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Undying Promise: Agricultural Biotechnology's Pro-poor Narrative, Ten Years on

Dominic Glover

Bt Cotton

Undying Promise: Agricultural Biotechnology's Pro-poor Narrative, Ten Years on

Many people and organisations have sought to promote genetically modified (GM, transgenic) crops as a 'pro-poor' technology. However, developing-country farmers' experiences with GM crops have been mixed. Some farmers have certainly benefited, but others have not. Predictably, the performance and impacts of transgenic crops depend critically on a range of technical, socio-economic and institutional factors. By themselves, genetically modified seeds are not enough to guarantee a good harvest or to create a sustainable and productive farm livelihood.

In spite of this emerging picture of complex and differentiated impacts, the simplistic narrative of GM crops as a uniformly 'pro-poor' technology has proved to be extraordinarily resilient. Why has it persisted? Part of the reason is that a substantial number of econometric studies have claimed to demonstrate that GM crops are a technological and economic success in the developing world. But methodological and presentational flaws in those studies have created a distorted picture of both the performance and the impacts of GM crops in smallholder farming contexts. This has seriously distorted public debate and impeded the development of sound, evidence-based policy. This paper examines the hidden assumptions that have shaped both the pro-poor claims on behalf of GM crops and the methods that have been used to evaluate them. Those assumptions have involved the radical simplification of the complex agronomic and livelihood contexts into which GM crops have been inserted. They have thus undermined the usefulness and relevance of the information which has been presented to both farmers and policy makers.

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SUMMARY

Many people and organisations have sought to promote genetically modified (GM, transgenic) crops as a 'pro-poor' technology. However, developing-country farmers' experiences with GM crops have been mixed. Some farmers have certainly benefited, but others have not. Predictably, the performance and impacts of transgenic crops depend critically on a range of technical, socio-economic and institutional factors. By themselves, genetically modified seeds are not enough to guarantee a good harvest or to create a sustainable and productive farm livelihood.

In spite of this emerging picture of complex and differentiated impacts, the simplistic narrative of GM crops as a uniformly 'pro-poor' technology has proved to be extraordinarily resilient. Why has it persisted? Part of the reason is that a substantial number of econometric studies have claimed to demonstrate that GM crops are a technological and economic success in the developing world. But methodological and presentational flaws in those studies have created a distorted picture of both the performance and the impacts of GM crops in smallholder farming contexts. This has seriously distorted public debate and impeded the development of sound, evidence-based policy. This paper examines the hidden assumptions that have shaped both the pro-poor claims on behalf of GM crops and the methods that have been used to evaluate them. Those assumptions have involved the radical simplification of the complex agronomic and livelihood contexts into which GM crops have been inserted. They have thus undermined the usefulness and relevance of the information which has been presented to both farmers and policy makers.

1. INTRODUCTION

The period around the turn of the twenty-first century was punctuated by the release of a succession of weighty reports by major international organisations and august scientific institutions, which encouraged the development and commercialisation of genetically modified (GM, transgenic) crops to improve developing-country agriculture (FAO 2004; IFAD 2001; IFPRI 1999; Nuffield Council on Bioethics 1999; Royal Society of London *et al.* 2000; UNDP 2001). Although they were sprinkled with qualifications about careful safety assessment and socio-economic factors, these documents nevertheless appeared to represent an emerging scientific and policy consensus that GM crop technology would be ‘pro-poor’.

That optimistic consensus depended on a number of key, unacknowledged and often questionable assumptions about the ways in which the technology would be developed and its likely impacts on poverty, hunger and the livelihoods of the poor (Levidow 2001; Scoones 2002a, 2007). Some commentators seemed to assume that GM technology would simply reinvigorate the stalled Green Revolution, in spite of the striking institutional and geopolitical differences that would make the new ‘Gene Revolution’ a very different creature from its predecessor (Parayil 2003; Scoones 2005b; Seshia and Scoones 2003). (There was, however, a good deal of continuity between the two eras in terms of their shared technological culture and agrarian social structures (Shah 2008)). The vital role that economic and political contexts and institutional frameworks would inevitably play in shaping the outcomes of technological change was often overlooked: in other words, delivering the pro-poor promise of biotechnology would require appropriate governance (Chataway 2005; Jasanoff 2005; Newell and Mackenzie 2004). In summary, without troubling to analyse the complex, context-dependent ways in which new agricultural technologies might affect poor people, poverty was typically invoked merely as a moral platform on which a series of assertions about the value of GM technology could be made (Jansen and Gupta 2009).

The narrative depicting GM crops as a sustainable, environmentally friendly and developmental technology emerged in part from the biotechnology industry (Glover 2008). These claims were among the factors that provoked popular opposition to GM crops in Europe during 1998 and 1999 (ESRC Global Environmental Change Programme 1999; Schurman 2004). Many consumers, environmentalists and international development campaigners suspected that the biotech companies’ real intention was to take control of food and farming, and believed that GM crops would actually undermine the sustainable livelihoods of farmers in the developing world (e.g. ActionAid 2003; Christian Aid 1999; Shiva *et al.* 2000). In response to the backlash, industry players such as the transnational biotechnology company Monsanto redoubled their efforts to depict transgenic crops as a technology that would benefit the poor. These kinds of claims have remained prominent in debates about biotechnology and agricultural development in the decade since (Glover 2008; Hisano 2005).

Looking back at the events of 1998 and 1999, we can see that they represented a pivotal moment in the global politics of GM foods and crops. Of course, both the 'pro-poor biotechnology' narrative and the opposition to the technology have roots that stretch back much further than the late 1990s (Bud 1993; Glover 2008; Schurman and Munro 2006). Nevertheless, ten years on from the anti-biotech backlash, we have the opportunity to look back at the career of the 'pro-poor biotechnology' narrative during a decade in which evidence has begun to emerge that sheds light on the actual experiences of developing-country farmers who have cultivated GM crops.

