parthasarathy (2002) put it, the ability and freedom to innovate.

Thus, the fast-food and slaughterhouse workers who are such notable contemporary examples of industrial deskilling (Schlosser 2001) are poor models for agricultural deskilling. A better metaphor would be a chef whose job is to continuously develop new dishes in a kitchen where someone keeps changing the labels on the ingredients and the stove will not hold a constant temperature.

A range of factors may contribute to agricultural deskilling, the common denominator being the raising of the cost and the inaccuracy of environmental learning. I have identified three such factors (Stone 2004; also Bentley 1989, 1993). The first is inconsistency of a technology's effects. Seeds and other technologies may have qualities that become apparent only over time or under special circumstances (Tripp 2001*a*). 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 an example, as their effects can vary from year to year in their impacts on target and predator species, leading to insecticide resistance and chaotic fluctuations in insect populations (Brogdon and McAllister 1998). The second is unrecognizability of a technology. An even more fundamental problem than inconsistency is farmers' being unsure of what is being planted. The problem often worsens as marketed seed replaces replanted seed, but it is not a problem exclusive to marketed seed; farmers have encountered "identity confusion" with the second generation of replantable modern varieties (Tripp 2001*b*). 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 impedes skilling. The third impediment to agricultural skilling is an accelerated rate of introduced technological change. Skilling takes time. Even if a technology avoids the other impediments to skilling—being unambiguously recognizable at the time of acquisition and displaying reasonable consistency—the skilling process may fail to keep up with rapid technological change. This is not to endorse a romanticized view of unchanging "traditional" farming; traditional agriculture changes all the time (Stone 2004). The issue here is whether the change occurs too rapidly to accommodate the social-environmental process of skilling.[7]

7. Skeptics of the value of genetically modified organisms for Third World farmers have been accused of advocating a museum-like preservation of indigenous practices. The same false choice arose in the planning stages of the Green Revolution, which led the Rockefeller Foundation to ignore the 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."

This is an essential background for understanding the rapid adoption of Bt cotton. I will first examine the characteristics of the cotton seed system that induce deskilling and then turn to an empirical study of the cotton fads that deskilling produces.

Warangal Cotton and Agricultural Deskilling

Cotton has a long history on the subcontinent; the two *Gossypium* species—*arboreum*, which was domesticated here, and *herbaceaum*, developed elsewhere but present here for a long time—provided the basis for a textiles trade that led the world for centuries (Prasad 1990). Production of hybrids based on the New World species *G. hirsutum* began in the 1970s, the labor-intensive production process capitalizing on cheap field labor (often by children). Today India is the only area in the world where cotton production is based on hybrids, and Warangal farmers plant commercial hybrid cottons almost exclusively.[8] Hybrid cultivation spread throughout Warangal District in the early 1990s, when the combination of strong prices, trade liberalization, and government campaigns led many farmers to take up cotton as a cash crop.

Andhra immigrants from coastal areas with a strong tradition of cash cropping led the way into commercial cotton cultivation. These immigrants are a small, prosperous, and generally well-educated minority in Warangal. The indigenous majority had a history of small-scale cultivation of open-pollinated (i.e., nonhybrid) indigenous cottons, grown without external inputs and with scant pest problems and used mainly for local cloth production. Their shallow history of skilling on hybrid cotton surely plays some role in the problems described below, yet it is easy to overestimate its importance. Depth of experience with a crop is hardly an overriding determinant of the skilling process, and the literature abounds in cases of successful adoption and integration of new crops. The Nigerian Kofyar provide an example, expertly integrating a major yam component into a complicated cultivation regime as they moved into a new area from a homeland where they had grown no yams at all (Stone, Netting, and Stone 1990; Stone 1996). It is not so much the relative newness of commercial *hirsutum* cotton cultivation as the nature of the seed market that has impacted the skilling process.

In Warangal, the market offers not only hybrids that must be repurchased each season but an extensive, rapidly changing, and sometimes deceptive roster of seeds. There are over 800 input shops in the district, including at least one in virtually every village of any size. Warangal City has around 190 shops, including several dozen concentrated around Station Road (fig. 3). A 2005 survey of 37 input vendors in Warangal City gives a snapshot of the market for 2003–5.[9] These vendors collectively sold 125 different cotton brands from 61 companies during this three-year period; the total number of cotton brands sold during this period was over 200. The number available at any given time was smaller, since seed products come and go rapidly. Of the 78 seeds sold by our sample vendors in 2005, only 24 had been around since 2003.

Farmers must also deal with several levels of deceptiveness in seed products. On the one hand, there is often variation among packs of a single seed product. Causes of variation range from lax controls over the hybrid production to the corrupt practice of packaging different seeds as a single brand. Every year brings new cases of severely flawed seeds on the market. Flawed or mislabeled products, known as "spurious seed," are a bane not just for farmers but for vendors, who have on occasion been closed down for selling a seed that turned out to be spurious. On the other hand, the seeds sold under different brand names may be identical: it is widely known that cotton parent lines have been appropriated from state agricultural universities and research institutes by cotton seed companies, which then market the hybrid offspring under different names. For instance, Bunny cotton (a recent local favorite in several towns) is identical to four other seeds on the market, according to a local cotton expert. (Ziegenhorn [2000] gives a parallel account of the systemic deception in the American maize market.) Seeds that have lost their popularity are sometimes brought back to the market under a different name to capitalize on farmers' penchant for new products. Government seed inspection is largely ineffective. In Warangal City, a single inspector visits fewer than half of the seed vendors, taking a few samples which are then tested for physical purity and germination rate but not for whether the seed is what the box claims. When substandard seed is found, the dealer (not the seed company) is assessed a minuscule fine.

There are numerous seed traits that differ and should be assessed in the skilling process, but the "anarcho-capitalism" (Herring 2006*a*) of this cotton seed sector, with its large, unstable, and deceptive array of seeds, is clearly incompatible with the processes of experimentation and evaluation. Primary variables are boll size, time to maturity, flowering period, and irrigation requirements/response; other variables in-

8. Public-sector breeders produce very little cotton. In Andhra Pradesh they have released one open-pollinated (i.e., nonhybrid) variety called Narsimha and have persuaded a tiny percentage of the farmers to grow it.

9. The survey of Warangal input vendors was conducted in June 2005. Since no complete list of vendors is available, we developed a list by reconnaissance of the Station Road area, adding any others that appeared in interviews with farmers, vendors, or officials. Thirty-seven shops provided cotton data for 2003–5: 5 were new and so provided data only for 2005, 18 provided data for 2004–5 (some had opened only in 2004, and others would not or could not provide accurate data for 2003), and 14 provided data for 2003–5. Therefore the data cannot be used to compare overall sales but should provide a fair reflection of market shares by product. Sometimes one vendor is the sole or primary purveyor of a brand, and if the survey missed such vendors it could leave a gap in the analysis; however, on the basis of numerous interviews with vendors, I do not believe any major brands were missed in this way.

Figure 3. Station Road in Warangal City, a concentration of several dozen shops selling seeds, fertilizer, and pesticide (*left*), and (*right*) Station Road vendor with a pack of Mahyco Bt cotton and some of his other cotton seeds.

clude number of bolls per plant, plant configuration (water-intensive plants may be bushy, which makes spraying more difficult), insect/disease resistance, and average germination rate. Output traits include staple length and quality. A thorough product evaluation would also consider characteristics of the seed company, including location, size, age and reputation, diversity of offerings, commitment to customer service, and guarantee policy (some companies have signed a "memorandum of understanding" promising to recompense farmers who can show that their seed failed because of seed flaws). To this list of variables we must now add expression of Bt proteins, which varies markedly among approved brands (Kranthi et al. 2005) and certainly among the rapidly spreading illicit Bt seeds described below.

But even if farmers were to try to skill on these variables in such a volatile seed market, there are other unpredictable factors with the power to override such fine considerations. Paramount among these are the frequent but erratic insect outbreaks, which vary in location, severity, timing, and response to pesticides. The localized nature of outbreaks often confounds farmers' ability to compare crops. Pest populations also exhibit longitudinal changes such as the spread of pesticide resistance and shifts in life cycle. (Data collected by the Warangal Agricultural Research Station show that outbreaks of a leading cotton pest, *Helicoverpa ameriga* or American bollworm, have in recent years moved from October to August.[10] With the rapid spread of Bt cotton, which, as Kranthi et al. [2005] have shown, begins to lose its insecticidal characteristics after 100 days [for Warangal, in September], it seems likely that the outbreaks will eventually shift back to the later time.) Pesticides too may be spurious or adulterated. Vagaries of rainfall and dependability of irrigation sources can easily have much greater effects on yield than the relatively minor differences in the recommended water requirements of different seeds.

External sources of seed information, rather than mitigating these multiple impediments to skilling, exacerbate the problem. Government-sponsored agricultural extension programs are virtually nonexistent. Local Telugu-language publications provide agricultural information, but its reliability varies, and advertisements are often presented in the form of objective information.[11] The most common external source of information on cotton seed is corporate promotion. Cotton seed

10. I am grateful to Jalapathi Rao for providing these unpublished data.

11. Newspapers may also magnify seed scandals to boost readership. One local agricultural scientist cited a recent case of a cotton seed company that got into a dispute with a local daily. Despite the lack of evidence of any problems with its seeds, there were enough damning articles published to put it out of business.

advertising is seemingly ubiquitous in Warangal: signs hang from trees, walls are painted, flyers are distributed, and pitches blare from company vehicles (fig. 4). Only cotton is so heavily promoted; rice seed, which is selected more on the basis of environmental learning and is overwhelmingly nonhybrid, is rarely advertised. Assessing the impact of advertising on seed choice is beyond the scope of this article, but it is likely that the ubiquity of low-credibility noise contributes to farmers' general indifference to analysis of seed performance.

The plight of Warangal cotton cultivators, then, goes well beyond Fitzgerald's (1993) description of the deskilling caused by adoption of hybrid maize. They face a frenzied turnover in the seed market (which they encourage with their penchant for new products), deceptiveness in seed brands, unpredictable ecological events such as pest and disease outbreaks, secular changes in insect ecology, and a noisy and unreliable information environment. These factors make seed evaluation costly and inaccurate and suggest that environmental learning should be scant. Viewing the dynamics of cotton decision making (and especially seed choice) in Warangal therefore becomes as important to theory as it is to the topical question of why genetically modified crops have spread so quickly.

Cotton Fads

My analysis of seed choice is based on three household agricultural censuses conducted between 2003 and 2005.[12] Information on agricultural decision making also came from 24 in-depth interviews with a range of farmers covering knowledge, skill, and decision-making criteria and participant-observation in Warangal and Hyderabad over eight periods of fieldwork amounting to approximately 45 weeks between 2000 and 2006. Table 1 shows the villages studied and the numbers of cotton-planting households represented in these surveys (actual sample sizes were considerably larger; for example, 26% of the households censused in 2004 planted no cotton that year). The 2003 and 2004 surveys elicited detailed household social and economic information along with information on agricultural decision making; the 2005 survey was more focused on agricultural decision-making and seed choice. Surveys were conducted mostly between July and October, allowing for the collection of seed choice data for the census year and the preceding year but input-output information only for the preceding year. Census takers were natives of the area, and most were college graduates in agricultural economics. In the following analysis, data on the 2002 seed choices and yields come from the 2003 census and data on the 2003 seed choices and yields from the 2004 census. Data on the 2004 seed choices come from both the 2004 and 2005 censuses (only the nonrepeat interviews added in 2005).

12. All censuses were designed, tested, and administered in collaboration with the economist A. Sudarshan Reddy of the Centre for Environmental Studies, Hanamkonda (formerly of CKM College, Hanamkonda). The 2003 census also benefited from input by Robert Tripp of Overseas Development Institute, London.

Table 1. Village Summary, Cotton-Planting Households Only

	Households Surveyed by Crop Year			
Village	2002	2003	2004	2005
Bhandarupally	–	–	38	38
Gudeppad	62	150	90	68
Kalleda	41	37	34	27
Oorugonda	–	–	58	62
Pangidepally	–	–	66	68
Pathipally	–	71	81	54
Ravuru	44	31	63	71
Saireddipally	19	31	80	66
Tekumatla	–	89	81	67
Total	147	409	591	521

Data on 2005 seed choices come from the 2005 census. (Further information on the criteria for village selection appears in the appendix.)

Sampling frames were derived from the government's 1996 Multi-Purpose Household Survey, which lists all households in the district along with socioeconomic variables including land ownership. Stratified random samples were drawn in each village to ensure representation of farmers differing in wealth and connectedness to information networks. From ethnography it seemed clear that larger landowners tended to be more "cosmopolitan" (to use the term from classic innovation-diffusion studies) and better connected to nonlocal information sources, and this was confirmed by the census.[13] As research was initiated in each village, households were ranked on land ownership and divided into terciles (landless households were excluded because they rarely plant cotton). Terciles were randomized and sampled equally. For subsequent-year censuses, farmers were recensused when possible, and other households were added using the same randomizing strategy. (For further information on sampling procedures, see the appendix.) The survey was designed to reveal variation in agricultural decision making across space and time and to collect data on social organizational, spatial organizational, economic, educational, and ethnic effects on this variation (only a small portion of which appears in this analysis). It was not explicitly designed to allow characterization of Warangal District, and several distinctive sectors of the district were not studied.

