Whose Numbers Count? Resolving Conflicting Evidence on Bt Cotton in India

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What's at Stake in Pro-Poor Biotechnology?[1]

Biotechnology in agriculture has raised a globally contentious politics; effects on the poor have figured prominently. If opponents of transgenics are correct, but proponents win politically, lives of the poor could deteriorate further for want of better technology. If proponents are correct, but critics win politically, inappropriate policy toward biotechnology could have adverse consequences for the poor – both poor nations and poor individuals. In addition to denying superior technology to individual farmers, cost advantages of transgenic production adopted only by richer farmers in richer countries could produce a backwash effect of lower prices for poorer farmers as a class, unable to compete for lack of technology (Lipton 2007). One can easily imagine development of a technological divide in agriculture comparable to the global digital divide in information. Precautionary approaches are therefore not costless: the status quo is hardly risk-free for the world's poor, technologies are changing rapidly, markets are global. Proponents of genetic engineering argue that alternatives means of plant breeding are costlier, slower, less certain, or in some cases impossible.[2] The global shift in the policy and scientific community has been toward a settled science endorsing genetic engineering with precautionary caveats (Herring 2007a).

India was for some time been caught between these alternatives, as have been activists in social movements claiming to represent farmers, the poor and the environment. Cotton received attention first: yields are low in global terms, but India has more land under cotton than any other nation. Pesticide contamination from cotton cropping is extreme, affecting workers, soil and water. Bt cotton is designed to alleviate some of these constraints on production and externalities. On March 26, 2002, India became the 16th nation in the world to certify a genetically altered crop for commercialization, in the face of ferocious opposition. Since then, there has been a veritable explosion of entrants into the transgenic seed arena in India, some sanctioned by the state and some generated by an opportunistic rural anarcho-capitalism enabled by biotechnology.[3]

India's Prime Minister Atal Bihari Vajpayee stated on September 7, 2001, that national policy was for "shaping biotechnology into a premier precision tool of the future for creation of wealth and ensuring social justice – especially for the welfare of the poor."[4] In the Prime Minister's vision statement, biotechnology was to increase agricultural production, fight obdurate diseases, combat nutritional deficiencies and protect the

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[1]For the conference *Q-Squared in Policy: Use of Qualitative and Quantitative Methods of Poverty Analysis in Decision-Making***.** Centre for Analysis and Forecasting (CAF) Vietnamese Academy of Social Sciences (VASS) Hanoi, July 7-8, 2007.

[2] E.g. some forms of biofortification. See Bouis 2007. Also, Herring Ed. 2007.

[3] The latter is more pro-poor than the former, as property rights disappear from the equation. Anil Gupta has called the situation in Gujarat "the greatest participatory plant breeding experiment in human history (pers com 2004)." The experiment has been vigorous, but entirely illegal, though Delhi has been unable to do anything about it. See Herring 2005; Jayaraman 2001; 2004.

[4] Department of Biotechnology 2001.

environment. Any and all of these outcomes could be pro-poor if realized. In agriculture specifically, pro-poor arguments for biotechnology lines assume scale neutrality in seeds and property arrangements that do not exclude poorer farmers. Most important, the government's argument assumes agronomic and biological success of transgenic crops: this has been the point of contention.

Mr. Vajpayee's hopeful policy scenario has been countered by stories of rural catastrophe.[5] Much of the world, especially in the organized popular opposition to globalization, believes that farmer suicides are increasing in India, and that Bt cotton has contributed; the discourse is of "seeds of death" or "suicide seeds." The discourse of suicide seeds began in 1998, coterminous with the launching of "Operation Cremate Monsanto." In Curitiba, Brazil, in 2006, transgenic cotton seeds in India were characterized not only as "homicidal," but even "genocidal." Much of the world believes that not only has "Bt cotton failed in India," as numerous reports have said directly, but that "tens of thousands" of farmer deaths have resulted. Farmer catastrophes were joined by reports of deaths of sheep that eat Bt cotton leaves (February 2006), later joined by reports of death of cows (February 2007). In both cases the suspiciously consistent number of 1,600 deaths appeared; both incidents came from NGOs in Andhra Pradesh.

These constructions of ground realities are not without consequences: activists convinced the Government of Andhra Pradesh, for example, to ban two hybrids of Mahyco-Monsanto Biotech Ltd. ***on agronomic grounds***, even as seeds with the same transgene were spreading rapidly among farmers. In Warangal district, Mahyco-Monsanto was forced to pay compensation for a "failure of their Bt cotton," despite absence of evidence of failure of those specific hybrids.[6] Responding to opponents' briefs, the Supreme Court put a moratorium on further development and testing of Bt plants, though evidently cotton may remain [mostly] legal.

Despite court stays and state-government bans, Bt cotton is spreading rapidly by all accounts, even those of biotech opponents. There are increasing numbers of Bt cotton firms and hybrids officially certified in India. Monsanto has made largish profits, the Chinese public sector has an approved hybrid with Nath Seeds and the Indian private sector has a new Bt hybrid. As of June 2006, there were 58 officially approved Bt cotton hybrids in India, and the number is growing; on a single day in 2007, 49 new hybrids were approved officially for cultivation. By any measure, Bt technology in cotton has spread rapidly and widely in India.

The Government of India approved the three original Mahyco-Monsanto Bt hybrids for cultivation in March 2002, the day after a rally of the Kisan ["peasant"] Coordinating Committee demanding de-regulation of Bt cotton. National civil disobedience was threatened if the Government did not approve transgenic cotton hybrids. In fact, approval

[5] E.g. Shiva and Jafri 2004; Shiva, Emani, and Jafri 1999; Shiva et al. 2000; Rao 2004.
[6] I discovered in Warangal district, December 2006, that some farmers still prefer MECH 12 and travel to Nanded in Maharashtra by bus to obtain the banned seeds. Some of these farmers received compensation for crop failure in 2004 "and also we got the crop."

was largely a *fait accompli*, as two state governments had already agreed to farmer demands – Gujarat and Maharashtra (Herring 2006). Bt cotton was not officially for sale until the cropping season of 2002-2003; by 2003, the area under official Bt hybrids came to 230,000 acres; in 2004 this area expanded to 1,213,359 acres and to 3,212,300 acres by 2005. The NGO ISAAA estimates official Bt plantings on 7,907,200 acres in the 2006 planting season. Even by official data, the adoption curve is very steep, as it has been in China.

But ISAAA's estimates, and the government's numbers, and thus international numbers for Bt cotton adoption in India, count only official seeds—i.e., varieties vetted by the Genetic Engineering Approval Committee in Delhi on biosafety grounds. But long before official approval, farmers were growing Bt cotton in stealth mode. The first underground Bt utilized Monsanto's transgene, beneath the radar screen of both firm and state. No one knows the actual area under what I have called "stealth seeds," but ISAAA estimated in 2005 this area to be double the area under official seeds[7] Numbers for officially reported area in transgenic cotton have always lagged behind the actual transgenic area, for obvious reasons: the dozens of farmer-bred Bt hybrids are illegal. Even at this level, we are reminded of the caution to recognize data as social product: conditions of production affect the relation of numbers to reality (Herring 2003).

In summary of a very dynamic situation, it is certain that official Bt seeds are spreading to more farmers and acres very rapidly; in most cotton areas, Bt seems dominant. Additionally, unofficial seeds – variously called "indigenous Bt" or "*deshi* Bt" or "Navbharat variants" -- have become a cottage industry, especially in Gujarat.[8] The reason for more rapid adoption of illegal over legal transgenic cotton is primarily price,[9] though some farmers believe stealth seeds are better adapted to local conditions: new varieties are produced by hybridizing the transgenic with a local variety (Gupta and Chandak 2004; Roy et al 2007).[10]

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[7] See Herring 2007b for comparisons of the same phenomenon in Brazil for transgenic soy. Also Roy et al 2007.