Those experiences have been mixed, as this paper will show. The performance of GM crops in the developing world has been very variable and their impact contingent on a wide range of social, institutional, economic and agronomic factors. Some farmers have clearly benefited, but others have not. Yet others may have been bypassed altogether. Serious concerns remain about the medium and long-term sustainability of those benefits that have been realised.

In spite of this emerging picture of complex and differentiated impacts, however, the simplistic narrative of GM crops as a uniformly 'pro-poor' technology has proved to be extraordinarily resilient, as I will show. This paper will explore that resilience through a close examination of a selection of the econometric studies that have purported to show that GM crops have produced a range of benefits for poor farmers in the developing world. I will argue that methodological and presentational flaws in those studies have produced a misleading picture of both the performance and the impacts of GM crops in smallholder farming contexts, and that this has seriously distorted public debate and impeded the development of sound, evidence-based policy. Through this analysis, this paper will shed light on the hidden assumptions that have shaped both the pro-poor claims on behalf of GM crops and the methods that have been used to evaluate them. These assumptions have involved the radical simplification of the complex agronomic and livelihood contexts into which GM crops have been inserted. The assumptions have thus undermined the usefulness and relevance of the information which has been presented to both farmers and policy makers.

2. A FLAWED NARRATIVE FROM THE START

The narrative of GM crops as an intrinsically ‘pro-poor’ technology rested on a number of often implicit, highly questionable and contentious assumptions (Altieri and Rosset 1999; Levidow 2001; Scoones 2002a, 2007). In order to make a reasoned judgement about the potential of GM crop technology to deliver its vaunted benefits, these hidden assumptions needed to be examined and tested. The failure to openly acknowledge them compromised the mainstream policy debate and helped to stoke public anxiety and disaffection (Scoones 2002a; Wynne 2001).

Often, the assumptions were actually acknowledged, but only in passing, and typically brushed aside. For instance, the 1999 report from the Nuffield Council on Bioethics explicitly acknowledged that food insecurity was largely a problem of inequitable distribution, not merely of aggregate food supply; but the report set that issue aside as too difficult and expensive to deal with, thus implicitly assuming that genetic modification would be a less complex and simpler route to food security (Nuffield Council on Bioethics 1999).The authors of the report also discussed the importance of attending to the political and economic institutions and contexts that would shape the development and impacts of GM crop technologies, with the warning:

> As GM crop research is organised at present, the following worst case scenario is all too likely: slow progress in those GM crops that enable poor countries to be self-sufficient in food; advances directed at crop quality or management rather than at drought tolerance or yield enhancement; emphasis on innovations that save labour-costs (for example, herbicide tolerance), rather than those which create productive employment; [and] major yield-enhancing progress in developed countries to produce, or substitute for, GM crops now imported in conventional (non-GM) form from poor countries (Nuffield Council on Bioethics 1999:66-67).

However, the report effectively side-stepped the issues of corporate ownership and control of technology development, with a hopeful call for more investment in public-sector research and public-private partnerships.

A striking example of this practice of setting aside difficult and complex issues can be found in the opening paragraphs of a paper by Robert Paarlberg (2006), a political science professor who has been a staunch advocate for the rapid commercialisation of GM crops in the developing world (e.g. Paarlberg 2000, 2008). In classic style, Paarlberg began his 2006 article by invoking the profound, urgent challenge of addressing persistent African food crises as a kind of moral platform for taking action (Jansen and Gupta 2009). He then set those issues to one side. Reproduced below is an extract containing the second and part of the third paragraphs of the article:

> Africa mostly missed the original Green Revolution of the 1960s and 1970s, which brought higher yielding varieties of wheat and rice into Asia, made productive through expanded irrigation and increased applications of chemical fertiliser. These conventionally developed Green Revolution 'miracle seeds' worked well under the conditions that prevailed in much of Asia: good water and topography for irrigation, access to credit for the purchase of chemical inputs, adequate road systems to get the fertiliser in and the expanded grain production out, and established local traditions of growing crops in monoculture, including wheat and rice. In most of Africa these conditions do not exist. Most farmers do not grow Green Revolution crops such as wheat or rice in monoculture; instead they intercrop cash crops such as cocoa or cotton along with a wide variety of subsistence food crops (cassava, sorghum, millet, cowpea, yams, banana) that have not yet been improved by local crop breeders. More important, Africa's long dry seasons and uneven topography have made bringing water to crops through irrigation difficult, and the rural road and credit systems in Africa are weak, which drives up the cost of fertiliser and drives down the crop price received by farmers.
>
> Under these challenging circumstances, the options for creating a 'uniquely African Green Revolution' might seem limited. One new technical option is the development of new crop varieties through genetic engineering techniques, which splice desired genes into crop plants from more distant relatives, or even non-relatives... (Paarlberg 2006:82, reference removed).

What immediately strikes the reader is the startling logical non sequitur that (dis) connects these two paragraphs. Having noted the daunting range of technical, agronomic, socio-economic and infrastructural factors that made the Green Revolution in Asia possible but typically do not apply in Africa, Paarlberg brushed these considerations aside in order to alight on genetic engineering as a key intervention for creating an African Green Revolution. Although Paarlberg excused himself by acknowledging that crop genetic engineering may be just 'one new technical option', that caveat cannot erase the logical disconnection between the broad socio-political, technical and moral content of the premise laid out in his first two paragraphs and the exclusive focus on genetic engineering that followed in the rest of the article.

One might have hoped that the obvious flaws in these kinds of rhetorical ploys would help to restrain the excessive enthusiasm of many commentators, advocates and policy makers with regard to the potential of GM crops in developing-country agriculture, but often they did not. But the failure to frankly address the hidden assumptions that lay beneath the 'pro-poor GM crops' narrative meant that it was always liable to be contradicted by the unfolding of events and, indeed, that is what has come to pass. In 2006, Smale *et al.* (2006) carried out a detailed review of published literature on the impacts of GM crops in developing countries, which focused on methodological questions but also discussed the empirical findings of the published studies. On the methodological questions, Smale and her colleagues pointed out numerous limitations and weaknesses of the studies accomplished to date, including small sample sizes, a narrow range of methods used, and the small number of seasons in which data had been collected. This should have meant that it was impossible to make broad generalisations on the performance of GM crops in developing contexts, but such generalisations were still made, even explicitly, in both peer reviewed academic articles as well as industry-sponsored documents.