The household censuses recorded seed choices, defined as a farmer's purchase of a particular type of seed, whether it

13. The 2004 census collected information on acreage owned, which corresponded moderately well to acreages reported in the Multi-Purpose Household Survey. It also contained four variables reflecting the farmer's connectedness to information networks: radio listening, newspaper reading, TV watching, and watching the agricultural-extension TV program *Annadata* were rated on a scale of never-sometimes-frequently. These were combined in a connectedness score (low-medium-high), which shows a clear correlation with land ownership. An analysis of the extent to which access to external information sources affects participation in cotton fads is beyond the scope of this article.

Figure 4. Cotton ads. *From top left*, large cotton advertisement painted on the side of a building, cotton advertisement painted on a pillar, cotton signs in a tree, and cotton seed marketer distributing flyers on Station Road.

was one box or more and whether or not it was the only seed type the farmer bought that year. The numbers of seed choices tend to be higher than the numbers of cotton-planting households because many households plant more than one seed. In the following analysis, the seed choices are expressed as percentages,[14] and the top choices are plotted for the years for which data are available.

Figure 5, *top*, shows the top-selling seeds in the sample villages combined, based on the seed-choice data. The highlight is the precipitous rise of one seed: Rasi Seed's RCH-2-Bt. The first Bt cottons marketed in Warangal were not particularly popular, not simply because of the Bt trait but because it had been put into unpopular Mahyco hybrids. RCH-2 (a seed that, according to open secret, was produced from parent lines appropriated from a state-run research center) was a fairly popular hybrid in many parts of the district. The Bt version appeared on the market in 2004, and in 2005 it achieved sudden wild popularity in much of the district, accounting for 45% of the 777 seed choices in the sample—particularly striking because the Bt seeds cost Rs. 1600 ($38) per acre-pack, compared with around Rs. 400 for other hybrids. When the other Bt seeds are included, Bt seeds account for 54% of all seed choices. Figure 5, *bottom*, shows that the take-off of RCHZ-Bt reported by the sampled farmers is mirrored in the seed-vendor survey.

What is particularly interesting is the striking local variations in adoption patterns. Figure 6 shows village-specific patterns in seed choices. Almost all villages show the sharp climb in RCH-2-Bt adoptions, but a closer inspection shows a pattern of abrupt and ephemeral seed fads preceding the Bt fad. In Gudeppad, for instance, Brahma and Ganesh were strong local favorites in 2003 but had virtually disappeared by 2005; Chitra went from being negligible to town favorite (in 2004) and back to negligible. In Kalleda, Brahma was a

14. This is similar to market share but differs in not allowing for farmers' buying more than one box.

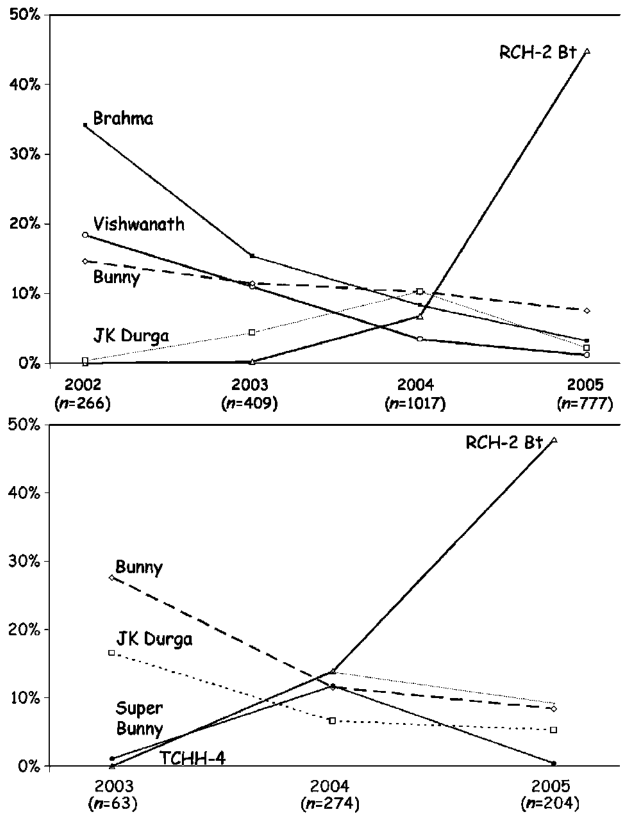

Figure 5. Trends for the five most popular cotton seeds. *Top*, seed choices as reported in farmer surveys; *bottom*, percentage of total sales reported in survey of seed vendors in Warangal City.

runaway favorite in 2003 before dropping sharply as Gemini became the town favorite for a year. In Ravuru, Brahma was by far the favorite in 2002 but had dropped to virtually nil by 2005; Bunny, the strong favorite in 2004, lost its popularity to Vikas in 2005. In Tekumatla, the 2003 favorite, Dassera, dropped precipitously in 2004, when JK Durga rose to almost 40% of cotton choices before crashing to 4%. In Pathipally there was a steady market for Brahma and Bunny, but it also had a fad, with Dyna rising to town favorite in 2004 before dropping to almost nil.

Moreover, the fads tended to be highly localized, with the notable exception of RCH-2-Bt. As figure 6 shows, Kalleda and neighboring Ravuru shared the Brahma and Bunny fads, but Kalleda's 2004 Gemini fad did not touch Ravuru. Chitra was the top seed in Gudeppad in 2004 but negligible in neighboring Oorugonda. JK Durga, the runaway favorite in Tekumatla in 2004, was also the top seller in neighboring Pangidepally, but Pangidepally's other 2004 favorites—Mahalaxmi, Sudarshan, and Bunny—were negligible in Tekumatla. Pathipally's 2004 favorite, Dyna, was negligible in neighboring Bhandurapally in 2004 (although Tulasi was popular in both villages).

The agricultural economist Matin Qaim got a different glimpse of this cotton faddism in his survey of 375 Indian cotton growers. He found that after the 2002 season, more than half the farmers who had adopted Bt cotton abandoned it. Then "interestingly, a remarkable share of the disadopters re-adopted Bt technology after a break of one or two years" (2005, 1321). To Qaim, these patterns "clearly demonstrate that genetically modified crop adoption and disadoption are not irreversible decisions for farmers; they are part of a normal learning process." However, as argued above, "normal" learning (skilling) is an environmental-social process, and it is difficult to imagine what environmental assessments would lead farmers to such short-term, localized cotton seed fads. None of the seed vendors interviewed were aware of any agroecological rationale, and the farmers too were consistently unable to justify the seed fads on the basis of seed traits. The paired villages in each case have the same soils, microclimate, and access to input markets.

There are some conditions under which abrupt adoption of new seeds may have a definite agroecological basis. For instance, disease is a major problem for pearl millet growers, and Rajasthani farmers adopt each new disease-resistant seed variety quickly (Tripp and Pal 2000; Robert Tripp, personal communication). The faddism contributes to the chronic cycle of breeders' adjusting plants to pathogens and pathogens' adjusting to plants, but farmer decision making is responding to agronomic problems and has a basis in environmental learning. No such agroecological advantage, and certainly none that would explain neighboring villages' exhibiting such different patterns, is evident in the Warangal seed fads. The growers themselves offer no agroecological justification for the faddism. In fact, not one of the 12 Gemini planters I interviewed in Kalleda attributed the adoption of Gemini to specific traits (beyond the ubiquitous anticipation of "good yield"), and none knew much about Gemini's specifications. Only 2 mentioned firsthand knowledge of Gemini's performance (both had seen a field of Gemini the year before). Indeed, the farmers were generally agnostic on qualities of the seeds (the only specific trait that farmers regularly evaluate in cotton being boll size).

This situation stands in marked contrast to various studies showing rational and often highly strategic seed selection practices when farmers know what they are planting and technological change is more limited and/or gradual. For instance, despite some breeders' complaint that farmers ignore the benefits of improved maize varieties, adoption studies often show farmers making astute comparisons of crop performance through time (e.g., Perales, Brush, and Qualset 1998; Soleri and Cleveland 2001, 109). Excellent examples of farmers' assessment of the ecological aspects of proposed seed changes are provided by Barlett (1982, 70) for maize farmers in Costa Rica and by Richards (1997) for rice farmers in Sierra Leone. (I have no control case of skilled cotton seed selection in Andhra Pradesh because the impediments described above have been present for many years and no detailed studies of the dynamics of cotton seed selection were conducted be-

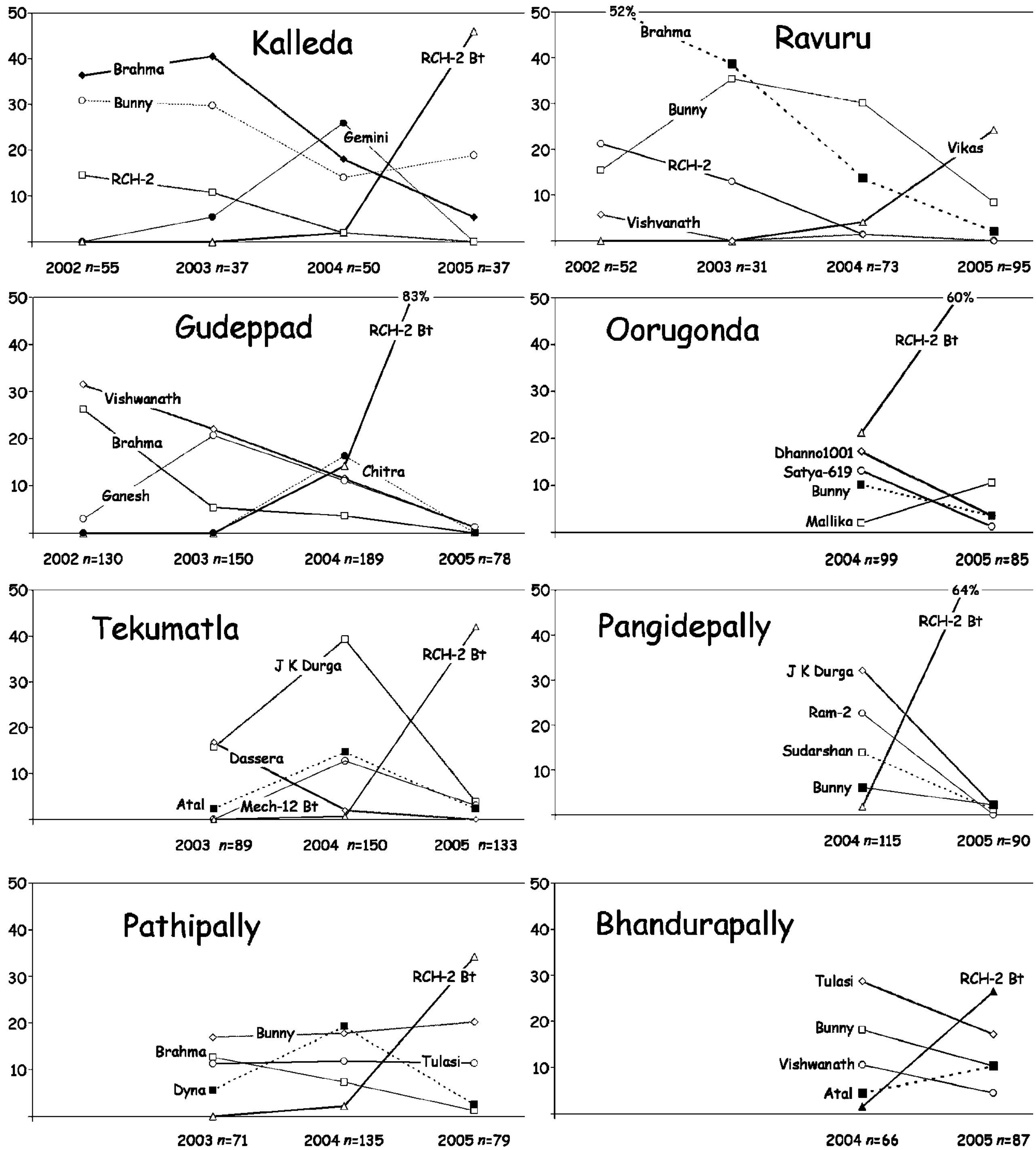

Figure 6. Village trends for the five most popular cotton seeds in each village. The *y*-axis shows the percentage of the village's yearly seed choices accounted for by each seed. The paired graphs are neighboring villages.

forehand. However, interviews with elderly Warangal farmers provide an inkling of prehybrid cotton cultivation: a handful of indigenous *desi* cotton varieties were generally replanted and often grown in intercrops with pigeon pea and other pulses without the use of pesticides.)

One village that has been less faddish in seed choices is Saireddipally, which is also anomalous in being a "settler" community populated mainly by immigrants from the Andhra coast. This, as we have seen, was the group that had led the way into commercial cultivation of cotton (and chillies and maize as well), and it has a higher level of education and connectedness than any of the other sample villages. This village participated in the 2005 district-wide RCH-2-Bt fad, but otherwise its top seed choices show more gradual change (fig. 7). This was also one of the first villages to adopt Bt cotton on a significant scale soon after its release; this fits innovation-diffusion orthodoxy but adds the twist of being a village-specific pattern. Given the village's higher level of education and connectedness and its low degree of cotton faddism, it stands to reason that more environmental learning is taking place in this village. Indeed, table 2 shows that Saireddipally farmers are somewhat more likely than others to use small experimental plantings.