[8] Jayaraman 2004 cites "industry sources" as estimating that more than half the transgenic cotton in India comes from illegal varieties; my discussions with Gujarati seed producers and farmers in 2005 suggest a much higher figure for that state. Data from Navbharat Seeds indicate that on an all-India basis, about 34 percent of the cottonseed packets sold are transgenic, of which 9 percent are legal and 25 percent illegal. These estimates apply only to packaged and branded stealth seeds – *Viraat, Rakshak, Agni, Vasach*, etc, and do not include F2 seeds saved by farmers for replanting.

[9] Price ratios were initially very steep: F2 Bt seeds I found in Gujarat in 2005 were selling for Rs 10 for a 450 gram packet; the same packet of locally produced stealth seeds was Rs 300-500; official Bt seeds sold for Rs 1450-1800 per packet. Prices have predictably converged, though F2 seeds are still by far the cheapest, by an order of magnitude.

[10] As prices of the official seeds have dropped significantly all over India for both market and political reasons, the underground seed market in transgenic cotton will decline in relative terms. Transgenic Cry1Ac seeds are now typically Rs 750 per packet.

A great puzzle is then set: if, as most NGOs active in the arena claim, Bt cotton has failed, why would farmers adopt, and even save the seeds of and breed, plants that will ruin them financially? Why would capitalist enterprises license expensive technology that does not work? Are Indian firms and farmers irrational?

Divergent Studies

Measuring yields and returns of cotton is not exactly rocket science. [Though it is not easy, either.] But the numbers on Bt cotton agronomics and economics diverge dramatically.

Studies showing higher Bt yields and farmer profits are consistent with an emergent international consensus on pro-poor biotechnology that is scale-neutral (Herring 2007a: 6-9). The early large-scale studies were distrusted on several grounds in the NGO sector. Most important is that these studies tend were corporate sponsored, as they are expensive, and are in the mode of industrial research, farmed out to consulting firms with shifting survey personnel. They represent the antithesis to local knowledge. Macro studies by government agencies – e.g. the Indian Council for Agricultural Research – are rejected as well: the government has itself become a proponent of the technology, and cannot be trusted to produce objective science. Paralleling everything else in India, we may think of the studies as falling into two sectors: formal and informal.[11]

The earliest data came from the formal sector, mandated by the state. Open field trials were required by the operating rules of the Review Committee on Genetic Manipulation (RCGM) and the Genetic Engineering Approval Committee (GEAC), both statutory bodies of the Union government of India. Mahyco-Monsanto conducted the first open-field trials in 1998-99, under supervision of the RCGM of the Department of Biotechnology. The results were precisely as the technology promised: increases in harvested yields of 37-40%, reduction in pesticide application, and reduced damage to cotton bolls by bollworms.[12] Though seeds were expected to be more expensive than conventional hybrids, reductions in pesticide expenditure were expected to make the technology essentially scale neutral and thus attractive to the smallest farmers under Indian conditions (Naik 2001). Because of protests by anti-biotechnology NGOs, additional trials were required in 2001 and were monitored by the Indian Council of Agricultural Research. These trials resulted in similar findings: net economic advantages of Bt seeds over local and national checks in the range of Rs 4,633 to Rs 10,205 per hectare (APCpAB 2006:16). Physical improvements in yields were higher than earlier studies, indicating a very important biological point often missing from the literature: the value of the trait added by biotechnology – the endotoxin lethal to bollworms – varies

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[11] This discussion cannot be exhaustive in study coverage; some studies in the informal sector are referred to only obliquely and are not widely available. I will essentially use stylized facts to demonstrate the central tendency of divergent outcomes of studies.

[12] See APCoAB 2006: 15; Naik 2001. For similar results, for Maharashtra, see Bennet et al 2004.

with density of insect infestation, year by year, field by field.[13] There are years in which the Bt toxin may yield little benefit, and years in which the absence of Bt may produce complete crop loss, as in the "bollworm rampage" of 2001 in Gujarat (Herring 2005).

These formal-sector macro studies suggested effective technology addressing a perennial source of agronomic failure in cotton areas: bollworm infestations and the high cost of increasingly ineffective and very toxic pesticides.

Opponents of genetic engineering had a different story to tell. Gene Campaign carried out a study of 100 farmers in Andhra Pradesh and Maharashtra that concluded quite the opposite of the emergent consensus: Bt yields were 15% lower than non-Bt yields; Bt fibers were shorter and weaker; net returns to Bt were lower than to non-Bt.[14] Indeed, net returns on low-yield farms were negative, a loss of Rs 79/acre. This study found not only economic, but biological problems in Bt cotton. Plants lacked size and vigor, bolls dropped early, boll size was small and lacked density on the plant, fibers were shorter and the cotton was graded lower in quality.

These conclusions are supported by a three-year assessment of Bt cotton in Andhra Pradesh by the Deccan Development Society in Hyderabad (Qayum and Sakkhari 2005). They found significant reduction of yields, and large net losses to farmers growing Bt cotton. Not surprisingly, 78% of the farmers said they would not grow Bt again (p32). Moreover, they reported that Bt cotton received Rs 200-300 less per quintal in the market because of low fiber quality. Farmers complained as well of small bolls that were hard to pick, with too many seeds in the boll (p 45). This comparison used the official seeds of Mahyco-Monsanto, mostly MECH 162 and MECH 12 in comparison to "non-Bt hybrids." Both MECH hybrids were subsequently banned by the AP government, largely because of reports of this nature in the state, especially in Warangal district.

In a similar vein, Shabana Zahoor's 2004 paper – "Bt Cotton in India: Two Years of Failure" -- finds that failure is both biological and economic. First, the "Terminator Technology" means that farmers incur extra expense purchasing new seeds every season, and cannot re-sow saved seeds (p 2). Short staple lengths incur a price penalty in the market (p 12); bolls were small, plants were short, and there was evidence of premature drying and boll shedding; Bt cotton was less tolerant of abiotic stress; Bt hybrids allowed fewer pickings, and there were twice as many seeds as non-Bt. The paper reports a great increase in the presence of sucking pests, based on the RFSTC study (p 11). Zahoor's study is also heavily dependent on the "Gene Campaign Study" and studies of the Andhra Pradesh Coalition in Defence of Diversity and the Deccan Development Society, mentioned above.

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[13] For farmers, this fact complicates the calculation of the insurance value of the Bt trait, as it varies continuously and unpredictably. Cf Roy 2006; Roy et al. 2007.

[14] These results were presented in a number of fora see: Sahai and Rahman 2003, Sahai 2003.

These small scale studies are typically organized by NGOs that have local talents and contacts, but not deep pockets. They are studies in agro-ecological pockets. It is interesting that there is no study -- micro or macro -- to my knowledge that finds similar agro-economic or biological failure in Gujarat. Indeed, small-scale studies in Gujarat confirmed the all-India macro-study conclusions of Bt success and for similar reasons: higher profits on farm because of better and cheaper pest management (Gupta and Chandak 2005; Roy 2006; Roy et al 2007). Why should a technology that by all accounts succeeds in Gujarat cause catastrophe in Andhra Pradesh?

Checking the Regional Hypothesis:

Speaking broadly, Andhra Pradesh has been the site of the earliest and most continuous Bt cotton disaster stories. Andhra Pradesh is the source of the most consistent failure literature and the only state to ban Bt hybrids and force Mahyco-Monsanto to pay compensation for the failure of its technology in 2004. Gujarat is at the other end of the spectrum: agro-economic success of Bt cotton is neither qualified nor controverted. From the beginning, it was understood that regional variations were of great importance: cultivars were officially approved only for certain zones of cotton agriculture in India. Thus regional variation in results might account for differences in evaluations of the technology. Is it possible that what has become the dominant technology and a cottage industry in Gujarat fails in Andhra for reasons of history, soil, climate, general agronomic variation?