The outstanding lesson from the studies reviewed by Smale *et al.* (2006) was that the performance of GM crops had varied widely, across farms and farmers, crop varieties, regions and seasons. The performance of GM crops depended crucially on a diverse range of factors, including the performance and local adaptation of the background variety into which the new genetic traits had been introduced, as well as local agronomic, socio-economic, political and institutional factors. As the authors observed, these results are exactly what should have been expected in the light of previous experiences with the introduction of new agricultural technologies and improved crop varieties.

The wide variability in performance was confirmed in a similar analysis by Raney (2006), who noted that 'institutional factors such as national agricultural research capacity, environmental and food safety regulation, intellectual property rights and agricultural input markets matter at least as much as the technology itself in determining the level and distribution of economic benefits' (Raney 2006:abstract). The observation of widely variable performance is a crucially important finding in its own right, because that variability itself represents a source of potentially serious risk for poor farmers.

Over time, the evidence has begun to pile up. This paper will refer to more examples below, but for now it is sufficient to observe that, although some farmers have done well out of the new crops, others – especially poorer farmers, lacking the support of key resources – have not. Instead of revealing GM crops as a technical fix to complex agronomic and socio-economic problems, the equivocal, highly contingent nature of small farmers' experiences have led the authors of the recent global review of agricultural science and technology for development (the IAASTD)[1] to conclude that GM technology can play no more than a small role in addressing the challenges of agricultural development in the global South (IAASTD 2008).

In summary, according to some observers, 'the initial enthusiasm for the technology has been superseded by a more cautious weighing of economic advantages and disadvantages by crop and trait' (Smale *et al.* 2006:62-3). Interestingly, this downward revision of some of the early, exaggerated expectations about biotechnology in agriculture echoes similar reassessments that have occurred in the fields of medical biotechnology (Hopkins *et al.* 2007; Nightingale and Martin 2004) and plant-made pharmaceuticals (Milne 2008). Indeed, as Geels and Smit (2000) have shown, it is quite typical for advance expectations about the potential of new technologies to be too high, so that they have to be scaled back in the light of experience. In that light, the reports by Smale *et al.*, (2006) Raney (2006) and

[1] The International Assessment of Agricultural Knowledge, Science and Technology for Development (www.agassessment.org (12/09/08)).

the IAASTD (2008) give cause for optimism that we may be approaching a point in the debate about agricultural biotechnology where it will be possible to reassess the simplistic image of GM crops as an unproblematically beneficial technology for the poor, and so enter a more mature phase of the debate.

And yet, that reassessment seems to be taking a long time. If anything, the simplistic narrative of GM crops as a straightforwardly successful pro-poor technology has persisted in spite of the highly equivocal evidence emerging from the field. Indeed, the narrative has even been renewed in recent months, partly in response to the rise in food prices during 2007 and 2008. It seems there is a reluctance to let go of the powerful illusion of GM crops as a silver bullet against hunger and poverty. For instance, responding to the publication of the IAASTD report in April 2008, British newspaper columnist Dominic Lawson wrote an op-ed article castigating its authors for 'pandering to superstition' and indulging in 'anti-scientific hysteria' for failing to endorse a technology from which 'Africa could benefit most'.[2]

In November 2007, British politician and GM-enthusiast Dick Taverne published an article in the prominent UK magazine Prospect in which he claimed that the 'anti-GM lobbies' had 'exacted a heavy price' for their opposition to GM crop technology, including 'the needless loss of millions of lives in the developing world' (Taverne 2007:27). Taverne's article strongly implied that, if it had not been for the opposition, drought-tolerant and salt-tolerant crops would already be a commercial reality – a claim that may well have come as a surprise to the scientists and developers struggling to make such products a reality. Even more outlandishly, Taverne also claimed that 'Plant-based oral vaccines should now be saving millions of deaths from diarrhoea and hepatitis B; they can be ingested in orange juice, bananas or tomatoes, avoiding the need for injection and for trained staff to administer them and refrigeration to store them' (Taverne 2007:24). In one stroke, that claim sweeps aside not only the daunting technical challenges involved in developing transgenic pharmaceutical crops, but also the difficulties involved in delivering standardised, controlled doses of vaccines to the right target populations, the risks entailed when common food crops are used to produce pharmaceutical compounds, and the efforts being made by production engineers to build the elaborate containment systems they need in order to isolate drug-producing plants from sources of environmental contamination (see Milne 2008; Moschini 2006; Nature Biotechnology 2004; Shama and Peterson 2008).

However, Taverne's real complaint was that, under the influence of the media, '[t]he public in Britain and Europe seems unaware of the astonishing success of GM crops in the rest of the world' (Taverne 2007:24). The conviction that GM crops have been an 'astonishing success' seems to have an iron grip on the imagination

[2] Dominic Lawson, 'Feed the world? Tear down trade barriers and let GM crops flourish across the globe', The Independent, Friday 18 April 2008, http://www.independent.co.uk/opinion/commentators/dominic-lawson/dominic-lawson-feed-the-world-tear-down-trade-barriers-and-let-gm-crops-flourish-across-the-globe-811176.html (5/11/08).

of some protagonists in the biotechnology debate, in spite of the more measured conclusions of those who have examined the evidence in detail. In recent months, Taverne's Panglossian view has been echoed by senior policy-advisers and government ministers in the UK, who have suggested that there is a good news story to be told about the impacts of GM crops in developing countries and even that they might provide the solution to the current global food crisis.[3] But it is hardly surprising that policy makers think they are on solid ground in making such claims, because serious academics – such as the Oxford economist Paul Collier – have continued to bang the drum for GM technology as a necessary feature – not merely a useful, helpful or alternative one – of an equally necessary transformation of agriculture that will sweep aside the livelihoods of millions of peasants and supposedly release them to do something else for a living (Collier 2008).