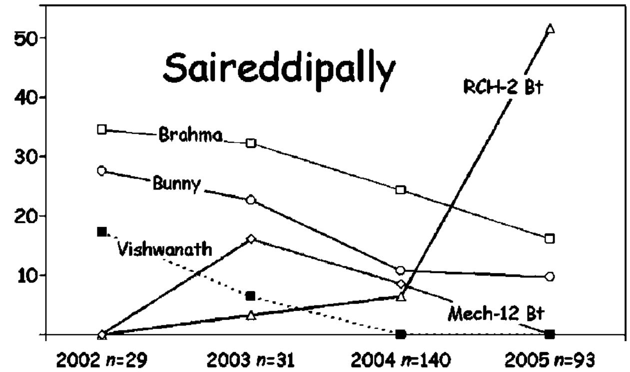

Figure 7. Trends for Saireddipally.

Novice and Experimental Planting

Small-scale experimentation and evaluation are often used by Indian farmers as a basis for seed selection (e.g., Gupta 1998, 197), but the Warangal seed fads seem irreconcilable with this practice. We can investigate this empirically by isolating cases of "novice planting"—defined as the planting of a type of seed brand for the first time. I have used data on 2003 plantings for this, avoiding the spread of new Bt seeds, which would have caused unusually high rates of novice plantings in 2004–5. In 2003, among cotton-planting households a median of 2 acres were planted to cotton (mean = 2.86; s.d. = 1.97; $n = 231$). Within this sample of households, 55% planted one seed type, 26% planted two, and 19% planted three or more, for a total of 410 seed choices. Of these seed choices, 59.3% were novice.

But are these novice cotton plantings actually tests of new seeds on small plots, as claimed by innovation-diffusion orthodoxy and by Monsanto? In contrast to the farmers in the classic Iowa study, who initially planted 30% of their maize acreage in hybrid maize, in 2003 the median percentage of acreage in novice plantings in Warangal was 100%. Table 2 gives a finer breakdown of cotton acreage percentages given to novice plantings. (There is a small spike in the distribution at 50% because the median area planted to cotton in this sample is two acres and commercial cotton seed is sold in "acre packs" with enough to seed one acre; less than 1% of the cotton purchased in my surveys consisted of "loose seed." This packaging makes experimentation slightly inconvenient but hardly prevents it; farmers can split packs to plant subacre plots.) Of particular note is that when farmers plant seeds for the first time, the new seeds take up 100% of their cotton 70% of the time and 50% or less less than 15% of the time.

What this analysis does not tell us is how decision making differs among large versus small farmers. A general expectation in innovation-diffusion theory is that inclination to adopt innovations increases with the farmer's socioeconomic status, including farm size (Rogers 2003, 288). A refinement on this general pattern, argued by Frank Cancian (1967, 1980), is that farmers in the upper-middle levels of the socioeconomic spectrum are unusually conservative, an anomaly called the "Can-

Table 2. Novice Percentages, 2003

	Acres Planted						
Percent Novice	Gudeppad ($n = 52$)	Kalleda ($n = 13$)	Pathipally ($n = 23$)	Ravuru ($n = 18$)	Saireddipally ($n = 14$)	Tekumatla ($n = 31$)	Total ($n = 151$)
<50	13.5	0.0	4.3	0.0	21.4	0.0	7.3
50	7.7	15.4	8.7	0.0	7.1	6.5	7.3
51–99	25.0	0.0	8.7	0.0	14.3	19.4	15.2
100	53.8	84.6	78.3	100.0	57.1	74.2	70.2
100	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Note: The 151 cases shown here are households that had any novice cotton planting (planted a seed for the first time) in 2003.

cian dip" in an otherwise linear relationship between wealth and rapidity of innovation adoption. For figure 8, farms were classified by the total acreage of all crops planted in 2003 to show how novice versus more experienced plantings break down by farm size.[15] There is indeed a general tendency for larger farmers to conduct more novice plantings. (However, in an inversion of the Cancian dip, farmers in the second-largest category are the most enthusiastic novice planters.)

Interviews provided consistent evidence that Warangal cotton farmers' propensity is for trying new seeds on the market rather than trying seeds on an experimental scale to choose one for long-term adoption. A frequent response to the question why a particular seed was chosen was that it was new in the market—meaning that no experimental information whatsoever was available. This attraction to new seeds exacerbates the turnover of seeds in the market, as seed firms sometimes take seeds that have fallen out of favor, rename them, and launch marketing initiatives for the new product.

The absence of seed evaluation is further confirmed by farmer knowledge of key seed traits. Farmers in the 2004 survey were asked if, for the cotton type they planted the most that year, they knew what to expect in the cotton's boll size, water requirements, time to maturity, and resistance to any crop pests. Despite the fact that farmers are understandably reluctant to admit to knowing little about the seeds they were planting, substantial numbers pled ignorance (table 3).

Even taken at face value, some of these figures are striking; water requirement would under normal conditions be a prime

15. Of course, whereas Bt cotton is clearly an innovation, novice plantings are innovative only in a limited sense: new seeds on the market are sometimes merely rebranded old seeds, and a seed being planted for the first time may have been around for years before the farmer decided to try it.

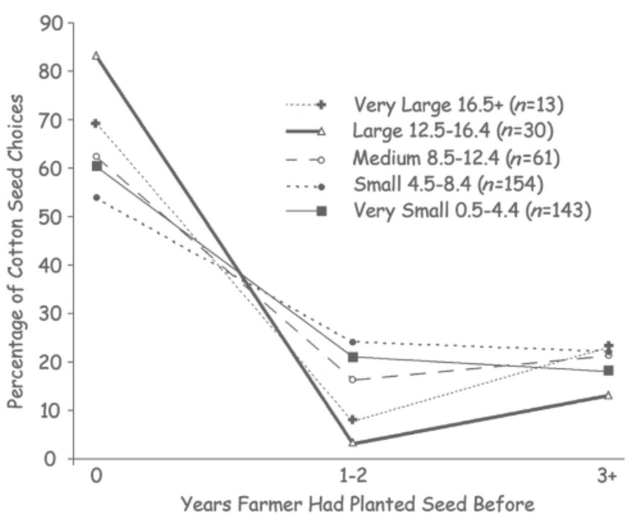

Figure 8. Novice versus experienced plantings by farm size, 2003.

Table 3. Percentage of Farmers ($n = 520$) Reporting Knowledge of Key Seed Traits

	Boll Size	Water Requirements	Time to Maturity	Insect Resistance
No	17	45	29	38
Yes	83	55	71	62

criterion for seed selection. The only trait for which few farmers confessed ignorance was boll size; large boll size is one trait that Warangal farmers consistently claim to value most highly.[16] However, given the fads that dominate cotton plantings, it is not surprising that there is confusion on even this trait. For instance, of the farmers in the sample who planted RCH-2-Bt in 2005, 83% claimed to know what boll size to expect (interviews were conducted before bolls were mature). Boll size is frequently discussed and routinely divided into small, medium, and large; according to producer, the RCH-2-Bt boll weighs 4.5–5 g, which is medium-sized. However, of these 280 farmers, only 44% identified the size as medium; 30% and 27% thought the boll was large or small. There were also interesting indications that expectations were forming on a village-specific basis.[17]

As a final consideration regarding the lack of experimental seed evaluation, it is instructive to look empirically at the variability in cotton performance (Qaim et al. 2006). Studies of Indian cotton yields (of which there has been a small surge due to interest in the performance of Bt cotton) tend to obscure variability by emphasizing averages. Table 4 summarizes brand-specific yields for 2003 collected in the 2004 survey of 420 farm households. The figures seem to show clear differences in output, much larger differences than have been cited in other studies as evidence of one seed's "outperforming" another (Bambawale et al. 2004; Morse, Bennett, and Ismael 2005). But by plotting the variability of seeds' performance in each village, figure 9 gives a fuller picture of the variability farmers confront. It gives another view of localized favoritism (e.g., Ganesh is planted only in Gudeppad, Bhavani only in Tekumatla) and, more important, shows the variation that is collapsed in the yield averages. What it does not depict is the important interyear variation; 2002 yield figures (collected in the 2003 survey) are given, but these are not broken down by village because of small sample sizes (and exclude Tekumatla and Pathipally, which were added in the 2004 census). Finally, it shows the frequent lack of correlation between seed yields in one year and the seeds' pop-

16. Plants with large bolls do not necessarily give high yield, as the number of bolls produced is variable. Large bolls may reduce costs for harvesting labor, but they also increase the economic losses due to bollworm attack (Jalapathi Rao, personal communication, 2005).

17. In Pathipally a plurality expected large bolls, but in neighboring Bhandarupally most expected small ones; in Kalleda a majority expected small bolls, but in neighboring Ravuru most expected large ones.

Table 4. Cotton Yields by Seed Variety, 2003

Cotton Seed	Average Yield (quintals/acre)	s.d.	*n*
Atal	7.5	2.9	14
Bhavani	6.7	2.7	10
Brahma	6.7	3.2	62
Bunny	6.9	3.6	45
Dassera	6.5	3.5	18
Dhanno	9.1	2.7	16
Dyna	9.7	3.3	7
Ganesh	10.1	2.2	28
Geetha	6.3	2.1	7
JK Durga	7.3	2.5	16
Mallika	6.9	4.4	8
Mech-12 Bt	9.5	4.1	5
RCH-2	5.6	4.3	12
Satya-619	10.2	4.1	14
Sigma	8.8	2.7	8
Tulasi	8.1	3.1	15
Vishwanath	9.3	2.4	43
Total	7.9	3.3	341

Note: Seed brands appearing fewer than five times were rejected, since the samples were too small for meaningful analysis.

ularity the next. For instance, Ganesh did particularly well in Gudeppad (leading all seeds in average yield) but dropped sharply in 2004; there was nothing special about the yield of JK Durga the year before it was the subject of a fad in Tekumatla.

We have seen that Warangal cotton farmers face an extensive, ever-changing, and often deceptive roster of seeds, that many of the key determinants of a good crop (germination, reliability of seed, insect and disease outbreaks) are unpredictable and there is wide intrabrand variability, that villages show sharp ephemeral fads lacking agroecological rationale, that most cotton plantings are novice and nonexperimental, and that, as a result, very little environmental learning can occur. The question of what drives seed choices therefore becomes quite important not only to an understanding of the spread of Bt cotton but also to a more general understanding of agricultural deskilling.

Ethnography of Cotton Fads

Given the obstacles to environmental learning in cotton cultivation, it should not be surprising that various forms of social learning are instrumental in decision making; what is surprising is the loose standard for accepting social information or choosing models to emulate. For illustration, let us consider two of the 2004 fads shown above: Gemini in Kalleda and Chitra in Gudeppad.

Gemini was planted by a handful of Kalleda farmers in 2003 and took off in 2004. Extensive interviews with 2004 Gemini-planters revealed a set of primarily social explanations that do not trace back to any agroecological rationale. Gemini cotton seed was introduced in 2003 by a newly formed company of the same name (it may have been a seed previously marketed under a different name). Its marketing strategy capitalized on the farmers' penchant for untried seeds and on local connections in Kalleda; the principal owner is from a nearby village. Many Kalleda farmers buy their seeds from a Warangal shop owned by Sampath Rao (pseudonym), from a large and influential Kalleda-area family that has traditionally had a paternal relationship with many small farmers in the area. As the principal distributor for Gemini in Warangal, Sampath got a high profit margin on this seed and recommended it strongly to his customers. The company owner was also an affine of the president of Parvathagiri Mandal, who recommended the seed. Gemini also ran a marketing campaign in Kalleda before the 2004 cotton season, with farmers who made advance purchases of Gemini seed getting scratch cards for prizes. The only hint of environmental learning was that one of the 2003 Gemini-planters was a *pedda rytu*; he apparently got a good yield, although no better than yields farmers obtained from various other seeds. Interviews with 2004 Gemini-planters turned up virtually no prior knowledge of traits of the seed; the most common rationale for adopting was that "other farmers around here were planting it." By 2005, Gemini had virtually disappeared from Kalleda fields.[18]

Gudeppad's 2004 Chitra fad was driven by emulation of a single local farmer and by marketing. Chitra was introduced in 2003 by Nath Seeds. A Nath marketer who had grown up in Gudeppad used his local knowledge to recruit Nagaraju Reddy (pseudonym) for a demonstration plot. Nagaraju Reddy was a *pedda rytu* and an attentive farmer whose crops often outpaced others in the area. In 2003 the marketer gave Nagaraju a free box of Chitra and, when it did well, transported many area farmers to see it. Because they liked the look of his field or simply because he was planting it, Chitra became the most popular seed in Gudeppad the next year. Of the 25 Gudeppad Chitra-planters who reported a primary factor in their adoption, 16 (64%) cited Nagaraju by name. None of the Chitra planters interviewed could specify what they had seen in Nagaraju's field beyond *manci digubatu*. Nagaraju actually planted five different brands in 2003. He reported that one brand yielded around 10 quintals/acre, three yielded around 14 quintals/acre, and Chitra yielded around 15 quintals/acre. (Such a small difference in yield would not have been visible to farmers visiting the demonstration plot, although Nagaraju could have told them of the yield later.) What set Chitra apart from Nagaraju's other brands was that it was new and that it was being touted by the Nath marketer. Chitra then virtually disappeared from the village in 2005.

An ethnography of the 2005 RCH-2-Bt fad is harder to construct. The surge to 45% of seed choices at the district level is unprecedented and is particularly surprising given the

18. In 2005, in a group interview, I asked why no one had planted Gemini again. One farmer mentioned that the bolls were too small, but others had no specific reasons; several said that they simply wanted to try something new.