It is true that the world's first hybrid cotton originated in Gujarat: Shankar 4. Perhaps the technology worked better in communities with superior experience with cotton hybrids. Moreover, the highly developed cooperative structure and extension services of that state might explain success in comparison with other regions of India. Aseema Sinha's (2004) comparative study of state-level developmental statism in India singles out Gujarat as especially effective in promoting investment and growth.

One approach is to look to adoption rates; if the technology is failing in Andhra, farmers would not be adopting it at the same rate as in other regions. In the ISAAA data, adoption of Bt technology was more rapid in Andhra than in other states: a gain of 250% from 2004 to 2005, a year after the state government was forcing MMBL to pay compensation for crop failure.[15] Andhra companies have licensed the technology and now sell their own Bt cotton varieties. Moreover, the seed breeding that produced the first and many believe most successful stealth hybrid – Navbharat 151 – was done in Mahbubnagar and Kurnool districts of Andhra Pradesh. Similar illegal Bt hybrids called *vijay* and *digvijay* were likewise produced and sold in AP before being shut down for lack of GEAC approval. Priti Ramamurthy has documented the extensive cotton hybrid seed market of

[15] The rate of change in cultivation of official *Bt* varieties varies quite a bit across states, but is everywhere increasing. Interestingly enough, Gujarat shows the smallest increase, 15.4%. The reason is almost certainly that the unofficial *Bt* varieties are so well established in Gujarat, and have been significantly cheaper than MMBL versions and are held to be agronomically superior by many farmers.

Andhra: it is the source of many of India's leading hybrids.[16] Glenn Stone's (2007) detailed empirical work in Warangal district, Andhra Pradesh, finds that farmers are adopting *Bt* cotton seeds with such alacrity that he could legitimately write of "more than innovation adoption, more than a tipping point: it was a craze." If there are agro-ecological reasons for Bt cottons to do badly in AP, presumably farmers and firms would have known of these, or found out quickly. To the contrary, both firms and farmers aggressively pursued Bt cotton technology in Andhra Pradesh, with no sign of turning back.

Limited data on cross-regional variations suggests similar results. Having marketed its three approved varieties of Bollgard Bt seeds widely in 2002 and 2003, Mahyco-Monsanto Biotech Limited sought to discover what experience farmers were having with their product.[17] ACNielsen was retained by MMBL for a nationwide survey. Their study involved field interviews with 1672 Bollgard cotton farmers and 1391 conventional cotton farmers in five states.[18] The results confirmed large regional differences, but consistently supported the agronomic theory behind Bt cotton: improved yields, reduction in pesticide sprays against bollworms and higher profits across five cotton-growing states: Maharashtra, Madhya Pradesh, Andhra Pradesh, Karnataka and Gujarat for the growing season 2003–2004 (Table 1).

Table 1: State-wise Comparison of MMBL (Bollgard) Bt Cotton Outcomes

State	Bollworm Pesticide Reduction		Yield Increase		Increase in Net Profit	
	%	Cost (Rs)	%	Q/ac	%	Rs/ac
Andhra Pradesh	58	1856	24	1.98	92	5138
Karnataka	51	1184	31	1.36	120	2514
Maharashtra	71	1047	26	1.48	66	2388
Gujarat	70	1392	18	1.20	164	3460
Madhya Pradesh	52	889	40	2.2	68	3876
All India Weighted	60	1294	29	1.72	78	3126

Source: (ACNielsen 2004a:1)

[16] See Herring and Gold 2005; Priti's latest work is not yet published.

[17] At the time officially approved seeds came to market – about three years after the Navbharat 151 Bt stealth seeds became available in Gujarat -- farmers were making cropping decisions in a national picture still dominated by the 'Monsanto-terminator-suicide-seed' hoax (Herring 2005; 2006). Monsanto was portrayed widely as a threat to India and to Indian farmers, and Bt cotton as a biological disaster: why would farmers buy into such a technology?

[18] For research design, see ACNielsen (2004). The text benefits from unpublished data collegially supplied by ACNielsen ORG-MARG researchers.

This study concluded that on an all-India basis the increase in yields in Bt [Bollgard] fields was approximately 30% or 1.7 *quintals* per acre, compared with “conventional cotton fields.” Net profits to farmers increased by nearly 80% or Rs. 3126 per acre. The largest percentage increases in profits came on the smallest farms, for predictable reasons (Roy et al 2007; Ramgopal 2006: 7). The major mechanism for higher profits was exactly as the endotoxin transgene theory would predict: “reduction in bollworm pesticide sprays … translates into an average savings of Rs.1294 per acre (reduction of 2–3 sprays per acre).” Since this survey was a marketing study, intended to find out how farmers were responding to Bollgard seeds, it is of interest that, of the surveyed farmers, “more than 90% of Bollgard users and 42% of non-users express their intention to purchase Bollgard in 2004. ”[19]

Far from being a site of transgenic disaster, Andhra Pradesh in this study falls in the middle of yield increases and pesticide reduction, but at the very top of increases in net profit. The ACNielson study finds regional variation, but variation within a successful technology. There results were replicated in subsequent studies organized by MMBL or utilizing their data, and the results were roughly similar.

No consistent regional explanation of divergence can then be sustained. But the convergence of macro-studies with success and micro with failure, however, resonated with NGO distrust of corporate science – or Government science. Corporate science is accused of making up net-return figures in early studies; indeed, Qaim and Zilberman (2003) used some of these data for an article in **Science** that produced something of a firestorm in India, and much criticism globally.[20] On the other hand, studies cited by Suman Sahai of Gene Campaign prove hard to track down; sampling and measurement remain hazy (Shantaram 2005). Some micro studies that report failure of the technology (eg Qayum and Sakkhari 2005) are in the same district as that of Glenn Stone, who documents the rapid and wholesale adoption of Bt cotton in the same period (Stone 2007). What could explain the co-existence of two seemingly careful empirical studies in the same district -- Warangal -- coming to such diametrically opposed conclusions?

Mechanisms of Data Dispersion

How do policy makers and concerned citizens make sense of the avalanche of reports claiming “failure of Bt cotton in India” counter-balanced against a very steep adoption curve in all cotton areas of the nation? This is a complicated question, and much is unknown. But we can by analyzing this particular dispute understand something of how numbers are made to count.

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[19] ACNielsen 2004a: 1. The marked intention of farmers to use Bollgard either as repeat users or as non-users who noticed their neighbors’ experience is consistent with Roy’s (2006) ethnographic study in Gujarat; Ramgopal 2006 finds similar effects, but not at such high rates, in Andhra Pradesh.

[20] Precisely because trait value depends on pest infestation levels, and local agro-ecology, Qaim and Zilberman’s projection of Indian data from a bad bollworm year to the poor world generally was problematic.

Much public discourse in India – and increasingly *about* India – is filtered through media that do not present full accounts of methods or provenance of "studies." For example, *The Hindu Business Line*, November 14, 2003 told the world: "in North Telengana region, the net income from Bt varieties was five times less than the yield from local non-Bt varieties. In Southern Telengana, the income from Monsanto's Bt crop was nearly seven times less than what was obtained from the indigenous non-Bt cotton varieties, demonstrating the resounding failure of the Monsanto variety."

Yield and income get mixed in odd ways in this example – and in the public discourse feeding on media reports generally -- as do varieties and traits. That is, both independent and dependent variables are poorly specified in the media reports of studies – and sometimes in the studies themselves.