In the introduction to a special issue of the *Journal of Development Studies* in early 2007, Cornell University academic Ron Herring was confident enough to assert that the 'pro-poor GM technology' narrative had actually been renewed and strengthened over time. 'Development professionals,' he wrote, 'have increasingly agreed to something like a standard narrative of biotechnology. It is an optimistic but cautious consensus' (Herring 2007a:7). He went on: 'transgenics will not solve the problem of ''world hunger'', but represent a new tool, just as many traditional tools are proving either inadequate or come with too many cumulative externalities – particularly environmental' (Herring 2007a:7). By distinguishing the 'new' tools from the 'traditional' ones in this way, Herring clearly implied that transgenic crops would be both adequate to the challenge of tackling hunger and come with fewer undesirable side-effects. The assumption that GM crops would not be encumbered with 'externalities' is significant, as this paper will show. It reveals an implicit analytical framing of the technology that separates it from the wider social-technical system in which it is, necessarily, embedded.

Against the background of assertions like these from respected academics, it is hardly surprising that many policy makers, journalists and others involved in the public debate believe that the 'pro-poor GM crops' narrative is backed up by a growing body of convincing empirical evidence that has been gathered by researchers from farmers' fields. For instance, in another of his opinion articles, in August 2008, Dominic Lawson quoted the findings of an EU report which had stated that 'analyses show that adoption of dominant GM crops and on-farm economic gains have benefited both small and large farmers... Moreover, detailed analyses show that increases in gross margin are comparatively larger for small and lower-income farmers than for larger and higher income farmers' (Gómez-

[3] 'Brown must embrace GM crops to head off food crisis – chief scientist', The Guardian, 28/11/07, http://www.guardian.co.uk/science/2007/nov/28/foodtech.gmcrops (7/11/08); 'Genetically modified crops "may be answer to global food crisis"', The Telegraph, 19/06/08, http://www.telegraph.co.uk/news/uknews/2154307/Geneticaly-modified-crops-'may-be-answer-to-global-food-crisis'.html (07/11/08); 'Science minister attempts to reopen the debate on GM crops', The Guardian, 22/09/08, http://www.guardian.co.uk/environment/2008/sep/22/gmcrops.food (07/11/08).

Barbero and Rodríguez-Cerezo 2006:35).[4] In this paper, I will show that that kind of confident assertion has been seriously misleading – not because the statement itself is inaccurate, but because it represents a selective and incomplete picture of the impacts of GM crop technology in real situations.

It is important to observe here that there is indeed a growing body of evidence that confirms that transgenic, insect-resistant cotton – which is the most widespread GM crop in the developing world – has performed as designed, in a technical sense, and that it has had some beneficial impacts at both household and aggregate levels. But, as I will show, those benefits are neither as simple, as uniform, as context-independent or as sizeable as they have frequently been depicted to be. A full appreciation of GM crop technology's impacts needs to weigh both their benefits and disadvantages, as well as acknowledging the limitations of what can be achieved by devoting effort to the enhancement of just a few crop traits in a complex agronomic system.

In an effort to understand why and how the simple narrative of GM crops as a straightforward boon to small farmers has survived in the face of evidence that is more ambiguous and mixed, the next sections will examine in detail a selection of the key studies that are frequently cited in support of those claims. I will focus on studies that have assessed the impacts of transgenic, insect-resistant cotton, which is the only GM crop that has been commercialised widely in the developing world. These transgenic cotton varieties are known collectively as 'Bt cotton' because they contain a gene taken from the soil bacterium *Bacillus thuringiensis*; plants modified with the 'Bt gene' express an insecticidal protein that confers a degree of protection against a group of insect pests, primarily lepidopterans, which are conventionally known as bollworms or the 'bollworm complex' (see FAO 2004:44).[5] I will concentrate on studies that have looked into the crop's impacts among smallholder farmers in China, India and South Africa. The experiences of small-scale farmers in these three large and important developing countries have become key battle grounds in global debates about the benefits and risks of GM crop technology (Bernauer and Aerni 2007; Glover 2008).

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[4] Dominic Lawson, 'The Prince is entitled to his view – but not his ignorance', The Independent, 15/08/08, http://www.independent.co.uk/opinion/commentators/dominic-lawson/dominic-lawson-the-prince-is-entitled-to-his-views-ndash-but-not-his-ignorance-897493.html (12/11/08).

[5] See University of Tennessee Extension Service factsheet at http://www.utextension.utk.edu/fieldcrops/cotton/cotton_insects/btcotton.htm (18/01/09).

3. BT COTTON IN CHINA

Bt cotton was commercialised in China in 1997. The area under Bt cotton expanded rapidly, reaching about 3.5 million hectares in 2006. Since then, it has grown more steadily, to about 3.8 million hectares in 2007, equivalent to 69% of the total cotton area in China that year. In the northern, Yellow River cotton zone, Bt varieties are reported to account for nearly 100% of the cotton area. The crop is said to be grown by about 7.1 million small-scale farmers in China (James 2007; Keeley 2006).[6]

YIELDS AND PROFITABILITY

According to an early study, Bt cotton farmers in China were spending between 20% and 33% less on cotton cultivation than non-adopters (Pray and Huang 2003; Pray *et al.* 2001). They also received a very slightly higher price for their cotton seed, so that they made a small profit per kilogramme of seed sold. Non-adopters suffered losses. The conclusion was obvious: farmers benefited from adopting Bt cotton; indeed, it appeared that Bt cotton rescued cotton cultivation from being economically unviable.