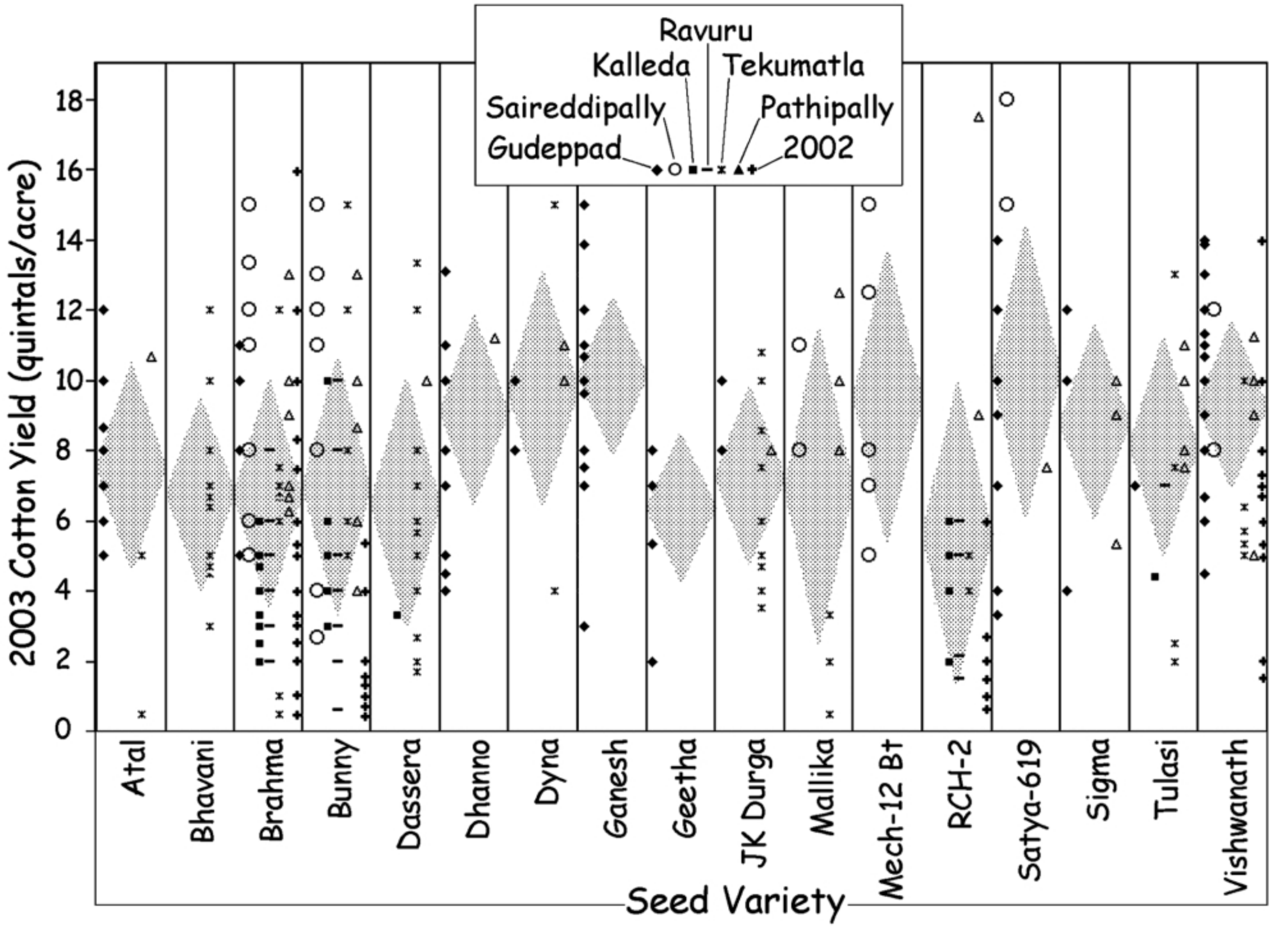

Figure 9. Cotton yields by seed type for 341 plantings. Cases are plotted individually for each seed and village, with the six-village averages and standard deviations superimposed in stippling.

area's considerable microethnic diversity: there is a shared language across the district, but there are dozens of generally endogamous communities or "castes," as well as tribal groups, and we have seen the strong tendency for villages to go their own way in seed favorites. At the village level the surges are not such a dramatic departure from past fads (Gudeppad being the notable exception). The difference is that instead of each village's having a fad for its own favorite, in 2005 most villages had a fad for the same seed; the fads were synchronized. This may result partly from the history of Bt seeds. The Mahyco hybrids that were the first Bt seeds sold (in 2002) were unpopular in Warangal, and moreover they were "old" seeds (on the market for over ten years) in an area where farmers were compulsive buyers of new seeds. Following reports of a poor year in 2004 (resulting mostly from problems unrelated to the Bt trait), these Mahyco seeds were banned in Andhra Pradesh; also in 2005, "Bt" versions of 16 seeds appeared on the market, including several popular seeds (of which RCH-2 was only one). None of the Warangal vendors or farmers could offer an agroecological rationale for sales of this particular seed (as compared with, for instance, Mallika-Bt, another popular seed in Warangal) to take off, and it is difficult to explain the RCH-2-Bt fad as the result of superior performance in the previous year. Controlled experiments by Kranthi et al. (2005) show that the Cry1A(c) gene does not express particularly well in this germplasm. What several farmers did tell me was that they chose RCH-2-Bt because it seemed to be the seed most others were buying; there was, in effect, a "buzz" about it on Station Road, and conformist bias was clearly in operation (fig. 10).

Theorizing Deskilling and Interpreting Bt Adoption

In contrast to the claims of consistent benefits discerned by small-plot experimentation, Warangal farmers have largely

Figure 10. Farmers buying cotton seeds at a shop in Warangal. Visible behind them are a few of the many hybrid seeds available at the shop. The man in the middle is paying Rs. 1600 for a pack of RCH-2-Bt (four times the cost of conventional seed). When asked why had chosen it, he said that it was what other farmers were buying.

forsaken experimentation now and practice an agriculture notably lacking in consistency. To situate these dynamics of decision making in social theory, let us return to the evolutionists' claim that reliance on social learning is a function of the cost and accuracy of individual/environmental learning and that reliance on "pure social learning . . . will increase as the costs of individual learning increase and the accuracy of individual learning decreases" (McElreath 2004, 310). But McElreath's approach is more cognizant of the overlap between environmental and social learning; it sees social learning as adaptive in such cases because it embodies results of prior experiments by others. This must be true in many situations, and studies in various contexts have documented the importance of the flow of agroecological information among farmers (Besley and Case 1993; Fischer, Arnold, and Gibbs 1996; Tripp 2006, 54). But our discussion has shown how agroecological information may be disrupted before it is transmitted. What if so little individual/environmental learning is taking place that social learning is based almost entirely on the sort of nonenvironmental signals we saw in Kalleda and Gudeppad? Agriculture is challenging even in the best of circumstances: "Every farmer knows that many factors influence yield, leading to high variance in yields for apparently similar crops and methods, and so distilling the signal from the noise in such information is difficult" (McElreath 2004, 311). Now imagine that (to use the evolutionists' terms) the predictability of the payoff space and thus the accuracy of individual learning is slashed by the characteristics of the seed market and information flows presented above. The result is agricultural deskilling, the underlying cause of which can be restated as inconsistency, unrecognizability, and excessive rates of technological change causing an exceedingly low accuracy of individual/environmental learning. Too little individual learning occurs for social learning to exploit, yet farmers nonetheless rely on the latter in the hope that it will offer a higher payoff. What emerges is nonenvironmentally based fads.[19]

19. Richerson and colleagues anticipated a parallel situation in microsociety experiments. They suggested that when payoffs are so variable that individual learning is inadequate to explore the entire payoff space, "participants will copy suites of choices of other individuals, leading to the formation of 'traditions' among groups wherein different neutral aspects of the decisions hitchhike along with important aspects" (Richerson, Lubell, and McElreath n.d.). Warangal cotton farmers afford us an empirical view of a similar situation and show us how localized and ephemeral the resultant traditions are.

This analysis of farmer decision making directly contradicts Monsanto's interpretation of the basis for Bt cotton adoption, but it is not entirely at odds with the historic trend in anthropology of functionalist interpretation of indigenous agroecological knowledge. Rather, it identifies conditions under which the skilling process can be subverted. Other students of agroecological knowledge have recognized the need to "avoid rationalizing farmer practices beyond what can be convincingly tested simply to satisfy researchers' desires for a mechanistic logic underlying those practices" (Soleri and Cleveland 2001; see also Richards 1993, 1995). A more comprehensive understanding of agricultural knowledge and practice requires consideration of Michael Dove's (2000) case that development concepts ("participatory development," "community-based conservation") follow a life cycle in which they are eventually appropriated by the very interests they were developed to oppose. This certainly fits the concept of "sustainable agriculture," which has come to embrace "almost anything that is perceived as 'good' from the writer's perspective" (Conway 1997, 163; Tripp 2006, 3), and "integrated pest management," which is now often sponsored by pesticide producers. So it is with "indigenous knowledge" on the front lines of genetic modification in Third World agriculture, as the same companies who have traditionally scorned peasant farmers as mired in tradition and in need of instruction (especially when they are slow to adopt purchased inputs) now salute the wisdom of farmers who buy genetically modified seeds.

Are the new genetically modified seeds an agent of deskilling? This charge has been made by some opponents (Simms 1999; Harwick 2000), but it is deceptive because the deskilling here was in full effect before the new seeds arrived. It is important to be clear on the underlying causes. A prime cause has been technology: the two agricultural technologies prominently implicated in deskilling—hybrid seeds and pesticide sprays—are both ubiquitous here. This is the only area in the world that relies on hybrid cottons, and the seeds are of a New World species that is highly susceptible to the Indian repertoire of pests. Another cause has been the market, with its brand turnover, confusion, and unreliability. There has been cultural complicity as well: packaged inputs from shops are widely perceived as effective and modern, while seed replanting is seen in many quarters as quaint and backward. Knowledge of the latest brands of seeds and pesticides on the market is a form of cultural capital.

Still, genetically modified seeds may make their own contribution to deskilling depending on local circumstances (Stone 2004, n.d.). For Warangal farmers the technology introduces new sources of inconsistency and unrecognizability and accelerates technological change. The performance of Bt in India has recently been shown to be inconsistent from brand to brand (Kranthi et al. 2005); inconsistency over the growing season has been documented in both the United States and Australia (Olsen et al. 2005) and certainly occurs in India. Although all Bt cotton in India to date has contained the same Bt gene, seeds containing different genes are now being tested (GEAC 2006), and this will likely contribute to unrecognizability and accelerated technological change. On top of these developments has been a powerful surge in the number of parties clamoring to shape farmer decisions (Yamaguchi, Harris, and Busch 2003). As Herring (2006*a*) has put it, "Farmers in India faced transgenics through the mediation of rumour, NGO's, public intellectuals, and contradictory official signals."

But there is nothing intrinsically deskilling about the technology, and these deskilling effects depend on local conditions. Where conditions are different, there are intriguing hints that genetically modified seeds may mitigate deskilling. In Gujarat farmers have also adopted Bt cotton with zeal, but the nature of the seed supply there differs in several key regards. Bt cotton first appeared (illegally) in or around 1999 in the hybrid Navbharat-151, which apparently performed exceedingly well (Roy 2006; Shah 2005).[20] This seed was banned after the 2001 season because as a transgenic crop it required approval by the Genetic Engineering Approvals Committee (which did not approve any Bt cottons until 2002). However, the parent lines found their way into the hands of farmers, many of whom began making their own Bt crosses—both hybrid and open-pollinated—in a thriving cottage industry, and by 2003 Gujarat was awash in illicit Bt seeds and cotton fields were estimated to contain up to 80% illicit seed (Gupta and Chandak 2005; Roy, Geister, and Herring n.d.; Herring 2005*a*; Shah 2005).

There are other differences in the seed system here. Some Gujarati farmers plant (and replant) indigenous nonhybrid species of cotton (Kranthi 2005). In addition, much of the seed is purchased in loose form (rather than the acre packs that dominate Warangal purchases), which facilitates small-plot experimentation. These differences in seed systems should greatly reduce inconsistency, unrecognizability, and accelerated technological change, and it is therefore not surprising that a recent investigation into agricultural decision making there has shown a much greater degree of control than what I have shown in

20. Not surprisingly, the agronomic performance of the illicit Bt seeds has been hard to measure. Gupta and Chandak (2005) reported on a survey of 363 farmers randomly selected from 75 villages in Gujarat, where illegal Navbharat-151 Bt was sold. This study compared yield data from 2001 (based on farmer recall) with yields from legal Bt cotton. This appears to be comparing yields from two different years, since no legal Bt cotton was being grown outside of test plots. The study reported increased yields for Bt cotton over conventional counterparts but higher average yields for legal Mahyco seeds than for illicit ones. Morse, Bennett, and Ismael (2005) failed to find higher yields for illicit Bt cotton, but their study is problematic; it appears to have taken all farmer responses at face value regardless of the illegal nature of the seeds they were being interviewed about, and it appears to have recorded only harvests through December, thus missing the late-season harvest which is a strength for some illicit seeds. Despite these limitations in published research, the field success of the illicit Bt seeds is validated by the Gujarat Agriculture Department's estimates that cotton yields in the state have more than quadrupled over the past four years, during which time illicit Navbharat-151-descendant seeds have spread to 60–80% of the state's cotton area (Shah 2005).