Even in specifying the independent variable, there is considerable imprecision that matters. Bt technology confers a trait, and cannot be used to stand in for a cultivar. That is, there is a sense in which the common statement "Bt cotton has failed" makes no sense. Varietal characteristics such as staple length, boll size, seed density and sensitivity to wilt have no biological connection to the addition of the Bt trait. Phenotypic variations in cotton cultivars are significant, and the subject of historical controversy – eg colonial attempts to force Indian farmers to grow cottons better suited to Manchester mills – but are biologically independent of the Bt gene contruct. These days, farmers in Andhra can choose Bunny with or without Bt, and Mallika with and without Bt – both popular hybrids for many reasons. The Bunny and Mallika labels each indicates a specific aggregation of germplasm, to which one may or may not add a Bt trait that makes both hybrids more expensive and pest-resistant.

First, then, and most obviously, studies will diverge if there is mis-specification of the thing being measured. There is agronomically no such thing as the generic "Bt cotton" of political dramaturgy , but rather many hybrids with the Bt transgene. Studies virtually always[21] fail to distinguish performance of Bt technology from performance of specific cultivars. Bt confers a trait; some hybrids with this trait do better than others. Because of vast agronomic differences, varieties that work well in one region, district, farm, or even field, may fare less well in the next. There is an easy methodological solution: isogenic varieties should be compared, one with and one without the transgene, to isolate the effect of the trait.

The importance of this simple methodological caveat is that reasons for variance in performance of cultivars are not always discernable, either by farmers or researchers. There are many unmeasured variables in complex interactions, including local climate, soil ecology, soil chemistry, pest incidence, water timing, and nutrient availability. These variables, and their interaction, vary over time and space. For example, the most criticized official Bt hybrid, MECH 184, does well for some farmers in some years, but wilts in years of inadequate early moisture. This agronomic characteristic is true of the

[21] With the significant exception of Bambawale et al 2004, discussed below.

cultivar with or without the Bt trait. Some farmers – typically those with good water control -- find MECH 184 their best producer (Roy et al 2007). This agronomic characteristic of the hybrid is probably the source of the many NGO reports that "Bt cotton causes leaf wilt."

Second, spurious seeds are pervasive, in part because of what Stone calls the "Bt cotton craze." Some varieties sold as Bt are not; some farmers honestly but mistakenly believe that their Bt crop has failed. There is a simple and inexpensive field test for the Bt protein in plant tissues, developed in Nagpur at the Central Institute of Cotton Research, but I have found no study that employs this critical check.

Market characteristics reinforce the problem of identifying what seeds are failing or succeeding. Shortages of Bt hybrids have periodically appeared as demand outstripped supply; hustlers rush in to fill the niche. Seeds are sold through many and unregulated channels; price differences are large, creating an incentive for farmers to go for the unbranded bargain Bt over the official but expensive Bt. There is no way for farmers to verify the quality of these seeds, or their Bt trait. One reason many farmers prefer Mahyco-Monsanto seeds to the farmer-bred "variants" (*Maharakshak*, *Luxmi*, 151, etc.) is the firm's reputation for reliable seed quality – high germination rates, seed purity.

Third, farmers and their representatives have an interest in failure. There are demands for financial compensation from Mahyco-Monsanto and the government for Bt crop failure, creating material incentives to claim poor results. That these demands sometimes succeed makes their appearance more likely in survey results.

Fourth, poor performance of some Mahyco-Monsanto hybrids in some settings is attributed to the technology (Bt) when the fault seems to lie in the original germplasm into which the Bt gene was inserted. No one who knows cotton well in India would consider the three MMBL hybrids especially outstanding cultivars, yet they got the first Bt gene. Many farmers appreciate these hybrids and go back to them season after season. But cotton hybrids have a fairly short life, generally; new hybrids are continually produced and planted. The three MECH cultivars have been around a long time for cotton hybrids: the open field trials commenced in 1998. The very nature of the regulatory system ensured that the first official Bt seeds would not be the freshest hybrids.

Finally, and most important, none of the claims of failure compare two isogenic varieties, one with and one without the Bt gene, to assure control of varietal characteristics.[22] Rather, all disadvantageous variance across over time and space—which will be extreme in India—is attributed to the Bt gene, constructing a biological absurdity. The Cry1Ac gene codes for a single protein; there is no biological reason for production of that protein—lethal to Lepidoptera—to cause staples to shorten or leaves to wilt. These characteristics are in the germplasm of the hybrid to which the Bt gene is added.

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[22] Narayanamoorthy and Kalamkar, 2006: 2717, for further critiques of studies in a similar vein. See also Naik et al. 2005 on cultivar differences as a source of divergent field results.

There is a method for correcting this error, but it is seldom deployed. The most careful controlled study I have seen is of Mahyco-Monsanto Bollgard MECH-162 compared to the isogenic non-Bt MECH 162 and a conventional hybrid. This study used a participatory field trial to test meaningfully paired hybrids with and without integrated pest management (IPM). Consistent with other studies, Bt plants required half the sprayings of other plants for bollworms, and experienced less bollworm infestation. With IPM, the Bt variety recorded a yield of 7.1 q/ha and a net return of Rs. 10,507/ha. Damage to fruiting bodies was much less with Bt plants, which would account for the premium some Bt farmers receive for their lint in the market.[23] The authors of this exemplary study concluded: "Bt Mech-162 used in an IPM mode resulted in highest yields and economic gains to the farmers; pesticide consumption was also reduced (Bambawale *et al.* 2004: 1633)." Bt technology and improved agro-ecological practices, rather than being incompatible, each contributed to superior outcomes. The most sustainable solution turned out to be new germplasm with labor-intensive pest management.

Hypothetical explorations above assume dis-interested inquiry on the part of investigators. But in the real world of transgenic crops and development studies, we must entertain the hypothesis that, as often in other spheres, data are social products. Their relation to reality is affected by their mode of production. In introducing a study demonstrating extensive illegal transgenic soy cultivation into the Brazilian legislature in 2002, Deputy Vasconcellos was suspicious of his own numbers. His speech underscored the political consequences of stealth seeds for biotechnology data. He suggested that disseminating exaggerated figures had a political rationale: to present transgenic soy as a *situacio´n de facto* (*fait accompli*), and thus seemingly irreversible. Some opponents explicitly termed stealth seeds a "contamination strategy:" by making impossible a "GMO-free Brazil," the purveyors of illegal transgenic soya were paving the way for acceptance of their desired outcome. This was indeed the end result (Herring 2007b). But the more interesting point is that exaggerating or minimizing the extent of cultivation of transgenic crops was recognized to be connected to concrete political interests – by politicians. The reality of stealth seed crops is that no one knows the real extent, as the plantings are illegal.

Given the conflicting evidence, and confusion about mechanisms producing that conflict, a ground-level check in the most controversial district seemed a reasonable way to put the debate on sounder empirical footing.

The Warangal Check: Mixing Methods

To investigate some of these propositions, Kameswara Rao, Shanthu Shantaram and I visited Warangal district in December of 2006. We of course did not mean to settle the issue with another agronomic study: it is by now clear that such studies cannot be decisive. Every study with results supporting biotechnology is dismissed by opponents

[23] See Ramgopal 2006: 8. This result makes sense, but is not systematically present across all reports. Cotton marketing is somewhat chaotic in India.

for bias introduced by corporate or state sponsorship. Studies finding crop failure are criticized for lacking in scientific rigor (Shantharam 2005). What we looked for was mechanisms that might explain divergent interpretations of the Bt experience on the farm in a district that has produced more horror stories about Bt cotton than any other, and yet experienced as well very rapid adoption of the technology.