On closer examination, however, the case appeared not to be so simple. The data in the articles by Pray *et al.* (2001) and Pray and Huang (2003) showed that, in a season with low pest pressure, yields had actually been broadly similar for Bt and non-Bt varieties, especially when controlling for farmer skill and location. In fact, that season, the best-yielding variety was a newly released non-Bt variety called 9418, which was regarded by government scientists as susceptible to bollworms. Clearly, the 1999 season was not one in which the benefits of insect-resistance would have been expected to make themselves felt. On top of that, Bt cotton seed was significantly more expensive than most non-Bt varieties, except for bollworm-resistant conventional varieties which, for some reason, cost 75% to 167% more than the Bt varieties. And yet Pray, Huang and colleagues claimed to have identified a substantial financial benefit to cultivating Bt cotton. If the Bt varieties did not offer a yield advantage over bollworm-susceptible ones when pest pressure was low, where did the economic advantage come from?

The Pray–Huang group's (Pray and Huang 2003; Pray *et al.* 2001) calculations showed that the cost advantage of bollworm-susceptible, non-Bt seed was more than wiped out by the additional costs for pesticides and the labour required for

[6] The annual reviews of global GM crop commercialisation, published by the International Service for the Acquisition of Agri-Biotech Applications (ISAAA) (James 2007), may not be reliable. Their data sources are obscure, methodology unclear and presentation demonstrably inflected towards the representation of a favourable picture of GM crop adoption and impacts worldwide (see FOEI 2007 for a strong critique). However, no other comparable source is publicly available.

spraying them. According to Pray and colleagues' (2003; 2001) calculations, Bt farmers invested between 9,100 and 10,700 yuan per hectare (RMB/ha.), depending on the variety grown, whereas non-Bt farmers invested at least 11,270 and up to 14,200 RMB/ha. According to these figures, it could be anywhere from 570 to 5,100 RMB/ha. at the extremes, or about 2–3,500 RMB/ha., more expensive to cultivate non-Bt varieties than Bt varieties, despite the cheaper price of non-Bt (bollworm-susceptible) seed.

At first glance, these calculations seem reasonable, and the results in line with the expectation that the high price of Bt cotton seed would be offset by savings in expenditure on pesticide applications, which include both the costs of the chemicals themselves and the labour required to spray them. However, Pray and colleagues' (2003; 2001) results need to be interpreted with care. Their analysis was an economic rather than a financial one, and it is important to observe the difference. In economic analysis, it is accepted practice to convert economic values into monetary ones, for the sake of clear comparison, but it is important not to lose sight of the distinction between economic and financial measurements. However, that distinction is not always clear in the Pray–Huang group's interpretation and presentation of their findings. This can be seen, for instance, in their treatment of labour inputs. They took labour costs into account by monetising them, using the local farm labour wage as an index. Summarising their calculations, they wrote that '[t]he *cost of labor increased* [for non-adopters] between 1,500 and 2,400 RMB/ha.' (Pray *et al.* 2001:818, emphasis added).

However, most of the labour used in the region is not paid labour but family labour (Pray and Huang 2003; Pray *et al.* 2001). Of course, if there is a labour saving associated with the technology, that is an important benefit for smallholder farm households. However, such a saving cannot necessarily be equated directly with a monetary gain. The farming families concerned are not likely to have had the financial resources to substitute their own labour with paid labour. Nor can one assume that, by saving labour through cultivating Bt cotton, they would necessarily have been in a position to sell their own labour to others for financial gain.

Thus, Pray and colleagues' overall finding of a substantial economic advantage to cultivating Bt cotton should be interpreted very carefully. In financial terms, the outcomes of cotton cultivation were rather similar for both Bt adopters and non-adopters in a season with low pest pressure. By remembering that farmers did not actually pay for farm labour, one also sees that non-Bt farmers realised, on average, a small financial profit per kilogramme of seed cotton rather than a financial loss (see Pray and Huang 2003: table 12.5). In other words, it was the imputed monetary figure, representing the additional labour expended by non-Bt farmers or saved by Bt farmers, which created the impression that Bt cotton had significantly outperformed non-Bt cotton during the season in question. That being the case, one is left with the nagging question why, in a season with low pest pressure, so many cotton farmers apparently still spent significant sums of money and a good deal of time on pesticide spraying. The next section turns to that question.

REDUCING PESTICIDE USE AND POISONINGS

Pray *et al.* (2001) claimed that the adoption of Bt cotton by Chinese smallholders had led directly to a reduction in pesticide use and a consequent reduction in incidents of pesticide poisoning among farmers. Other papers by the same group of authors have affirmed the same finding (Hossain *et al.* 2004; Huang *et al.* 2003; Huang *et al.* 2002; Pray and Huang 2003; Pray *et al.* 2002). The confident conclusion that 'Bt cotton … reduces chemical use' (Pray *et al.* 2001:822) has been widely cited ever since.

Pray, Huang and colleagues have indeed shown a substantial reduction in pesticide use by Chinese Bt cotton farmers. What they have consistently failed to show, however, is a convincing causal relationship between the adoption of Bt cotton and the observed reduction in pesticide use. The most they have shown is a correlation between the two phenomena. The authors appear to have assumed that the reduction in pesticide spraying could be attributed directly to the adoption of Bt cotton without examining the question of causation. Yet the precise mechanism of causation should be of great interest to agronomists and policy makers.

Why were the farmers surveyed in early studies apparently spending rather large sums on pesticides in a year when low pest pressure prevented Bt cotton from demonstrating its possible technical advantage? Excessive use of pesticides by both cotton and rice farmers in China is widely recognised as a serious environmental, human health and economic problem (Huang *et al.* 2003; Widawsky *et al.* 1998). Farmers' use of pesticides is often economically irrational, which suggests that their decisions to spray are not always guided by careful assessment of pest pressure or an evaluation of the damage being caused to crops (Huang *et al* 2002). These observations ought to raise questions about whether the adoption of a new technology like transgenic Bt cotton, even if it is effective in technical terms, will necessarily lead to reduced pesticide consumption in line with the observable reduction in the risk to crops. At least, they caution against assuming that an observed reduction in pesticide consumption can be attributed directly and automatically to the greater technical effectiveness of new pest control measures.