Warangal (Roy, Geister, and Herring n.d.). In fact, Bt cotton in Gujarat appears to have played a role in getting some farmers *more* involved in seed production, turning the cotton fields into what Anil Gupta (a leader in studying and promoting farmer innovation) termed “the greatest participatory farmer plant-breeding *mela* [carnival] in history” (Herring 2006*b*; see also Herring 2006*a*; Stone n.d.). Whatever environmental regulation and intellectual property problems are posed by this wave of farmer Bt breeding, it appears to be instrumental in what might be called agricultural “reskilling.” This is another disadvantage of the popular arguments casting Bt cotton as a monolithic good or evil (see Stone 2002*b*); the lessons to be learned from the adoption of Bt cotton in Gujarat are quite different from those for Warangal, and by lumping the two we obscure crucial variation.

In Warangal, all parties must agree that 2005 was a remarkable year for genetically modified cotton, but it should now be clear that there is a surprising cultural context to the widespread adoption here. On the surface, it appears to be a dramatic case of successful adoption of an innovation, applauded by Monsanto in terms consistent with classic innovation-diffusion theory. However, a closer analysis of the dynamics of adoption in the Warangal cotton sector shows that the key elements of that theory do not fit and that the pattern that some see as an environmentally based change in agricultural practice actually continues the established pattern of socially driven fads arising in the virtual absence of environmental learning.

Acknowledgments

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Appendix: Sampling Strategy

Village selection was intended to sample different parts of Warangal District, as well as soil conditions and socioeconomic variability. The censuses in 2003, 2004, and 2005 expanded from four to six to nine villages; three “companion” villages located near other census villages were added in 2005 to provide information on the spatial extent of cotton fads.

Kalleda and Ravuru are within 4 km of each other in Parvathagiri Mandal. These villages have very similar soils, roads, markets, input vendors, and proximity to Warangal but differ markedly in ethnic and economic makeup. Kalleda has a population of around 3,000, with virtually all local castes present and a high degree of economic stratification. Ravuru is a largely tribal (Banjara, or “Lambadi”) village of around 800. Literacy is low, most residents are poor, and there is little economic stratification. Gudeppad is located in an area of black cotton soil in Atmakur Mandal, where commitment to cotton cultivation is very high. Population is around 1,100. Oorugonda, a village of around 3,300 3 km from Gudeppad, was added to the 2005 census as a companion village.

Tekumatla is a village of around 3,500 in Chityal Mandal with black cotton soil. Pangadipally, 3 km distant with a population around 2,500, was chosen as a companion village. Pathipally is a village of around 4,000 in Mulugu Mandal. Bhandarupally, 10 km distant with a population around 3,500, was chosen as a companion village. Saireddipally is a village with a population around 1,500 straddling the border between Parvathagiri and Nekkonda Mandals. Its residents are mostly Andhras who immigrated from coastal areas several decades ago. It is an unusually prosperous village, with a high level of education and a high commitment to commercial cultivation of not only cotton but chillies and maize. Censuses were also collected in Bandanagaram, a village near the southwest corner of Warangal District with relatively low involvement in commercial cultivation. Virtually no cotton is planted there, and it is excluded from this analysis. Farm sizes and crop acreages for the villages included in the 2004 census (the 2005 census did not include acreages) are shown in table 5.

Table 5. Acreage Planted for Various Crops, 2003

Village	Average Acres Planted by Household	Percentage of Plantings			
		Rice	Cotton	Chillies	Maize
Gudeppad	4.8	25	59	3	5
Kalleda	4.4	75	16	1	8
Pathipally	5.5	50	38	6	7
Ravuru	3.9	50	28	1	8
Saireddipally	6.5	25	35	16	24
Tekumatla	4.6	11	61	17	6

Note: The percentages do not sum to 100% because of minor crops not included here (e.g., sesame, pigeon pea, black gram).

One aim of the 2004 census was to update and verify the accuracy of the 2003 data. Therefore, in the recensused villages, census takers were given lists of the 2003 randomly selected households. However, knowing that some farmers would be unavailable, a randomized list of other farmers in the village was provided for "fill-ins," and the census takers added names from the top of this list as needed. For the two villages added in 2004 and the three added in 2005, the same sampling strategy was used as in the original four villages.

Comments

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It seems ironic that globalization has provided us with fresh opportunities to reevaluate our understanding of traditional knowledge systems. Like the active debate about protecting traditional knowledge from appropriation, the diffusion of biotechnology affords us new insights into the complexities of knowledge systems and the difficulties in understanding them. Stone deftly uses the case study of transgenic cotton in Warangal to rethink Braverman's generation-old idea of deskilling by setting it in a radically different context and giving it a more nuanced and complex analysis than earlier ones applying it to agricultural knowledge (cf., e.g., Fitzgerald 1993; Vandeman 1995). Besides Stone's own acumen and skills as a fieldworker, his accomplishment is aided by the new vigor that cultural evolutionary theory has brought to human ecology. One result of this theoretical work and Stone's use of it is to reassert the importance of the diffusion of innovations in understanding knowledge and technology systems. Stone's accomplishment is to show how social and environmental learning can be affected by social processes that are not embedded in kinship, local prestige systems, or environmental perception.

However, I am not entirely convinced that Warangal farmers have been deskilled by the diffusion of transgenic cotton and the rise of the seed vendors. The knowledge and technology systems of these farmers have been dynamic for many generations, and they have long had access to new technology that is potentially deskilling. Stone recognizes this in pointing to the importance of the previous shift to hybrid cotton seed in India. Yet, the diffusion of technology might be seen as offering farmers new skills as they replace older ones. Eventually, we may see new skills in demanding and evaluating more accurate information from seed suppliers.

Are contemporary farmers in the American Corn Belt who buy seed less knowledgeable than their grandfathers who saved seed but did not have to comprehend or adjust to the complexities of futures markets, the financing of capital-intensive operations, and government regulations? The appearance of loss of skills in this process may be analogous to the replacement of genetically diverse local seed on farms that adopt modern varieties. Duvick (1984) has pointed out that although there may be less genetic diversity on a particular farm after this replacement, the locus of diversity has changed. Farms using commercial varieties become linked to far more diversity through the international crop germplasm and breeding system. This may be one reason that there is scant evidence that the use of commercial seed leads to problems such as genetic vulnerability to pests and pathogens. Although farmers may no longer be skilled in seed selection, they are linked to a system rich in other skills. While the current state of the seed market and cotton fads in Warangal seem to cloud a similar situation, this market condition may be temporary, to be replaced by one with better information. It would be interesting to compare the early period of the corn seed market in the United States with the cotton seed market in Warangal.

Stone makes a compelling case for the problems of environmental decision making amidst the cacophony of seed vendors, but the yield data suggest that even without the competing claims of vendors, a farmer would be hard-pressed to rely on environmental rather than social learning. Explaining why different varieties obtain different yields is still a daunting challenge, even though crop scientists are equipped with statistical and experimental tools that are unavailable to most farmers. Farmers are caught in the vise of complex interaction of variety, environment, and yearly fluctuation. Even though a farmer may rely on social learning related to trust or prestige, the environmental fit between his farm and others in any one year is problematic, as Stone's yield data suggest. Over time, farmers may develop new skills to demand better knowledge from the commercial seed industry. With refreshing agnosticism toward this agricultural biotechnology, Stone shows us that it offers an excellent opportunity to understand knowledge systems and economic behavior.

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Stone provides a well-documented and fascinating glimpse into a world that few of us have seen close-up. In this brief commentary I shall attempt to look at the data presented from a slightly different perspective. Mainstream economic theory tells us that competitive markets are desirable for a number of reasons; for example, they reduce prices while enhancing quality and bring supply into equilibrium with demand. However, mainstream economic theory is rather silent about the institutional context within which markets operate. Put differently, we can see the story told here as a version of Akerlof's (1970) "The Market for 'Lemons,'" in which Akerlof noted that used-car markets operate quite differently from the conventional markets of mainstream economics. Consider a 2005 Cadillac for sale on a used-car lot for $1,000. In a textbook market, that car would be a great bargain, to be quickly purchased by a rational buyer, but anyone familiar with the used-car market would suspect that it was no bargain after all. In Akerlof's terms, the problem is the asymmetry of the information held by the dealer and the potential buyer. The dealer knows the history of the car (perhaps the frame is bent out of shape?), while the buyer is largely ignorant of its history.

In many respects this is the problem faced by seed buyers in Warangal: The visual cues provided—the characteristics of the package and the seed itself—are of little or no value in choosing which seed to buy. Indeed, in some sense the seed market described here is much like an unregulated gambling establishment, in which the odds of winning are known to management but unknown to the gamblers. The gamblers go on playing anyway in the vain hope that they will win. Occasionally, someone does win, and this convinces the others that perhaps luck will be on their side next time.

Stone's study also emphasizes the lopsided character of diffusion studies, which focus nearly entirely on the characteristics of the adopters and rarely on the characteristics of the technologies. As he suggests, the standards for germination, purity, and variety that characterize the American and European seed markets are poorly enforced in India, with the result that the technology's identity is itself in question. Moreover, since the seed cotton in question is hybrid, farmers cannot compare the performance of the purchased seed with what they know from years of experience. In Akerlof's terms, there is information asymmetry. (In contrast, some grain seed is grown by farmers, making for far greater symmetry.) Moreover, since seeds are a necessary input in cotton production (unlike fertilizers and pesticides, which are discretionary inputs) and hybrids have replaced varieties, farmers have little choice other than to purchase seed or to abandon cotton production.

Stone also examines the deskilling of farmers through the purchase of seeds, although, as he suggests, deskilling serves more as a metaphor than as a theoretical model of technical change in agricultural production. In contrast, Goodman, Sorj, and Wilkinson (1987) argued some years ago that the transformation of world agriculture is best understood as the use by nonfarm actors of two strategies: substitutionism and appropriationism, the former referring to the substitution of manufactured products for those produced on the farm (e.g., margarine for butter) and the latter to the appropriation of farm production by off-farm entities (e.g., seed dealers).

As Stone notes, the diffusion literature has tended since its inception—despite its sociological origins—to take an individualist view. Individual farmers have been studied *ad nauseam*, especially in the United States, where (we are told) farmers tend to be highly individualistic. (One suspects that U.S. farmers' individualism is much like that described by Tocqueville—rather conformist in character.) The social learning Stone describes is generally unrecognized by proponents of the diffusion of innovations.

Furthermore, a central premise of the diffusion literature is artifactual: the (in)famous logistic curve. Were one to study unsuccessful innovations, the shape of the curve would be quite different, probably more closely resembling a normal curve. Indeed, the patterns shown by Stone illustrate unsuccessful efforts at widespread adoption of selected hybrids.

The relationship between income and innovation is equally artifactual. The innovations usually chosen for study are those most likely to interest those with higher incomes. These can be contrasted with many of the innovations noted in Anil Gupta's newsletter *Honey Bee.* I am confident that adoption of the human-powered generator described there will be inversely related to income.

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Are genetically engineered crop varieties the best way to improve agriculture in the Third World, or are they just the latest method for taking resources and control from farmers? Stone's case study of farmer choice of cotton varieties in Warangal District is an important contribution to this debate, using field data to challenge the dominant economic and environmental approaches to understanding farmers' choice of technology.

Genetically engineered varieties are being promoted as the best or often as the only hope for making agriculture more sustainable and feeding the Third World (James 2005). The U.S. government even promotes genetically engineered varieties as a moral imperative (Nicholson 2004). However, the growth of biotechnology has led to publicly funded agriculture's losing control of financial, biological, and technological resources to private agricultural biotechnology companies. Therefore, to the extent that they embrace genetically engineered varieties as the only option, public organizations such as the UN Food and Agriculture Organization (FAO 2004) and the CGIAR (CGIAR 2006) and university scientists are dependent on the private sector and forced to negotiate rights to research resources (Atkinson et al. 2003), and farmers are often seen as passive recipients of the new technology (Cleveland and Soleri 2005).

Stone's research lends support to an alternative proposition—that farmers should be given the option of choosing and the information needed to make such choices. But the task is not easy, because, as Stone discusses in the case of cotton, genetically-engineered-seed companies have no interest in informing farmers, nor do genetically engineered varieties have monolithic effects or farmers monolithic responses. Our own work with farmers on genetically engineered maize in Cuba, Guatemala, and Mexico has shown that attitudes and practices differ significantly between and within communities and that some farmers' views of these crops depend on the possible consequences of adopting them, not on the nature of the technology per se (Soleri et al. 2005).

Stone's study of farmer choices of cotton varieties is a unique contribution to understanding of the genetically-engineered-crop variety debate. Especially impressive are data showing the dramatic differences in frequencies of varieties grown in different communities and in different years and those illustrating the lack of farmer experimentation with new varieties, both of which provide important challenges to conventional wisdom on the adoption of new technologies.

It would be good to have more information on the processes (practices) by which farmers choose and the units of choice (technologies), including details of the way farmers *learn* how practices and technologies perform together under variable conditions (see Cleveland, Soleri, and Smith 2000). These data would enrich our understanding of how knowledge and practice were affected as hybrid cotton replaced traditional open-pollinated varieties and genetically engineered (also hybrid) cotton replaced hybrid non-genetically engineered cotton. Then Stone's conclusion that farmers were consistently unable to justify choice based on seed traits or environmental process as a result of "deskilling" could be better evaluated independently and contribute more fully to the ongoing debate.