Our conclusion corresponds with ICAR and academic studies (on Maharashtra, see Narayanamoorthy and Kalamkar 2006) as well as claims of commercial firms: as in China, Bt cotton technology is appreciated and adopted by farmers for increasing on-farm profits, and reducing poisoning of soil, water and people. The technology is has become essentially dominant in the district.

The first indication of this outcome came from aggregate numbers of producers. At the state level, the seed industry had under estimated demand for Bt cotton seeds, and proved unable to supply sufficient quantities during the 2006 planting season: demand outstripped supply even though the number of firms and hybrids available for sale was increasingly over this time period. Equally telling, representatives from firms reported to us large quantities of unsold conventional hybrid seeds; there was no demand for these seeds. Bt hybrids have essentially taken over in Andhra Pradesh generally.[24] Locally, we found the same to be true in discussions with agro-chemical and seed dealers in Warangal district.

Projections of Bt penetration rate varied from 85-90 per cent from the director of the AP Seed Certification Agency in Hyderabad to 80-90 percent from the agricultural research station at Angrau to 95 percent from the district agriculture office to a somewhat higher figure – 98 percent – from the seed merchants. These numbers confirm Stone's (2007) report of a massive and complete move to Bt cotton in Warangal, which he called "a craze," but which farmers attributed to better results. The farmers' view was very much supported by the agro-chemical dealers: it is their ox that is being gored. Some pesticide dealers have lost one half of their cotton pesticide business, others 80%; some have closed shop. There is still spraying for sucking insects, and sometimes overly-cautious excessive spraying for bollworms,[25] but in general the reduction is pegged at around 50% by farmers and agro-chemical sources. We found that the notion that "Bt has failed" was incomprehensible to people who sell and grow Bt cotton and are affected by its success – eg the farmers and pesticide merchants.

We then asked: why do NGOs continue to report failure of Bt in Warangal, and in Andhra more generally? Many interlocutors seemed genuinely perplexed, others have darker interpretations: "it is an open secret that they are paid by the pesticide lobby." Evidently this is a powerful lobby; even a former agriculture minister in Delhi has made this comment, and it has been stated in Parliament. But no one has any evidence; even the

[24] Interviews with Dr Ranga Rao, of Prabhat Seeds, Dr Satynarayana of Nuziveedhu seeds, Dr P Satish Kumar Prabhat Agribiotech Limited, Hyderabad December 13 2006.
[25] Similar results come from field studies reported in Narayanamoorthy and Kalamkar, 2006: 2720; Ramgopal 2006.

question: “who exactly is the pesticide lobby?” draws no real response. Not only do data appear through processes that influence their relation to ground realities, but some of the most important explanatory variables are, for social reasons, beyond observation, or silenced.

We found that spurious seeds remain a problem, but not a major problem. As Stone’s careful empirical work documents, there has been confusion around seed marketing, with lots of hype and false claims, especially in the early years, when dealers were making exaggerated claims for the Bt technology. Farmers reporting Bt failure could indeed be experiencing failure of spurious seeds sold as Bt. Ramanjeylu and Kavita Gurukanti at the Center for Sustainable Agriculture confirmed that no one is testing actual cotton plants to make sure they are Bt, even though there is a simple and inexpensive test available in India (albeit not completely reliable). Unauthorized seeds are locally called “duplicates.” Unscrupulous dealers change the name a little to fool the buyer. Some farmers gave the example of changing the name from **Mahyco** to **Mahaco**. These duplicates are not Bt, and of course do not express the endotoxin unique to Bt hybrids. There is no mechanism for this spurious seeds – sold as Bt – to reduce bollworm damage. Some farmers “without knowledge” choose the duplicates, and suffer thereby. Therefore we can not rule out the hypothesis that some farmers believing that their Bt cotton has failed are not actually growing Bt cotton, but spurious seeds.

Duplicate seeds are a fraud on farmers. Stealth seeds are Bt seeds that are not approved by government. Both are present. Reports of persistence of “Kurnool Bt” varieties were still widely spread; these stealth seeds are sold by farmers who grow Bt seeds legitimately for the major companies, but leak some portion on the side through the gray market. Such seeds come from Kurnool district in cloth bags – hence their alternate local name “*gudda* Bt.” These illegal seeds sell for Rs 500-600 per packet, as opposed to Rs 750 for official seeds. There are no guarantees; dealers are not backing them, unlike the situation in Gujarat’s cottage Bt industry. In this specific form of anarcho-capitalism, the farmer has little information or recourse should the seeds fail.

Many of the stealth seeds are good, as in Gujarat. We met by accident a farmer who came into the research station at Angrau for help with another problem but confirmed for us that stealth seeds work well.[26] He himself had grown what he called “Gujarat Bt,” meaning a Navbharat 151 *variant*, unlabelled, and obtained what he considered a phenomonenal yield: 15 quintals. He tried the stealth seeds after a neighbor had tried them and done well.[27]Not all stealth seeds are bad seeds; spurious seeds are.

Reports of the “failure of Bt cotton” backed by farmer agitation in 2004 led to the removal of two Bt hybrids from the state’s list of approved transgenics – ie they were

[26] Though recent reduction in prices of the official seeds is decreasing the scope of the gray market. All official Bt hybrids in the district were selling at Rs 750 per packet, less than half the earlier price.
[27] For analysis of the decision frame of farmers facing these very complex seed choices in Gujarat, see Roy, Herring and Geisler 2007.

approved for a second period after the initial three years. Moreover, the state government pressured Mahyco-Monsanto into payment of significant compensation to Warangal farmers.

This outcome seems paradoxical: the technology is spreading rapidly, yet the state government is forcing compensation payments and withdraws certification of two major hybrids. One explanation for this outcome we uncovered was simple commercial rivalry. Nuziveedu Seeds of Secunderabad benefited from this outcome, and is politically well connected in Andhra Pradesh. Mahyco is a Maharashtrian firm. Nuziveedu produces two competing lines of Bt cotton, Mallika and Bunny, with Monsanto's technology licensed from MMBL. These lines were popular with farmers we interviewed. Removing Mahyco-Monsanto's seeds from state markets would benefit Nuziveedu. Other explanations suggested that MMBL was "arrogant" and refused to pay the bribes demanded for re-approval of their seeds for a second three year period; other interlocutors thought the outcome was entirely about "politics and personalities."[28]

In the field, the situation ramified further. The first farmer I spoke with, in Kadipikonda, Hanumakonda mandal, undermined the Bt failure story directly. He answered my standard question -- what cotton do you grow and why? -- with "MECH 12." Why, I asked. "Because of large bolls, easy picking, early flowering, bollworm resistance." I then asked if it was not banned in Andhra; he answered that he traveled three hours by bus to Nanded in Maharashtra to get the seeds, and gave me the empty Mahyco-Monsanto can to solidify his claim, since I looked a little surprised by the story.

But what of crop failure and compensation? In 2004, some cotton did badly in Warangal, Bt or non-Bt. Farmers said that when the rains are poor, Bt and non-Bt fail on rain-fed (*barani*) lands with thin soils, whereas both varieties did well on irrigated heavy soils. If there is a heavy bollworm infestation, the extra expense of Bt seeds pays off; if pests are few, it does not. But the real threat to cotton is the inherently risky agronomic situation in Warangal. The most important conclusion is that assured irrigation and good soils are critical for cotton production in Warangal – as one would expect. The farmers who had trouble with Bt cotton failure had trouble with non-Bt cotton failure: in thin, un-irrigated soils.[29]

Warangal district, then, is a risky place to grow cotton. Rainfall is uncertain in both aggregate quantity and in timing; irrigation is limited; appropriate soils are not universal. Crop failures are common – and have been for centuries. This conclusion assumes much greater importance as climate change exposes more land to these conditions of marginality across India. The region has experienced inadequate rainfall since 2001.