However, Huang *et al.* made precisely that assumption in their model, because they relied on an ex post assessment by the farmers in their sample about 'the per cent of the crop that the farmer believed would have been lost if he had not sprayed' (Huang *et al.* 2002:378). Yet it is at least strongly plausible that the more judicious and safer use of pesticides may be attributable in large part to the manner in which the new Bt seeds were promoted to farmers, rather than to the intrinsic characteristics of the technology itself. That implies that similar benefits might be attained independently of Bt cotton adoption. For example, if Bt cotton varieties were introduced to farmers as new varieties that 'do not require spraying' or are 'immune to pests', it would not be surprising if farmers adopting the technology reduced the amount of spraying they undertook. Similarly, the promotion of Bt cotton may involve sensitising farmers to the dangers of excessive and unsafe pesticide use. Farmers exposed to such messages might change their behaviour in response to the message itself, rather than because they had observed the superior insect resistance of the new crops. When attempting to evaluate the new crops, disentangling the different potential causes of changes in farmers' behaviour should therefore be a central concern.

As time has passed, work by a number of other researchers has raised questions about the Pray–Huang group's conclusions on pesticide use. For instance, Pemsl *et al.* (2005) have shown that many Chinese smallholders have continued to spray very high levels of pesticides, including some very hazardous chemicals, despite having adopted Bt cotton. Two studies by Yang and colleagues (Yang, Iles *et al.* 2005; Yang, Li *et al.* 2005) showed that Chinese Bt cotton farmers significantly overestimated the damage caused by cotton bollworms and sprayed too much pesticide as a result. Yang, Li *et al.* (2005), in particular, found that training in integrated pest management (IPM) methods was associated with a much bigger reduction in pesticide use than the adoption of Bt technology by itself. Indeed, they found that IPM had a bigger impact than Bt cotton on the population dynamics of pests and their natural enemies. Very similar conclusions were reached in a similar study by Lifeng *et al.* (2007). Finally, Wang *et al.* (2008), reinforcing earlier findings by Wu *et al.* (2002), found that any initial gains in terms of reduced pesticide use had been wiped out after a few seasons by the resurgence in the populations of formerly secondary pests.

Indeed, Huang *et al.'s* (2002) own research indicates that both Bt adopters and non-adopters applied pesticides far above the optimal level, even though Bt farmers applied much less than non-Bt farmers. When evaluating pesticides as a damage-abatement technology rather than a production-enhancing one, they concluded that 'one assessment of the results is that farmers are using so much pesticide that even when they adopt Bt cotton their marginal effect is near zero' (Huang *et al.* 2002:382). In their concluding remarks, Huang *et al.* gestured towards an acknowledgement that levels of pesticide use might be socially, culturally and institutionally shaped:

> Although a discussion of why farmers overuse pesticides is beyond the scope of the present paper, it is clear that such behaviour is systematic and even exists when farmers use Bt cotton varieties. One thought is that farmers might be acting on poor information given to them by the pest control station personnel. In fact, such a hypothesis would be consistent with the findings of work on China's reform-era extension system in general (Huang et al. 2002:384-5, citation deleted).

In another paper, Huang *et al.* (Huang *et al.* 2003) showed that farmers' decisions to spray were not influenced by pesticide prices, which undermines any suggestion that farmers were making rational economic calculations when deciding whether to apply pesticides. In short, the confident assertions, in these and other articles, that Bt cotton 'caused' or even 'enabled' a reduction in pesticide use simply cannot be supported by the evidence. A mere correlation does not provide firm evidence of causation.

Nevertheless, Huang *et al.* (2005; 2008) have carried the same basic assumption forward into their more recent pre-commercial evaluations of the possible impacts of transgenic insect-resistant rice in China. In these studies, their method has still relied on the non-GM rice farmers' perceptions of the yield loss that would have occurred if they had not applied pesticides. The approach cannot rule out the likelihood that the GM rice-adopters in their survey may have sprayed less because of a prior assumption that a rice variety presented to them as 'insect-resistant' would require fewer pesticide applications. Huang *et al.'s* (2005, 2008) studies also omitted an independent scientific analysis of pest pressure during the season in question. These weaknesses in their methodology made it impossible to isolate the possible causal effect of the insect-resistance trait itself, and left open the clear possibility that reductions in pesticide use of similar magnitude might be achieved independently of GM rice adoption – as they have in other documented cases (Heong *et al.* 2005).

This criticism is important because, although the observed reduction in pesticide use may be real, if it is not driven directly by the adoption of a particular kind of agricultural technology, there is no reason to suppose that further adoption or energetic promotion of that technology will necessarily, or sustainably, replicate that outcome. In short, though Huang, Pray and colleagues have identified a change in levels of pesticide use among the Bt cotton-farmers included in their surveys, they cannot account for that change. The studies by Pemsl *et al.* (2005), Yang, Iles *et al.* (2005), Yang, Li *et al.* (2005), Lifeng *et al.* (2007) and Wang *et al.* (2008) have all pointed to the same basic flaw in the Huang-Pray methodology, namely, that it has failed to take into account relevant insights into the complex forces that shape farmers' behaviour and overlooked the dynamism of natural processes. According to this growing body of evidence, the adoption of Bt cotton may be neither necessary nor sufficient to produce substantial reductions in pesticide use. To the extent that Bt cotton technology can in fact be judged a success in China, its widespread adoption and beneficial effects have as much to do with an exceptionally supportive institutional framework as with the technical performance of the technology itself (Fok *et al.* 2005; Keeley 2003).

4. BT COTTON IN INDIA

Bt cotton was officially commercialised in India in March 2002, although unapproved Bt varieties are known to have been grown in the state of Gujarat and parts of Maharashtra, Madhya Pradesh, Andhra Pradesh and Karnataka for an uncertain period of several years prior to that date (Scoones 2005a). After a difficult start (Glover 2007; Scoones 2005b), Bt cotton spread to about 6.2 million hectares by 2007, when the crop was reported to be grown by about 3.8 million small-scale farmers (James 2007).