For example, the terms "brands," "seeds," "type of seed," "hybrids," and "genetically modified seeds" are all used to refer to the units being chosen by farmers. How do these categories relate to each other and to the units (varieties, cultivars, and populations) commonly used in plant breeding? For example, the Bt cotton planted by farmers can be first-generation hybrids officially recognized by the Indian government or unofficially developed without permission to use Monsanto's Bt gene or unofficial second-generation seed from these first-generation hybrids saved by seed companies or farmers, leading to different results in farmers' fields. However, to the extent that the new varieties are similar, an alternative explanation of farmers' choices may be that skills learned with traditional open-pollinated varieties are no longer needed and therefore farmers are trying to capture the small average differences in yield advantage among varieties they know to be similar by imitating more prosperous farmers, who, Stone shows, experiment more and are more connected to information sources.

Stone says that farmers' highly variable growing environments are a major reason they were not able to gain knowledge about the new varieties, but this variability existed before the advent of genetically engineered varieties. Was it incorporated into farmers' knowledge, and how did this knowledge change with hybrid and genetically engineered cotton? Stone could not document the situation before the advent of hybrid/genetically engineered varieties, but could a comparison be made with rice or other traditional crops?

Some types of genetically engineered varieties might benefit Third World farmers, but this is likely only if they are developed specifically to do this in collaboration with farmers and/or if farmers can experiment on their own terms. Third World farmers' interests can be served by recognizing their right to active involvement in an extended risk management process that includes comparative benefit/cost analysis of alternatives to current genetically engineered varieties (Cleveland and Soleri 2005; Soleri, Cleveland, and Aragón Cuevas 2006). We will need detailed case studies of farmers and their communities linked to the processes of global agricultural and economic change. Stone's paper is a valuable contribution to this goal. Such studies will also support more collaboration between farmers and scientists, the potential for which has been weakened by increasing privatization (Cleveland and Soleri 2002; Lancon et al. 2006).

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Agricultural decision making is an old topic in anthropology (extending from more recent studies like Barlett's [1980] and Cancian's [1972] back to some of the earliest work in the field) interest in which waxes and wanes over time. It has recently come back into fashion with a spate of studies on genetically modified crops. Many of these studies focus on global dynamics, neglecting questions of practice at the farmer, household, and community level. In contrast, a focus on farm-level practice is a strength of Stone's study. He introduces an interesting twist to this subject. Whereas there is a long history of anthropological work on the development of local agricultural knowledge, what Stone might call "skilling," his interest lies in the unraveling of this process due to the forces of globalization, "deskilling." His study shows us the potential of applying the same conceptual tools that anthropologists have applied to the way communities learn to the way communities unlearn, which may be a vast new area for study. Stone joins a handful of anthropologists (such as Brush [2004], among others) in studying contemporary issues of seeds and crops in a way that goes beyond an exclusive concern with either advocacy, on the one hand, or global dynamics, on the other, to expand our theoretical understanding of people and communities.

Seed "fads" and "stampedes," Stone's focus, are not new phenomena, and they are not exclusively the province of farmers. The Green Revolution in wheat and rice might be characterized, in retrospect, in similar terms. Even more obviously characterizable in these terms (if only because more removed in time) is the vast colonial-era explosion of commodity production, accompanied not only by methodical development of knowledge in botanical gardens but also by political and economic intrigue, oppression, ignorance, and inefficiency (thinking here of the tortuous histories of rubber, coffee, and cinchona, for example). How do current events in places like Warangal resemble and how do they differ from this historical record? Contemporary Indian agriculture is increasingly being represented as an exemplar of a uniquely modern "hybridity, mistranslation, and incommensurability" (Gupta 1998), but this perhaps presumes a purity, commensurability, and ease of translation in earlier eras that is more useful as a foil than as a description of the time.

Stone argues that current farmer practices in adopting and planting genetically modified (Bt) cotton in Warangal are fundamentally different from what we have heretofore understood about the way that smallholders (in Netting's [1993] sense) experiment with and evaluate new crop varieties. The latter, "environmental learning," is based on empirical feedback from the farm; the former, "social learning," is based on what one's peers (especially one's wealthy or politically powerful peers) are doing. Adoption of different varieties of Bt cotton in Warangal is characterized by wild swings between one seed type and another, apparently unrelated to actual yields. Stone persuasively argues that in the context of current cotton production in Warangal, environmental learning about seed performance is in fact impossible. As result, the farmers seem in effect to be making random decisions about which seed type to plant, which is an extraordinary and alarming finding. This is indeed unlike what we know about the behavior of many smallholders; but it is not necessarily unlike what we know about the behavior of smallholders—and others—in commodity booms, which may be defined in part by the absence of environmental learning (hence the "busts" that follows the "booms").

Perhaps the most interesting finding of Stone's is what both the Indian government and the agro-industrial sector (Monsanto) have to say about smallholder adoption of Bt cotton. Long-held and frequently stated beliefs in the recalcitrance and ignorance of peasant farmers have literally been reversed, with these parties now publicly applauding the purported wisdom and independent decision making of the farmers who are planting Bt cotton. (This does indeed seem analogous to the way in which the political loading of indigeneity has been reversed in recent years from negative to positive.) It seems highly revealing that farmer knowledge is being glorified precisely when, according to Stone, it is ceasing to exist, and that farmer agency is being lauded precisely when it has become irrelevant (as is the case in randomized planting of one Bt seed type versus another). The heralding of farmer decision making by Monsanto thus seems to signal that farmer decision making is dead. If so, it is of interest that it is important for Monsanto to embrace farmer decision making at this particular historical juncture; it is of interest that farmer knowledge and agency remain a zone of discursive contest, as has been the case since the colonial era. Finally, it is of interest that the practice and representation of farmer knowledge and agency stand in such a complicated, antithetical relationship to one another.

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Transgenic[1] cotton has spawned tumultuous politics in India. Bt seeds were attacked first as suicide (escalating to "homicidal" and ultimately "genocidal") seeds. Even field trials to assess bio-safety produced crop burnings, parliamentary queries, protest rallies, and reams of litigation and newsprint (Shiva, Emani, and Jafri 1999; Stone 2002*a*; Herring 2005*a*, 2006*b*). Yet, as Stone's detailed empirical work makes clear, farmers are adopting Bt cotton seeds with such alacrity that he can legitimately write that the situation was "more than innovation diffusion and more than a tipping point . . . : it was a stampede." But some NGOs hold the new seeds responsible for agronomic disaster, suicides, agro-ecological catastrophe: dead sheep and dead farmers. Are activists out of touch with agriculture? Or are Indian farmers as ignorant as the oppositional coalition implies—planting expensive seeds that will be their ruin in ever-greater numbers on ever-increasing acres? Stone's work is especially valuable because of the spatial organization of Bt disaster stories in India: Warangal District in particular and Andhra Pradesh in general have been the epicenter of the catastrophe trope. No one reports such outcomes in Gujarat, the origin of hybrid cotton in India and, indeed, in the world.

Stone's analysis seems to support the assumption of anti-transgenic activists; he describes a "stampede" to Bt cotton seeds or sometimes a "fad." These characterizations imply unreasoned or socially driven—rather than empirically based—decisions. Warangal farmers are seldom able to give specific reasons for adoption of particular varieties. Empirical work in Gujarat, on the other hand, has pictured Bt hegemony in cotton fields as a result of experimentation, sharing of information, and adoption once the technology was proven (Roy, Geisler, and Herring 2007). Bt cotton farmers in Gujarat have been innovators and entrepreneurs, not sheep (Gupta and Chandak 2005). Why should farmers in Gujarat be establishing a "cottage industry" of home-brewed Bt crosses that are grown locally and exported to other states whereas farmers in Warangal cannot even assess the seeds they buy? Stone's answer is that "deskilling" is at fault. I am not sure that this concept from the industrial world travels well. If

1. Activists opposed to transgenics deploy the strategic construction of "genetically modified organism," as if all modern cultivars were not "genetically modified," whether by recombinant DNA technology or otherwise. Stone, along with most academics, accepts this construction, but we should be clear that it is a political, not a biological one (Herring 2005*c*).

contemporary "deskilled" Warangal farmers so casually run with fads, might not their more skilled grandfathers have just as irrationally planted the same crop over and over, despite low yields? What we cannot learn from Stone's work but must be assumed for his argument is that farmers could once explain seed choice in a way that an anthropologist would credit, rather than working under rules-of-thumb, habit, inertia. It is difficult to maintain that the skills of traditional agriculturists were superior: yields of Indian cotton have been the lowest in the world. In recent years, Indian yields and total production have increased substantially; proponents of biotechnology and many farmers attribute this to Bt technology. Warangal's "stampede" to Bt hybrids may be indicative of desperation search behavior in a difficult game against nature when much received wisdom has failed; the district was an early exemplar of the farmer suicide epidemic (Centre for Environmental Studies Warangal 1998; Government of India 1998). Stone writes: "Agricultural deskilling is *the disruption of the balance between social and environmental learning that is instrumental in farm production.*" Cotton farmers may through hard experience have recognized this "balance" as a low-level equilibrium trap; if there is deskilling, it may on the whole be good for farmers.

But it is not clear what causes deskilling. Hybrid cotton cultivation began in Gujarat, yet farmers there seem not so deskilled as farmers in Warangal, despite longer exposure to deskilling conditions. Presumably, organic farming preserves the skill set. If cotton holdings were not so small in India, organic farming with traditional cultivars might work; indeed, even some organic farmers do adopt Bt technology to continue pesticide-free agriculture with higher yields (Roy 2005, 2006*b*). The skill set is divisible, like the seeds. Those who believe that Bt technology works reasonably well in India largely rely on the rationality of farmers and comparative experience. With small margins and great vulnerability, would farmers adopt a new technology so rapidly, on such a large scale, if it were not beneficial? The Indian adoption curve is, like that of China (where farms are even smaller), very steeply upward-sloping. Perhaps farmers have good reasons to stampede. But Stone rightly argues that the evidence on the economics of Bt cultivation in India is chaotic: studies contradict one another, many are self-interested, few are methodologically sound (Naik et al. 2005). A great contribution of his careful fieldwork is documentation of extensive spurious seed marketing that may explain some contradictions: certain farmers claiming to have been ruined by "Bt" cotton may honestly believe they are growing Bt but have been cheated by unscrupulous merchants. Nevertheless, Stone presents what seems incontrovertible evidence that Warangal farmers know little of the critical agronomic characteristics of what they plant; the acceptance curve could be no more than mass hysteria. If Stone is correct in his characterization of Warangal farmers, their problem goes much deeper than skills.

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Between 2004 and 2005, the cultivation of genetically modified cotton in India experienced an outstanding increase, from 500,000 to 1,300,000 hectares—probably the fastest diffusion of an agricultural technology in history. This important phenomenon is, however, highly contentious. Promoters of such crops take this as a proof of the benefits of the technology, and some even consider these crops a contribution to the millennium development goal of reducing poverty by 50% by 2015. Such claims are supported by a few publications showing that the yields of Bt cotton are 40–60% higher than those of non-Bt cotton (Qaim and Zilberman 2003; Bennett et al. 2004). Opponents claim that the data provided are faked and that the government of Andra Pradesh has manipulated information to play down the failure of Bt cotton. They quote "independent studies" showing that Bt cotton has not significantly reduced the need for pesticides and has failed in terms of yield for small farmers. Stone has previously emphasized the shortcomings and even fallacies of both sides and called for a closer analysis of the way farmers choose their seeds (Stone 2002*b*). Conducting such an analysis here, he shows convincingly that the rapid diffusion of genetically modified cotton cannot be explained in terms of classic innovation-diffusion theory and is more accurately described as a "pattern of socially driven fads arising in the virtual absence of environmental learning."

The rate of choice of "novice" seeds is one of the elements which characterize the process of deskilling. A seed is considered as novice when it is planted for the first time by a given farmer. In 2003 (before the Bt fad) the average rate of novice seeds was 59%; 70% of households had a rate of novice seeds of 100%. This rate is not compatible with a model of learning, since such rapid change does not allow the comparison of different seeds to gain information on the new ones. Furthermore, as Stone shows, farmers do not explain their choices in terms of the quality of the seeds; they buy a given seed because it is the seed most people are buying.

However, the overall picture is not inconsistent with an alternative explanation—that the genetic differences between the available cotton varieties are so small that farmers are indifferent to them. This is consistent with the description of the seed market and the observation that the varieties are hybrids which combine a few lines produced by agricultural universities and research institutes. If the difference between varieties is small, frequent changes mainly explained by imitation and marketing are not surprising. This may explain the seed fads, which are localized, showing the influence of social networks, retailers' strategies, etc. As Stone says, the specificity of the situation with Bt cotton is that within a very short period the fads were synchronized. This situation may be explained by information on genetic differences related to insect resistance and/or the strategy for marketing the new varieties. Stone shows that the information in question is not available at the individual farm level. Thus, as far as Bt cotton is concerned, the deskilling hypothesis is confirmed, and marketing strategies are a good candidate for explaining the synchronization of fads. Unfortunately, this is a blind spot of Stone's analysis. We may assume that the RCH2-Bt fad did not appear by chance, since such rapid diffusion requires that the hybrid seeds be available (produced and provided to many retailers). We cannot exclude that Monsanto—through its local subsidiary Mahyco—knew the characteristics of this market and wisely exploited the characteristics of seed fads in Warangal District to create this rapid diffusion.