[28] When the GEAC agreed not to renew MMBL's two hybrids for sale in AP, they did so without any evidence from the state government on yields and performance, but at the request of the state government. Interviews, New Delhi, 2005.
[29] A secondary factor was extensive leasing of land for cotton by farmers from coastal Andhra seeking cheaper rentals: after paying the lease cost, they often lost money on the crop.

But, we asked, why grow cotton if soil and moisture conditions make this a risky proposition, especially for those who cannot bear much risk – the smaller farmers with shallow pockets and perennial debt? The answer was that few crops did better; the very drought-resistant millets, for example, were more reliable, but brought little income and were difficult to market. Other cash crops such as peanuts were as vulnerable as cotton. Moreover, cotton had one great advantage: it was a crop that could "change one's life": a large harvest, when prices are good, could turn around a household economy in ways not plausible with other crops. The lure of "white gold" is deeply rooted.

Secondly, though we did not find the level of confusion reported by Stone (2007; Herring 2007c), we did hear of spurious seeds and fraud. Certified seeds are not available for Bt cotton, and there are few ways to verify that the seeds claiming to be Bt actually contain the Cry1Ac gene construct.

Why should the *failure-of-Bt-cotton* story take root in Warangal, of all the districts in India? Part of the answer derives from path dependency. A previous cotton hybrid, marketed by Excel, was held to have failed and the company paid compensation; we heard around Rs 2.5 crores, but were not able to verify the amount. When farmers demanded compensation in 2004 for Bt cotton failure, they were relying on a proved model of gaining resources and a history of success. The district administration is especially sensitive to rural protest because of the history of the district as a center of "Naxalite" (Maoist agrarian insurrectionist) activity. Mahyco-Monsanto was willing to pay; an agricultural official told us even the Rs 3.27 *crores* paid out was a small price to pay for staying in the cotton game in Andhra Pradesh, where they have 15 *crores* of business.[30]

Moreover, farmers did not have to fail to get compensation; they needed only certification, and that was available from local officials. Pressure and paybacks worked at this level; once a case reached the level of the Director of Agriculture of the district there was no independent investigation of crop failure. Some farmers with assured irrigation then collected twice: they did well with the new technology and simultaneously got the government – that is MMBL -- to compensate for losses. The same mechanism worked in compensation for suicides; the state government paid Rs 2 *lakhs* in 1998 to each family in which a farmer committed suicide but then withdrew the payments when they feared that the compensation was encouraging more suicides.[31] But in 2004, pressures reemerged. And at this point, the government agreed, giving the Rs 2 lakhs for 10 years retroactively. One needed only a government certificate, from police and DAO that someone had committed suicide. One official estimated that "only 1 percent committed suicide because of agricultural failure, most were for other reasons: a daughter or a wife with illegal relations, alcohol, depression, many reasons are there." But there were incentives to record deaths as suicides, and to construct suicides as a consequence of agrarian crisis.

[30] Confirmed by the local Mahyco-Monsanto agent interviewed at the agrochemical shop.
[31] Or faked suicides; see Parmer and Vishwanathan "Hybrids and Hysteria…"

In sum, the Warangal field visit allowed us to approach the mechanisms for crop failure from different angles and assess the possible sources of inconsistency in field studies. Our conversations convinced us that there are both interest-driven reasons for data dispersal and information asymmetries that result in inaccurate reporting. We were able to establish that the logic behind the Bt technology was at work in the fields and locally appreciated. Reports of Bt cotton failure from Warangal are inconsistent with virtually universal adoption of the technology; the causes of reported failure are located in either interest or mis-information.

Numbers Seldom Counted in Biotech Discourses

Most discussion of agricultural risk and technological change centres around capital: who has put up money and may lose it? But there are many at risk in an agrarian economy who have no voice in technology choice. The Bt controversy in India has been about yield numbers, not wages and employment numbers for the landless.

The most obdurate problem of rural poverty is that of landless workers who must find wage employment on whatever crops need labor. They are put at risk by crop choice, but have no voice. What is a livelihood for the laborer is a cost for the farmer. In high-wage agriculture, labor-saving technologies are profitable and will draw investment and development. Herbicide-tolerant transgenics account for a majority of the global transgenic acreage; farmers save money and labor under certain agronomic conditions. Reduction in aggregate demand for labor under many agrarian conditions either destroys livelihoods or puts downward pressure on wage rates or both. Moreover, the rural poor who depend on weeding for a livelihood are frequently those cumulatively disadvantaged across dimensions of social stratification: women, depressed castes, ethnic minorities, migrants. Under those conditions, if herbicide-resistant crops are desirable on other grounds— soil conservation, for example, or use of less toxic herbicides—a pro-poor strategy would necessarily begin with simultaneous discussion of land reforms, rural public works, food subsidies, and other mechanisms to avoid making the poor pay for technology-induced profits (Herring 2003a).

In those instances in which transgenic crops do reduce demand for labor, effects on the rural poor would be differentiated by agrarian structure. Where holdings are small and relatively equal, as in China, smallholders would be saving their own labor, not depriving others of employment; this seems to be the case with *Bt* cotton.[32] Poor farmers may improve their position by freeing up time for other crops or other employment. Few small farms provide subsistence on their own, and off-farm employment often carries a higher wage. Where holdings are larger and less equal, as in India, laborers would lose work applying pesticides. Then the critical question becomes: are wage losses in chemical applications compensated by more harvest labor if yields increase, and by safer ground water and less exposure to toxins? If net wages are lost, but health improves, a difficult trade-off arises. This trade-off depends on variations in wage systems: for example, when

[32] Ruifa Hu and Carl Pray, pers communication, find in their survey of about 400 *Bt* farmers in China, self labour constituted 96.5 per cent of the total labour used, hired labour only 1.7 per cent.

wages are based on weight harvested—rather than a daily sum—income increases with yield and ease of harvest, as sometimes occurs in *Bt* cotton (see discussion in Roy, Herring and Geisler 2007). Moreover, whatever the effect on demand for spraying labor, protection from crop loss has implications for labor: there are no harvesting wages if crops are destroyed by bollworms. It was only fields of *Bt* cotton that survived the 'bollworm rampage' of 2001 in Gujarat (Herring 2005). To the extent that transgenics reduce risk of crop failure, they reduce risks for the landless poor, as well as farmers.

As in much of the world, the most precarious poor in India are the rural landless laborers. The ACNielsen study reports very large aggregate benefits for agricultural labor.[33] This finding is consistent with the agronomic findings in those agrarian settings in which laborers are paid by the weight of the harvested crop. As yields increase, so too does the harvest wage bill, assuming farmers cannot exert sufficient power to capture all the benefits of technical change. There is some support for the Nielson findings in Gujarat: some laborers interviewed in summer 2004 found *Bt* cotton beneficial, as they could pick more in a given day.[34] More systematically, in a study from Visakhapatnam University in Andhra Pradesh found that Bt farmers had much higher input costs in part because their harvestable yields were so much larger that their labor costs were much higher (Ramgopal 2006:6). The same result comes from a study of 150 farmers in Maharashtra (Narayanamoorthy and Kalamkar, 2006: Table 4.) What is a cost for the farmer is income for the laborer. Even with higher labor costs, farmer profits were much higher on Bt than non-Bt farms in this study; indeed, non-Bt farms in Warangal district produced net losses (Rs 983/ha). But more important, in the event of crop failure, there is no cotton to harvest, and hence no income for farm workers. In bumper harvests, laborers have a somewhat easier time making subsistence.