PRODUCTIVITY, PROFITABILITY... VARIABILITY

Early studies of the performance of Bt cotton in India reported very large benefits for farmers (Qaim 2003; Qaim and Zilberman 2003), but the value of these studies was seriously compromised by the fact that they were based on field-trial data (Arunachalam and Bala Ravi 2003; Sahai 2003). One of the studies in particular, published in the prestigious international journal *Science* (Qaim and Zilberman 2003), provoked a storm of criticism from various quarters in India, where questions were raised about the validity of the results, the rigour of *Science's* peer-review process and the ethics of the article's publication (e.g. Sahai 2003; Shantharam *et al.* 2008; see Scoones 2005b).

The largest group of publications on the impact of commercial Bt cotton cultivation in India has been produced by a group of academics from Reading University in the UK. The group's first set of papers presented the findings of research on the 2002 and 2003 growing seasons for Bt cotton in the state of Maharashtra (Bennett, Ismael, Kambhampati *et al.* 2004; Bennett, Morse *et al.* 2006; Kambhampati *et al.* 2006; Morse *et al.* 2005b). In their first paper, Bennett, Ismael, Kambhampati *et al.* (2004) found that the costs of cultivating both Bt and non-Bt cotton during 2002 were very similar, but that Bt cotton produced a significant yield advantage and so produced an overall boost to farm productivity. The higher costs of Bt seed were offset by savings in pesticide use and an improved yield.

One has to read the paper carefully to notice the observation, which is mentioned almost in passing, that the area chosen for the study had the benefit of irrigation and 'good growing conditions', which enabled higher-than-average production for all types of cotton (Bennett, Ismael, Kambhampati *et al.* 2004:99). However, as the authors noted in their introduction, 'Most of the cotton in India is grown in rainfed conditions, and about a third is grown under irrigation' (Bennett, Ismael, Kambhampati *et al.* 2004:96). Hence, despite Bennett and colleagues' conclusion that 'Bt cotton has had a significant positive impact on yields and on the economic performance of cotton growers in Maharashtra' (Bennett, Ismael, Kambhampati *et al.* 2004:99-100), the results clearly could not be generalised to farmers who lacked the benefits of irrigation and favourable growing conditions.

The finding of a productivity advantage should also have been qualified by the observation that any yield advantage of Bt cotton should be expected only in seasons where bollworm pest pressure is significant, since Bt cotton is not an intrinsically yield-enhancing technology. Similarly, Bennett, Ismael, Kambhampati *et al.'s* (2004) conclusion that Bt cotton adoption led to reductions in pesticide use also needs to be treated with caution, for the reasons discussed in the previous section: observed reductions in pesticide use by Bt cotton adopters in India cannot be convincingly attributed to the performance of Bt technology without knowing something about farmers' decision-making processes, as well as the levels of pest pressure in particular seasons. Unfortunately, Bennett, Ismael, Kambhampati *et al.* (2004) did not present any such data.

However, in a revealing section of their paper, they acknowledged the cognitive and social factors that shaped farmers decision making on pesticides. Commenting on the interesting observation that farmers had initially sprayed slightly less pesticide against sucking pests on Bt cotton than non-Bt cotton, but in the second season slightly more, Bennett and colleagues wrote:

> It may be that in the first season some farmers did not fully understand the nature of the new technology and reduced sucking pest spray input, believing that the Bt variety needed less of such sprays. Bad experiences in 2002 may have led to an upsurge in spraying against these pests by Bt adopters in 2003 (Bennett, Ismael, Kambhampati *et al.* 2004:97).

That explanation is indeed possible. Thus, Bennett and colleagues' acknowledgement that cotton farmers' spraying behaviour may have been based not on careful observation of pest pressure but shaped by a priori assumptions about the expected pest-resistant attributes of Bt cotton, which may have been based on misinformation or confusion, points to the error involved in assuming that changes in farmers' use of pesticides can be attributed directly to the performance of a particular kind of new seed.[7]

The Reading group's Maharashtra 2002/03 dataset was also presented in three other articles (Bennett, Kambhampati *et al.* 2006; Kambhampati *et al.* 2006; Morse *et al.* 2005b). Examining these papers alongside the first one, some interesting new issues appear. In particular, it becomes apparent that there was a very large degree of variation in the experiences of farmers in the sample. The research approach, however, has had trouble grappling with this variability. In their 2004 paper, the authors had claimed that 'As sample sizes were large, the standard errors were small and would not be seen as bars on [our] graphs' (Bennett, Ismael, Kambhampati *et al.* 2004:97). In their later papers, however, Morse *et al.* (2005b) and Bennett, Kambhampati *et al.* (2006),[8] displaying their findings in tables rather than graphs, showed standard deviations of considerable size in key statistics. For instance, revenue from yield for Bt cotton in 2002 was recorded as INR 42,948 per hectare, with a standard deviation of INR 20,853; the corresponding values for non-Bt cotton were INR 31,081 and INR 49,903, respectively. In terms of gross margin, cotton farmers' profits ranged from INR 25,730 per hectare (non-Bt cotton, 2002) to INR 50,903 per hectare (Bt cotton, 2003), but the standard deviations of these statistics were INR 49,708 and INR 22,744, respectively (Morse *et al.* 2005b:

[7] It is worth observing that Bennett *et al.* (2004) could also have discussed the possibility that the difference might be due to the first signs of sucking pests becoming a more serious problem on Bt cotton because of a decline in the bollworm population. That has long been a concern relating to the sustainability of Bt cotton technology, as explored by Wu *et al.* (2002) and Wang *et al.* (2008) in China, or discussed by Keeley and Scoones (2003) in relation to Zimbabwe, and so it is surprising that Bennett *et al.* (2004) did not mention it.

[8] Bennett *et al.* (2006) presents additional data to earlier papers, as well as a more detailed breakdown of their results by sub-region of Maharashtra.