Stone is right in rejecting the standard explanation for the diffusion of Bt cotton. This diffusion is not due to its obvious intrinsic superiority and to the wisdom of small farmers. However, for a comprehensive explanation of the diffusion process it is not enough to observe the adopters. It is necessary to have a better understanding of the strategies developed by companies like Monsanto to foster the use of genetically modified crops. In this respect, the parallel case of Brazil is illuminating, since it shows how Monsanto managed to overcome national decisions regarding the ban on genetically modified crops and the issue of intellectual property rights (Varella 2006). Such diffusion processes are anything but "natural."

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Stone's sharply focused, methodologically sophisticated, and well-explained research on the rapid rise in farmer adoption of genetically modified cotton is most welcome. While he points out that in other contexts a similar study might reach different conclusions, his case studies have important general implications.

Stone explains the uptake of genetically modified cotton in Warangal District in terms of a synchronization of highly localized "fads" and provides a long-overdue examination of the innovation-adoption theory underpinning agricultural extension and marketing. The central trope is the "rational scientific farmer," whose experimentation and innovation are the touchstone of successful (and appropriate) technology adoption. Stone does not deny that farmers have these capacities but shows that in the peculiar circumstances of hybrid and genetically modified cotton in Warangal they have become disrupted, marginal, or irrelevant.

Stone's evidence on the lack of individual environmental learning is compelling. Against seed-company claims, he shows that the rapid uptake of genetically modified crops tells us little about their benefits. His argument that the promotion of new technology can have unnoticed deskilling effects is important, but this still leaves the question why farmers choose certain seeds and not others. His ideas of "crop fads" and "deskilling" curtail the ethnography and limit exploration of the social nature of decision making.

First, the terminology of "fads" prevents exploration of some of the interesting leads about the social dynamics of seed popularity which Stone introduces. Branded seeds are powerful signifiers of social relationships; they can symbolize patronage or clientship and represent connections to kinsmen, traders, or political leaders and can be markers of sophistication, modernity, or social connection (see Mosse 2005). Seed technologies may also be "political technologies" (Winner 1999) party to certain forms of social ordering, embodiments of power and status. Even if subject to the logic of fashion, hybrid seeds can be statements about identity relationships, or aspirations. What are the (social) costs of making the wrong brand choices? Why do these costs differ with class (or caste or gender)? When do they cross village boundaries? The language of the "fad" forecloses exploration of such themes by separating style from function in the anthropology of technology.

Second, if farmers cease to attempt to discriminate the agro-ecological performance of different seeds but continue to discriminate their social meanings, does this mean that they are agriculturally "deskilled"? Perhaps, but such a judgement bifurcates cultivation again into its "agro-ecological" and "sociocultural" elements in a way that may not be true to agricultural practice. If cotton farmers in Warangal are like many elsewhere in India (Gupta 1998; Vasavi 1994), they do not divide practice cleanly in this way.

Crop *research*, however, is premised on the isolation of seed characteristics from the full range of factors involved in the social practice of cultivation, which include not only localized, contingent, and short-term agro-ecological factors but also the negotiation of social relations for input supply and credit and managing debt relations, family obligations, gender relations, or market connections. Experts impose a decontextualized view on farmers when offering an interpretation of farmers' choices and making this the criterion for success or failure of new technology. Stone notes this but faces the problem of rendering social relations of cultivation arbitrary once separated from agro-ecological payoffs. Something similar can happen in the case of "alternative" participatory approaches. By making farmer judgement on new technology a matter of local agro-ecology but not of social relations these approaches socially disembed this knowledge so that it can be accepted as science (necessary for variety certification) (Mosse 2005).

Constructions of the "scientific farmer" necessarily ignore the way in which South Asian farmers actually make judgements about technology. The genetic and general advantages of new seeds marketed by seed companies or produced through participatory selection and breeding tend to disappear or become indiscernible when re-embedded in specific complex ecological and social contexts. The problems or opportunities of cultivation are to be found not in the nature of technologies but in the wider relationships they entail.

Indian farmers' response to new seeds is often inconsistent with experts' assessments for the simple reason that their judgements do not separate seed characteristics from the wider culture and politics of cultivation.

All this may be self-evident to Stone, but his discussion has the effect of distributing farmer rationality unevenly between the technical and the social. In the end his important challenge to classic innovation-adoption theorists is offered entirely in their own terms. If convinced by his evidence, plant breeders and seed-company salesmen will also regard cotton farmers as deskilled fad-followers. But should anthropologists?

If cultivation is always a cultural practice, it cannot be analysed in narrow functionalist terms. The genuine imbalance between environmental and nonenvironmental signals that Stone's research on hybrid cotton discovered does not require an analytical asymmetry that reduces consumer choices to "fads" or skills in agriculture to their agro-ecological element.

Conventional extension ignored farmers' rational reasons for rejecting "improved" seeds, labeling them ignorant. Do approaches which label noninstrumental reasons for adopting popular varieties "faddism" (rather than considering them social and political effects) serve them better?

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Why do Andhra Pradesh farmers appear to have abandoned the local knowledge and small-plot experimentation so often associated with the "performance" of agriculture (see Richards 1989)? Does this suggest that conventional innovation and adoption theory needs to be turned on its head? These are just two of the questions posed in this fascinating paper. In India, of course, there has been much interest in the genetically-modified-crops debate, but, as Stone shows, much of this work (e.g., Qaim et al. 2006; Morse, Bennett, and Ismael 2005) misses the point. In many respects a focus on these crops is a diversion from a much larger and possibly more important issue—how farmers deal with increasing uncertainty and ignorance in decisions about technology choice.

In the past, crop-planting decisions were made on the basis of experience and experimentation. Local knowledge of seeds and their diverse agronomic responses was well established, and a repertoire of options associated with different field ecologies evolved. Choices were focused on the diversity of well-known local seeds and a limited array of new varieties. Such varieties usually came through public research and extension systems or the movement of people and were therefore associated with trusted knowledge. This pattern is well described in numerous examples of "indigenous" seed systems (e.g., Richards 1985; Tripp 2001*c*) and has been seen as the model for participatory approaches to research, field experimentation, and evaluation (e.g., De Boef et al. 1993; Sumberg and Okali 1997).

As Stone shows, this rather idealized and caricatured "past" no longer exists. Numerous uncertainties and sources of ignorance impinge on farmers' decision making, and the slow, deliberate accumulation of environmental and social learning is therefore not possible. Instead, farmers must cope with a combination of three types of interacting uncertainty: environmental, agronomic, and market. Stirling (1999) distinguishes between decision making about technology under conditions of risk (where probabilities of outcomes are known), uncertainty (where the full range of possible outcomes is not known), and ignorance (where we don't know what we don't know). In most conventional decision making, the likelihood of something's happening and the type of outcome are known, at least in probabilistic terms. This is where field experimentation and the resulting accumulation of local-level knowledge works well. Much decision-making about most crops still falls into this category, but in the case of genetically modified cotton under the environmental, agronomic, social, and market conditions of Warangal, this is clearly not the case.

But are "fads" an expected response to uncertainty or ignorance? The standard policy recommendation is to go carefully and develop approaches to adaptive learning (Stirling 1999), but village-level fads seem very risky behaviour. The key to understanding them is hinted at in a short section on the ethnographic context for seed markets: it is in particular the social underpinnings of "real" markets (see Hewitt de Alcantara 1993) which have added to farmers' challenges in the post-liberalization context. Since the reform of the seed market from the late 1980s, numerous seed companies compete for business through a complex array of licensing deals and sometimes illegal pirating arrangements. After the formal approval of genetically modified cotton in 2002, the multinational Monsanto licensed its Bt product to a number of different seed companies, each with its own portfolio of cotton seed. In addition, others have created pirate copies by backcrossing into their own varieties. Within the broader seed market and its genetically-modified-cotton segment in particular there is tough competition involving advertising, branding, attractive packaging, and incentives for dealers (Scoones 2006). In Warangal (as distinct from other areas), moreover, genetically-modified-cotton seed is sold largely in one-acre packs, making small purchases for field testing and experimentation less likely. Strong pushes of particular seed varieties in particular villages, combined with a sense of safety in numbers, probably account for the waves of adoption observed across several seasons before a more general adoption of one Bt cotton variety in 2004–5.

How might farmers be helped to deal with these uncertainties, particularly in a liberalized market setting? For example, what independent field demonstration and product certification efforts might help? Who might act as arbiters of trusted information for consumers in a complex market? What role might new information technologies play in sharing information with users? Answers to these questions will of course depend on the trade-offs between doing nothing and intervening. Where potential risks to livelihoods, health, or environment arise in the laissez-faire scenario, the case for precautionary intervention is evident. Yet farmers must learn to cope with uncertainty and ignorance.

Shifting our attention to the challenges of "reskilling" is critical in thinking about how farming livelihoods must interact with a fast-unfolding technology and market context. It is far from the case that all the technology is simply "in the seed." In this setting, as Lao Tzu (quoted by Stirling 1999, 19) observed, "Knowing one's ignorance is the greater part of knowledge."

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Stone's analysis is insightful and disturbing. His account of cotton growing in Warangal District leaves me wondering what farmers' seed fads tell us about the nature of the technological change. My purpose in engaging with Stone's perceptive ethnography of deskilling is to examine this question by comparing the Warangal situation with Bt cotton cultivation in western India.

Stone and I independently started with the same mission: to explain the popularity of genetically modified cotton seeds. Stone went south to Andhra Pradesh and I went to Gujarat in western India, and we seem to have ended up in two different places that are not necessarily contradictory. In Gujarat, in contrast to Warangal, experimentation preceded the adoption of Bt cotton seeds. The illegal Navbharat 151 seeds are being multiplied and cultivated only after experiments informally conducted by farmers. It was widely understood among seed-producing farmers that the Bt male parental line, though essential, was not the key; it was the female parental line that determined performance and stability under local agro-ecological conditions. After experimenting with several locally available female seeds for three to four seasons in the late 1990s, farmers finally settled on the female of GujCot 8. Considering the fact that the category of "farmer" is rife with social and historical heterogeneity, my main concern was to understand who among farmers continued to cultivate cotton in the midst of uncertainty and risk and how. Drawing on Richards's (2004) discussion of technological culture, I have argued elsewhere that the smooth incorporation of genetically modified seeds into social and agrarian space in Gujarat reflects the continuation of the Green Revolution paradigm (Shah 2005). The cultivation of genetically modified cotton has sustained and reinforced the hegemony of global and local elites. The *how* part of the discussion relates my arguments to Stone's.

The historically and socially powerful cotton farmers of Gujarat have compensated for the work of nature (militant resurgence of pests and scarce water) by modifying the nature of work (Gidwani 2001). They have experimented on the strength of their control over surpluses of skilled labour, a legacy of the Green Revolution paradigm. The difference between knowledge and skill is acute here. Cotton-growing farmers, when knowledgeable, rarely perform agricultural tasks that require embodied skills; much of performance-oriented cotton cultivation is left to lower-caste sharecroppers or tenants. Similarly, the hybrid-seed-producing industry in northern Gujarat traditionally employs child (largely female), tribal, migrant labourers from the neighbouring state of Rajasthan. The same is true of the production of hybrid Bt seeds. A large number of poorly paid and often physically abused, mainly young female labourers (aged 10–14 years) carry out the controlled and delicate process of cross-pollination (Katiyar 2006). In contrast to Warangal farmers, Gujarat farmers have a balance between environmental and social learning. The question is how this balance is achieved and what it indicates about the technological paradigm.

Seeds are sometimes considered biological artifacts (Fitzgerald 1993). No matter how much they are engineered, however, they still behave as nature behaves: unpredictably. Several biophysical traits that the engineered seeds continue to possess grant them a degree of ontological independence from the human world. The epistemology of improved seeds embodies this tension between biology and artifact (Yapa 1993). Without overlooking the tension, I intend to argue from the artifactual side.

One of my favourite descriptions of technology attributes its existence to replicability (Pfaffenberger 1988). Not only is it reproduction through the social organization of labour that makes technology work but in producing itself technology produces its potential to be reproduced (Sangren 1995). In other words, understanding what is reproduced and how it is reproduced may provide a vantage point for normatively confronting technological change. In my interpretation, the deskilling of Warangal farmers is a disruption of the reproduction of technology that hints at the problematic nature of technological change. The example of thriving Bt cotton cultivation in Gujarat based on the enskilling of highly exploited female child labour points in the same direction.

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This paper provides a very useful field-level window on the introduction of a genetically modified crop in a developing country, admirably free of the easy answers from the opposing camps that tend to dominate this debate. But its principal contribution seems unrelated to the genetic-modification controversy and instead addresses more general concerns about peasant agriculture and commercial input markets.

Stone contrasts environmental and social learning, although acknowledging that the two are not perfectly distinct. The basic question is whether farmers experiment with new crop varieties before making choices (environmental learning) or rather rely on advice from or imitation of other farmers (social learning). He amply illustrates that these cotton farmers do not develop, seek out, or take advantage of much of the information that might be available to them. One of the most remarkable pieces of evidence is what is *not* in the paper. All of the discussion is about the yields of various Bt cotton hybrids, while one of the most controversial issues is whether the Bt trait (for which farmers are paying four times the normal seed price) is efficacious. There is no mention of any farmer's discussing whether using a Bt variety has permitted savings on insecticide expenses or controls the insects it is supposed to, even though in the Indian environment (with exceptionally high pesticide use) Bt cotton should be seen as much as a cost-saving innovation as one that offers only (possible) yield advantages.