At this stage in development theory, we know better than to equate gains in aggregate production with improvements in well-being for the poor. The mechanism for a pro-poor outcome is increasing demand for labor. Most farmers I have talked with say this is universally true: less damage to crops means more crops to harvest. At the field level, more cotton planted and harvested means more wages to cotton laborers, among the poorest groups in India. At the national level, more cotton harvested increases demand for rural labor in general, from picking to ginning to transport and eventually for making of yarn and cloth. As Bt penetration of the aggregate cotton acreage has increased, so too has total production. Cotton production reached 25 million bales in the 2005 season, higher even than the target of 22 million bales for the tenth five year Plan under the Technology Mission on Cotton (TMC).[35]

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[22]But their methodology prevents a necessary disaggregation: 'labor' is imputed a value in their findings whether performed by the farmer or by hired wage labourers.
[23] Gupta and Chandak (2005) report that farmers who crossed the illegal Bt cotton varieties with local hybrids have extended the life of the crop from six to nine months to reap advantage of continuous flowering and thus higher yield. This mechanism too might increase demand for labor.
[35] ET 5-11-07.

Policy Conclusions

At the UN Meeting of the Parties to the Convention on Biological Diversity, in March of 2006, in Curitiba, Brazil, Vandana Shiva — always described as a scientist and recipient of the Right Livelihood Award (Alternative Nobel Prize) — summarized a common theme in oppositional literature:

> These seeds kill biodiversity, farmers, and people's freedom—for example, Monsanto's Bt cotton, which has already pushed thousands of Indian farmers into debt, despair, and death. Bt cotton is based on what has been dubbed "Terminator Technology," which makes genetically engineered plants produce sterile seeds.…High costs of cultivation and low returns from genetically modified seeds have trapped Indian peasants in considerable debt from which they are escaping by taking their lives. More than 40,000 farmers have committed suicide over the past decade in India—although the more accurate term would be homicide, or genocide.[36]

This statement about India has reverberated throughout the world; the construction has consequences. If the number 40,000 is anywhere near accurate, any sensible policy conclusion about biotech would err on the side of extreme caution. That is the case in many countries, and in movements that consider themselves pro-poor but do not know India. These positions are impervious to disconfirming evidence. The home page of the anti-biotech *GMWatch* contains the caution, very much in evidence on the ground among NGOs in India: "All policymakers must be vigilant to the possibility of research data being manipulated by corporate bodies and of scientific colleagues being seduced by the material charms of industry. Trust is no defence against an aggressively deceptive corporate sector."[37]

Much of the anti-globalization discourse takes an instrumental view of science; science ceases to be a method of inquiry with particular canons for truth claims and becomes instead a political weapon or artifact of power. This instrumental view enables constructions such as "Western Science" and "imperialist science" and "totalitarian science." PV Satheesh of the Deccan Development Society talks of "corporate science," and adds a darker implication. In his response to a critique of NGO studies of *Bt* cotton that were deemed unscientific, he responds to the author: "Bravo Dr Shantharam, you have done a yeoman service to your masters but on the day of judgement in a future not so far away, scientists like you will be remembered as 'Enemies of the People'. "

Rejection of Enlightenment values by well-educated people is a global phenomenon. Yet the de-valuation of science as knowledge is not randomly distributed. The post-modern and constructivist stance on multiple knowledges is affordable by some classes, but not

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[36] See www.ipsnews.net/africa/print.asp?idnews=32438. Accessed March 2006. See also Shiva 2006 for similar statements.

[37] The Lancet http://www.gmwatch.org/p1temp.asp?pid=1&page=1 accessed May 9, 2007.

others. Farmers as a class, because of their position in production, and the pressures of reproducing farm livelihoods, are driven to science of necessity. They cannot afford ideology: rather, an empirical pragmatism is rooted in, and necessary for, their material life. The same constraints do not apply to activists.

We find, then, again that data are after all social products (Herring 2003b). Moreover, the presence of authenticity rents for brokers in international coalitions create powerful incentives to produce dramatic but unverifiable results (Herring 2006).

More and better field studies are then unlikely to resolve the biotechnology policy dilemmas for developmental professionals, elected officials, or citizens interested in informed choice. There are deep divides on the validity of tools of assessment and on the effect of interests in designing, funding, conducting and reporting studies. Knowledge is contested. No new studies, or even meta-studies, meet on agreed epistemological turf.

What does this impasse mean for development policy? First, the strategic aggregation of the issue needs to be challenged. Social movement strategy is to bundle agronomic failure of transgenics with environmental risk and multinational corporate control via patents. This aggregation is patently misleading in India. Uncertainties in long-term environmental effects of biotechnology are logically separable from farm economics. The claim of environmental risk -- that there are uncertainties in the spread of transgenes from biotechnology implementations -- is beyond dispute. Many farmers recognize this, as do scientists and NGOs. Whether or not this effect is more or less threatening than gene flow from conventional breeding is unknown. But on the question of yield and income effects, surely behavior is a reliable, if indirect, guide to actual outcomes. Likewise, we found in Warangal, as others have found elsewhere, that rather than monopoly and control by multinationals, agrarian anarcho-capitalism is alive and well. There are no patents in any event, and if there were, research on Bt cotton suggests they would be violated at will.

In suggesting policy lessons from Bt cotton in India, it is impossible to sustain the argument that yields are falling or the technology fails. Environmental externalities are another question, but in micro studies, seem positive as well. Certainly our Warangal check was consistent with positive environmental outcomes. Bt is not a miracle technology, but it helps significantly in struggling against pesticide-indebtedness and poisoning and in controlling a devastating enemy of cotton. Small advantages count in a globally rigged cotton market on typically small holdings. Even at the very high initial prices, farmers found positive returns on Bt cotton seeds. Assessing impact on poverty of remains difficult. The technology certainly seems scale-neutral, and therefore of similar benefit to very small farmers as to large farmers, assuming access to water and good cotton soil.[38] But it is clear that massive crop failures, as in the bollworm rampage of 2001 in Gujarat, deprive the most vulnerable rural families of income. Anything that reduces crop loss reduces threats to the poorest laboring families, as well as the poorest farmers. Farmers in India have accepted Bt technology – whether official or stealth --

[38] Narayanamoorthy and Kalamkar, 2006: 2718, contrary to their expectations; Ramgopal 2006: 5.

with alacrity for its effects on reducing poisons in the fields and improving pest control and incomes. Farmers all over the world grow illegal genetically engineered seeds because they are profitable (Herring 2007b).

Individual farmers may make errors in assessing new technology, or be swayed by disinformation (Stone 2007). The great benefit of genetic engineering of seeds is "trialability:" it is possible to incur low costs in trying out small amounts of seed, expanding planting after assessing performance (Roy 2006). Of course, as opponents of biotechnology remind the public and policy makers continually, farmers have in the past made collectively bad choices: the pesticides that currently threaten human and ecological health in India resulted from collective decisions of millions of farmers.

Nevertheless, studies claiming agroeconomic failure of Bt technology are difficult to sustain; this essay has explained some of the reasons for errors in these claims. That the claims persist is puzzling. It is not surprising that opposition has continued with the frame of ecological uncertainty: that Bt cotton will "terminate biodiversity." Since there is no way of disproving a negative—that something will not happen—this strategy for stopping transgenics by raising anxiety surely stands a better chance than representation of biotechnology as a disaster for farm economies. Indeed, the science on gene flow ("biological pollution") is incomplete. Keeping uncertainty alive is clearly in the interest of all who have livelihoods as brokers in the global coalition against biotechnology. Tethering the campaign to distal threats prevents any decisive confrontation with facts, and rests on anxiety about the unknown, which is inexhaustible. Given the lack of definitive knowledge, and anxiety, the interest of most citizens is rooted in caution. Indeed, one could argue that there is no advantage whatsoever to most Indians in Bt cotton, at least before it was discovered that pesticide levels in bottled water and soft drinks had reached alarming levels.