One contribution of this study is to challenge many of the notions we anthropologists hold regarding farmers' abilities to fine-tune crop-variety choices (or other technologies) to their individual circumstances. Commercial, transgenic cotton seed is admittedly an extreme case, but it points to the need for a more realistic assessment of capacities and limitations in other farming environments. The fact that the varieties planted in most traditional farming systems are generally well suited to farmers' needs is evidence of an effective process of trial-and-error selection but not necessarily an indication of the type of experimental capacity required to deal with the short-term choices (in a complex climatic, biotic, and economic environment) described in this paper. It is certainly relevant that Iowa farmers used 30% of their fields to experiment with the early maize hybrids, but in most cases that proportion represents vastly more land than the entire holdings of these Indian cotton farmers. Smallholders regularly test small quantities of new varieties (commercial or local), but it appears that many of these Andhra Pradesh farmers do not have much land to set aside for a trial (and when the smallest packet of seed costs $38, experimentation becomes a luxury unless it can be shared with others). Many of these farmers try several varieties, but their continual switching indicates that they are rarely satisfied with the results and continue to search in the desperate hope of escaping the low productivity and indebtedness that characterizes this environment.

It is particularly important to examine the practical implications of this analysis. We do not want to see the choice framed as between (*a*) encouraging farmers to practice individual field-level experimentation to rediscover skills they may never have had or (*b*) remaining at the mercy of marketing propaganda, rumor, and political influence. It is obvious that these farmers are disadvantaged by the way seed markets are conducted, the lack of any government attempt to help them deal with those markets, and the cacophony of NGO "voices" offering alternatives. The solution is to see farmers not as retreating to the type of environmental learning represented by locally saved seed and (idealized) skills in experimentation but as organizing to gain access to better information and some control over these markets. Whether this is classified as "environmental" or "social" learning is not important. Farmers certainly have to be aware of their environments and the peculiarities of their own fields, but experimentation can be done in a more orderly and comprehensive way (e.g., through farmer organizations or university trials) and communicated as principles (e.g., this variety does poorly on sandy soils; that one is good for intercropping) that farmers can apply to their individual circumstances. Addressing the deception and political control that characterize some of these seed markets is a major challenge and one that would seem to require "social" responses such as the development of independent sources of information, local political organization, and the establishment of more effective consumer protection. The analysis presented in this paper is exceptionally relevant to making those arguments, although the deskilling/reskilling vocabulary may not be the most effective way of conceptualizing useful interventions.

Reply

I am grateful for the commentaries from this group of distinguished scholars. There are more points raised than I can reply to, but I will address comments falling into the three areas of (*a*) interpretations of the seed fads, (*b*) larger theoretical contexts for these fads, and (*c*) what might practically be done about deskilling.

In the first category is Mosse's interesting perspective on the social function of seed choice. He asserts that seed selection may be driven by kin, political, or economic relationships or may express identity—social functions that cannot be neatly cleaved from agro-ecology as we do in our constructions of the "scientific farmer." This is a valuable perspective on seed choice that I engaged only briefly. However, I lack Mosse's certainty about "the way in which South Asian farmers actually make judgements about technology." I urge caution about essentializing a South Asian decision-making process and about assuming we know how it "actually" works. In Warangal, seed choice is tenuously linked to kin relationships (as I show for Kalleda village); it could be seen as related to expression of identity in the limited sense that farmers seek to hitch their fate to that of their village-mates. Beyond this, it is not clear how expression of social relationships explains the serial fads documented in Warangal.

In different ways, three commentators seek greater functionality in the seed selection process. Joly posits that seed fads are expectable given that genetic differences among cotton seeds are so small; the point, I assume, is that farmers understand that seed choice makes little difference. However, product homogeneity in itself does not explain faddism; the differences between toothpastes, cigarettes, and mainstream American beers are certainly small, but most consumers show brand loyalty. More important, genetic differences are not small; there are several axes of variability, although the variability is extremely hard to "skill on." For instance, cotton seeds vary in staple length, boll size (which affects harvesting costs and also susceptibility to insect damage), and the related traits of duration (short-season seeds may stop producing after five months, but with irrigated long-season seeds it may be eight months) and water requirements. Seeds differ in disease resistance: a bacterial disease in 2004 ravaged some cotton seeds but not others. (Some of Mahyco's brands were especially susceptible; though the fact that these were also Bt seeds was irrelevant, there was devastating press coverage of the "failure of Bt cotton," and Mahyco Bt seeds were subsequently banned in Andhra Pradesh.) The most dramatic genetic diversity comes from spurious seeds, which can lead to complete crop failure. The seed companies themselves also vary from large, well-established firms with well-known seeds backed by germination/purity guarantees to small fly-by-night companies preying on the farmer penchant for new seeds. Genetic modification has now brought a new class of genetic diversity: there are numerous seeds containing a Bt gene, differences in expression among those seeds, seeds that lead farmers to believe they contain the Bt gene but do not, and others that will in the future contain a different Bt gene.

In a similar vein, Cleveland asks if farmers are trying to capture small yield differences by emulating prosperous experiment-oriented farmers. Farmers surely would love to capture wisdom generated by other farmers' experimentation, and so they do often look to prosperous farmers and to local trends. But what figure 8 shows is that large landowners rely more on novice plantings, not that they experiment more; they tend to plant most or all of their cotton land in a new seed each year. What the crowd is planting is not the seed that prosperous farmers have discovered through experiment but rather the seed that prosperous farmers are trying (or tried the year before). Emulating successful farmers and/or emulating the majority may seem obvious adaptive strategies, and in many situations such forms of social learning may capture knowledge generated by better-connected and more experiment-oriented farmers (McElreath 2004). But in the Warangal cotton case, the data on experimental planting and village fads show experiment-based environmental learning to be thwarted for understandable reasons: there are too many options on the market, too rapid change in those options, and too little correspondence between package and seed. This is an alarming problem rendered largely invisible by our "wise farmer" orthodoxies and now by biotech firms suddenly appreciative of the wisdom of farmers who buy Bt seeds. I do not see how the resultant seed fads could be modeled as a way to make optimal use of information available; they seem more a symptom of what Tripp calls "desperate hope."

Herring takes this search for functionality to the extreme by suggesting that disruption of the skilling process may be a good thing. He envisions a past when cotton farmers were "more skilled" yet worse off because yields were lower. We do not have data on the skilling process generations ago, but we do know that the lower *average* yields of cotton before the spread of hirsutum hybrids were much more predictable as well; farmers knew better what they were planting and could make management decisions based on their own and neighbors' learning. But a more important flaw in Herring's reasoning is that the best case for rising cotton yields is in Gujarat, where there has been more reskilling than deskilling. Herring's question of why deskilling occurs in Warangal but not Gujarat is a good one, and I included the comparison to answer it. Primary causes of deskilling in Warangal are inconsistency, unrecognizability, and accelerated technological change. These are characteristics of a chaotic, poorly regulated cotton seed market with a superabundance of ephemeral products in which farmers are completely out of seed production and largely out of experimentation. We do not know the extent to which such conditions and seed fads occurred in Gujarat in the past, but since 2000 Gujarat cotton fields have been taken over by seeds that are locally bred, often by farmers. Gujarati farmers have access not only to locally adapted Bt seeds but to greater consistency and recognizability and more measured change in a seed supply that they have a hand in generating. My conclusion was that the experimentation process is alive and well in Gujarat, and Shah confirms this.

Herring feels that the common term "genetically modified" is a political construction because the genes in all crops are in some sense modified. This earnest attempt to change the meaning of the term will be familiar to all who visit biotech industry web sites. In fact, the descriptor "genetically modified" appeared only in the 1970s specifically to denote organisms containing the new recombinant DNA technology (readers are referred to the *Oxford English Dictionary*). "Genetic modification" does not apply to ancient processes of domestication any more than "Native American" applies to me on the grounds that I was born in Charlottesville. Whether Herring's lumping genetic modification with domestication is itself a political construction I will let the reader decide.

Joly's suggestion that the RCH2-Bt fad was not by chance but rather the result of Mahyco's clever manipulation of seed faddism does not hold up; RCH2-Bt is produced not by Mahyco but by its competitor, Rasi Seeds. But it is true that seed companies seek to exploit seed faddism, and we can point to specific strategies by which they do this. One is the constant formation of new seed companies and continual introduction of new seeds. The flood of new seeds capitalizes on *and perpetuates* farmers' indifference to their own environmentally based skill. Another strategy is the recruitment of the emulatable big farmers that I described for Gudeppad. Demonstration plots on such farms are a mainstay of seed marketing campaigns, but the Warangal case shows that what is really demonstrated is not the seed's performance (the bottom line of input costs and market income is impossible to assess in a field visit) but who is planting the seed.

The second area covered in commentaries is attempts to place the Warangal case in larger theoretical contexts. I agree with Scoones and Busch that ultimately the issue at stake here is control of information. Scoones posits that if experimentation and trusted knowledge are being replaced by uncertainty and ignorance, then it behooves us to analyze uncertainty. His suggested parsings of types and levels of agricultural uncertainty offer an interesting framework for further research on social responses to uncertainty. Busch sees the situation as one of information asymmetry, and I concur, although there is an irony in the metaphor of the used-car lot. The car salesman normally does have information on the strengths and weaknesses of the car, but the buyer normally doesn't trust the salesman (and wants to test-drive the car and have a mechanic inspect it). The seed vendor often *doesn't* really know much about the seeds in his shop (especially the new brands that pour onto the market), but the farmers tend to place great trust in vendor recommendations.

Dove puts this case in the context of other striking seed shifts, such as the Green Revolution and colonial-era crop commodification; he asks if the Warangal fads are really different, if India today is really as uniquely modern and hybrid as some believe. Shah too draws a parallel between adoption of genetically modified seeds and the Green Revolution. I agree that Warangal's agricultural predicament is not uniquely "modern," but the comparison with Green Revolution seeds is complex. Common to the Green Revolution and to the spread of hybrid and then Bt cotton is an increased reliance on external sources (mainly for fertilizer and breeding). But in terms of the agricultural deskilling process analyzed here, I would point out that Green Revolution seeds lacked the unrecognizability, inconsistency, and hyper-rapid change (the initial wave of fertilizer-responsive seeds was followed by variants that did pose problems in recognizability [Tripp 2001*a*], but there was nothing like the churning of the cotton seed market in Warangal). Green Revolution seeds may be faulted on various grounds, but they do not appear to have significantly impeded farmers' ability to keep acquiring the information they need to make farm management decisions.

Brush looks at this case in the context of new technologies realigning skill sets, citing the American corn farmers who did not need the breeding skills lost to the seed industry because they could use the output of a vast system of professional breeding and genetic diversity. Clearly, when technologies and institutions change, skill sets or the details of the skilling process change. But as I have defined it here, the loss of an obsolete skill set does not constitute agricultural deskilling, and U.S. maize farmers, despite the fact that they have been labeled "deskilled" (Fitzgerald 1993), provide an important contrast to Warangal. U.S. farmers' breeding skill was rendered obsolete by the advent of large-scale formal corporate seed systems because the farmers were able to access the fruits of those larger systems. They were able to choose what to plant, in part because seeds tended to be recognizable, consistent, and subject to moderate rates of change.[1] In addition, U.S. farmers now can also hire commodified skill in the form of agricultural consultants (Wolf 2005). But in Warangal, the impeded skilling process is still vitally needed.

Busch's praise for the Honey Bee network (which scouts, publicizes, and helps acquire intellectual property protection for Indian innovations) leads to a larger point about indigenous innovation, assessment, and diffusion. Given the pathologies documented in this article, one worries if indigenous innovation per se is in trouble. This is not the case; the aim here is to present a particular situation that shows what can go wrong with innovation diffusion and to isolate the underlying causes. Where these causes are not present, Indian farmers continue to display great resourcefulness and innovativeness.

The third area broached by commentators is the practical ramifications. Commentators ask what could be done in Warangal. Scoones raises the possibility of using information technology; this prospect has captured the imagination of many, and indeed there is a new program that uses Internet and digital imagery to connect a team of experts in Hyderabad with farmers in a heavy cotton area near Warangal (Krishna Reddy and Ankaiah 2005). The question is whether there is anyone in Hyderabad who actually knows how to farm successfully in this uncertain environment. In some special situations, electronic information delivery may help: examples are market trends for farmers deciding when to sell or the diagnosis of an unfamiliar crop disease. But the answer to crucial, perennial questions such as which of the 134 cotton seeds to plant this year is not taught in the programs that train agricultural experts. Might information from other sources be disseminated through India's impressive communications infrastructure? Perhaps. Tripp, while (wisely) advising against trying to return to an idealized seed-saving past, suggests trials by farmer organizations or universities. This might, in Busch's terms, improve the symmetry of information. Information technology can be part of a solution only after the root problem of disrupted skilling is mitigated.

In fact, the innovative head of the Warangal Agricultural Research Station, Jalapathi Rao, has been trying to institute a publicly run program in which farmers are directly involved in the production process, including maintaining parent lines and producing hybrid seed. This could, in theory, lead to more consistent, recognizable, gradually changing seed products and allow local fields to function better as experiments. However, none of the parent seed lines being developed for this program contained Bt, and the program was torpedoed by the 2005 stampede to Bt cotton described in this article.

—Glenn Davis Stone

1. This is a relative statement; the U.S. seed system clearly does not always provide recognizability (Ziegenhorn 2000), consistency, and moderate change.

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