Whose numbers count depends fundamentally on the field of power in which they are produced and into which they are inserted. Official numbers count with the state; the developmental state in India pursues biotechnology, as in China and Brazil. Numbers that count in commercial ventures have generated overwhelming support for Bt cotton in India: the technology makes money for formal-sector firms, farmers and cottage industry entrepreneurs of illegal Bt seeds. NGO numbers count with the press, and with global coalitions of allies; representation of the most lurid, and often absurd, results resonate internationally because of social-movement dynamics and interconnected media sources. Such attention may delay the biotechnology project of firms and state, as it has in India intermittently, and deny the technology to some farmers, as has happened in many countries -- fed in part by stories coming from India's oppositional NGOs. But for farmers, the evidence from Bt cotton suggests that the numbers that count are those of their neighbors and their own fields; neither official nor NGO studies dissuade them from very empirical assessments of new technology in their own agro-ecological situations, on their own fields.

References

A.C. Nielsen. 2004a. “Nationwide Survey by A.C. Nielsen ORG-MARG Underscores Benefits of Bollgard^{TM} Cotton.” Press Release.” A.C. Nielsen ORG-MARG. Mumbai.

APCoAB 2006. Bt Cotton in India: A Status Report. Asia-Pacific Consortium on Agricultural Biotechnology. New Delhi.

O. M. Bambawale, et al. 2004. Performance of Bt cotton (MECH-162) under integrated pest management in farmers’ participatory field trial in Nanded district, Central India. *Current Science* 86 (12): 25 June.

R. M. Bennett, Y Ismael, V. Kambhampati, and S. Morse. 2004. Economic impact of genetically modified cotton in India. AgBioForum 7: 96-100.

Howarth Bouis, 2007. The Potential of Genetically Modified Food Crops to Improve Human Nutrition in Developing Countries. *Journal of Development Studies*. Vol 43 No 1. pp 79-96.

Department of Biotechnology, Ministry of Science and Technology, Government of India, 2001. *Biotech News* Vol 2, Issue 2, November.

Ronald J. Herring, 2003 a. The political impossibility theorem of agrarian reform: path dependence and terms of inclusion, in: M. Moore and P.P. Houtzager (eds) *Changing Paths: The New Politics of Inclusion*, (Ann Arbor, Michigan: University of Michigan Press).

________________ 2003b. Data as social product, in: R. Kanbur (ed) *Q-Squared: Combining Qualitative and Quantitative Methods in Poverty Appraisal* (New Delhi: Permanent Black).

_________________ 2005. Miracle seeds, suicide seeds and the poor: GMOs, NGOs, farmers and the state, in: R. Ray and M.F. Katzenstein (eds) *Social Movements in India: Poverty, Power, and Politics*, (Lanham, MD: Rowman & Littlefield; Oxford University Press, New Delhi), pp. 203–232.

________________, 2006. “Why Did ‘Operation Cremate Monsanto’ Fail? Science and Class in India’s Great Terminator-Technology Hoax,” *Critical Asian Studies*, Vol 38, No 4. December 2006. pp 467-493.

_______________, 2007a, “The Genomics Revolution and Development Studies: Science, Politics and Poverty,” *Journal of Development Studies.* Vol 43 No 1. pp 1-30.

_______________, 2007b, “Stealth Seeds: Biosafety, Bioproperty, Biopolitics.” *Journal of Development Studies*. Vol 43 No 1. pp 130-157.

______________, 2007c, Comments on Glenn Stone's 'Agricultural Deskilling…' " *Current Anthropology*, Feb 2007.

________________, Ed. 2007. *Transgenics and the Poor: Biotechnology and Development Studies***.** Oxford: Routledge.

Ronald J. Herring and Ann Grodzins Gold, 2005. "Indian Cotton: Biology and Utility, Meanings and Histories," *Economic and Political Weekly*, Vol 40, No 37. September 2005.

Clive James, 2002, Global Review of Transgenic Crops: 2001 Feature: Bt Cotton. ISAAA Briefs No. 26. ISAAA: Ithaca, NY.

K.S Jayaraman 2001. Illegal Bt cotton in India haunts regulators. *Nature Biotechnology* 19 (12): 1090 (December).

———. 2004. India produces homegrown GM cotton. *Nature Biotechnology* 22 (3): 255–56 (March).

Michael Lipton, 2007. Plant breeding and poverty: can transgenic seeds replicate the Green Revolution as a source of gains for the poor? *Journal of Development Studies.* Vol 43 No 1.

Gopal Naik, 2001. An Analysis of Socio-Economic Impact of Bt Technology on Indian Cotton Farmers. Centre for Management in Agriculture, Indian Institute of Management. Ahmedabad.

Gopal Naik, Matin Qaim, Arjunan Subramanian and David Zilberman. 2005. Bt Cotton Controversy: Some Paradoxes Explained. *Economic and Political Weekly* April 9. 1514-1517.

A. Narayanamoorthy and S. S. Kalamkar, 2006. Is Bt Cotton Cultivation Economically Viable for Indian Farmers? An Empirical Analysis. *Economic and Political Weekly*. June 30, 2006. 2716-2724.

M. Qaim and D. Zilberman,. 2003. Yield effects of genetically modified crops in developing countries. *Science,* 299(5608), pp. 900–902.

Abdul Qayum and Kiran Sakkhari, 2005. *Bt cotton in Andhra Pradesh.* Hyderabad: Deccan Development Society.

N. Ramgopal, 2006. Economics of Bt Cotton vis-à-vis Traditional Cotton Varieties: Study in Andhra Pradesh. Agro-Economic Research Centre of Andhra University. Visakhapatnam. Andhra Pradesh.

C. Kameswara Rao, 2004. *Frontline Mischief*. Bangalore: Foundation for Biotechnology Awareness and Education. 18 May.

Devparna Roy, Ronald J. Herring and Charles C. Geisler, 2007. “Naturalizing Transgenics: Loose Seeds, Official Seeds, and Risk in the Decision Matrix of Gujarati Cotton Farmers.” *Journal of Development Studies*. Vol 43 No 1.

S. Sahai and S. Rahman 2003. Study Reveals that Bt Cotton Performing Poorly in India http://www.genecampaign.org/Publication/Article/BT%20Cotton/BtCotton-is-failure.pdf

S. Sahai, 2003, Performance of Bt Cotton in India: Data from the First Commercial Crop. http://www.genecampaign.org/Publication/Article/BT%20Cotton/Btcotton-report%202003-bus.pdf

Shanthu Shantaram, 2005. The brouhaha about Bt-Cotton in India. *AgBioView*. 2 May. www.agbioworld.org.

Vandana Shiva, 2006. Resources, rights and regulatory reform. *Context* 3 (1): 85–91 (spring/summer).

Vandana Shiva and Afsar H. Jafri. 2004. Failure of GMOs in India. *Synthesis/Regeneration* 33 (winter). New Delhi, India: Research Foundation for Science, Technology and Ecology.

Vandana Shiva, Ashok Emani, Afsar H. Jafri. 1999. Globalization and threat to seed security: Case of transgenic cotton trials in India. *Economic and Political Weekly*. 6-12 and 13-19 March.

Shiva, Vandana, et al. 2000. *Seeds of suicide: The ecological and human costs of globalization of agriculture*. Delhi: Research Foundation for Science, Technology and Ecology.

Glenn Davis Stone, 2002. Biotechnology and suicide in India. *Anthropology News*. May.

______________, 2007, Agricultural Deskilling and the Spread of Genetically Modified Cotton *Current Anthropology*, Feb.

Shabana Zahoor, 2004. “Bt Cotton in India: Two Years of Failure.” Working Paper Series on Agriculture and the Poor No 20. March. Bazaar Chintan: International Development Enterprises