Table 1). Clearly, these statistics indicate the very high levels of variability in the experiences of cotton farmers with both types of cotton, even if there was much less variation in the results from cultivation of Bt cotton than non-Bt cotton. In fact, the high variation in cotton productivity in Maharashtra during 2002–03 and 2003–04 was confirmed by Ramasundaram *et al.* (2007), who identified it as a source of substantial financial risk for resource-poor farmers.

These indicators of variability qualify the headline averages of output and gross margin. Bennett, Kambhampati *et al.* (2006) and Kambhampati *et al.* (2006) presented a breakdown of their data across three different regions of Maharashtra for the year 2002. The figures revealed a complex, confusing picture of farmers' spraying behaviour and a startling degree of variability in their cotton output (see Table 4.1). Why was Bt cotton output so widely variable in the Vidarbha region, with a standard deviation more than 2.6 times as high as the average? Why was there so much variability in the spraying behaviour of farmers in Marathwada against sucking pests, but much less in Khandesh and Vidarbha? On the other hand, why did farmers in Khandesh and Vidarbha spray such widely varying amounts against bollworms, while the corresponding levels in Marathwada varied comparatively little around the average? The huge variation in these numbers was passed over without comment by Bennett, Kambhampati *et al.* (2006) and Kambhampati *et al.* (2006) in their discussions, yet it should have raised fundamentally important questions about how Bt cotton had fitted into farming systems and practices in Maharashtra and the factors that may have caused widely different outcomes to be observed.

The wide variability in cotton farmers' experiences can also be seen in two papers presenting data from a separate survey on the 2003 growing season in the state of Gujarat (Bennett *et al.* 2005; Morse *et al.* 2005a). These papers concluded that officially approved Monsanto Bt cotton hybrids had out-performed unauthorised Bt cotton, as well as non-Bt cotton varieties. That finding was based on average values calculated from their survey. However, the very large standard deviations reported by both Morse *et al.* (2005a) and Bennett *et al.* (2005) made clear that the data points in their sample were very widely spread around the average values; clearly, there had been a large degree of variability in the yield, revenue and gross margin for all cotton types (see Figures 4.1 and 4.2).

In other words, the average values which Morse, Bennett and colleagues highlighted should be heavily qualified. They mask the much more important fact that cotton farmers' experiences had varied very widely. Indeed, it appears that cotton cultivation of all types may have been a deeply uncertain and hence risky proposition for many, perhaps most, cotton farmers. However, that possibility is difficult to assess, because the authors did not indicate the median or mode values that might have helped the reader to judge whether the averages were in fact representative of any real farmers. Making that judgement is important because, as the next section discusses, the characteristics of different farmers and the contexts in which they farm play vital roles in shaping their capacity to use Bt cotton technology to advantage.

Table 4.1: Wide variations in output and pesticide sprays

	Khandesh			Marathwada			Vidarbha		
	Mean	SD	Number	Mean	SD	Number	Mean	SD	Number
Value of cotton output (Rupees/ acre)	25,217.50	8,399.94	684	17,531.10	5,896.98	1,024	16,227.10	42,597.90	1,095
Number of sucking pest sprays/ acre	2.41	0.68	711	2.34	17.67	1,150	2.04	0.77	1,092
Number of bollworm sprays/ acre	1.24	16.19	610	1.08	0.98	1,119	1.95	23.88	1,042

Source: Bennett, Kambhampati et al. (2006), Table 5 (p.69).

Figure 4.1: Wide variation in cotton yields

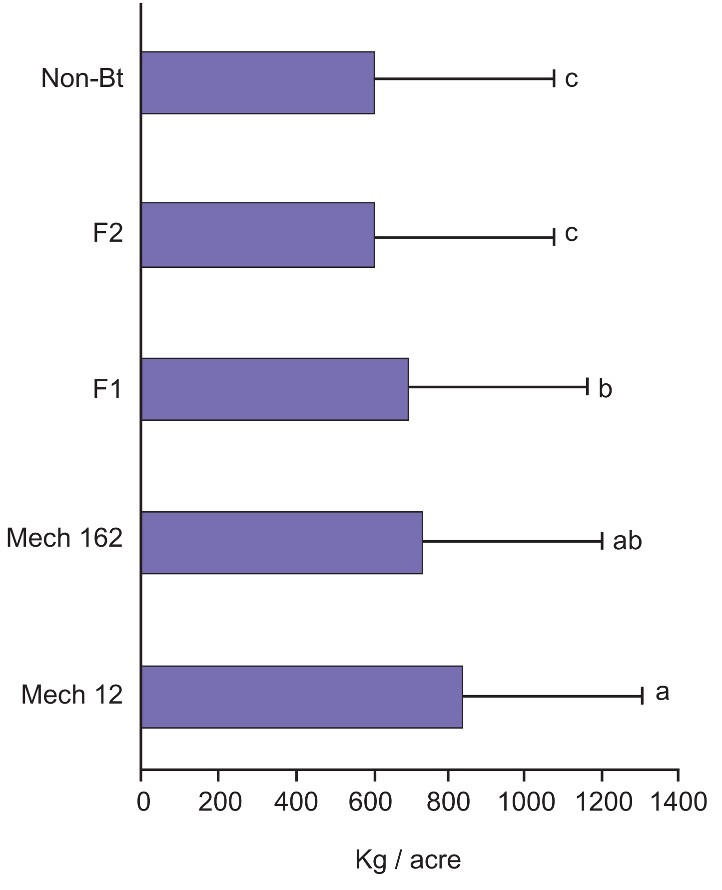

Figure 2.
Yields of the five cotton hybrids.
Note. Bars are mean values; error bars represent one standard deviation. Mean separation was via Duncan's Multiple Range Test. Means with a common letter are not significantly different at the 5% level.

Source: Morse et al. (2005a), p.3.

Figure 4.2: Wide variations in costs, revenue and gross margin

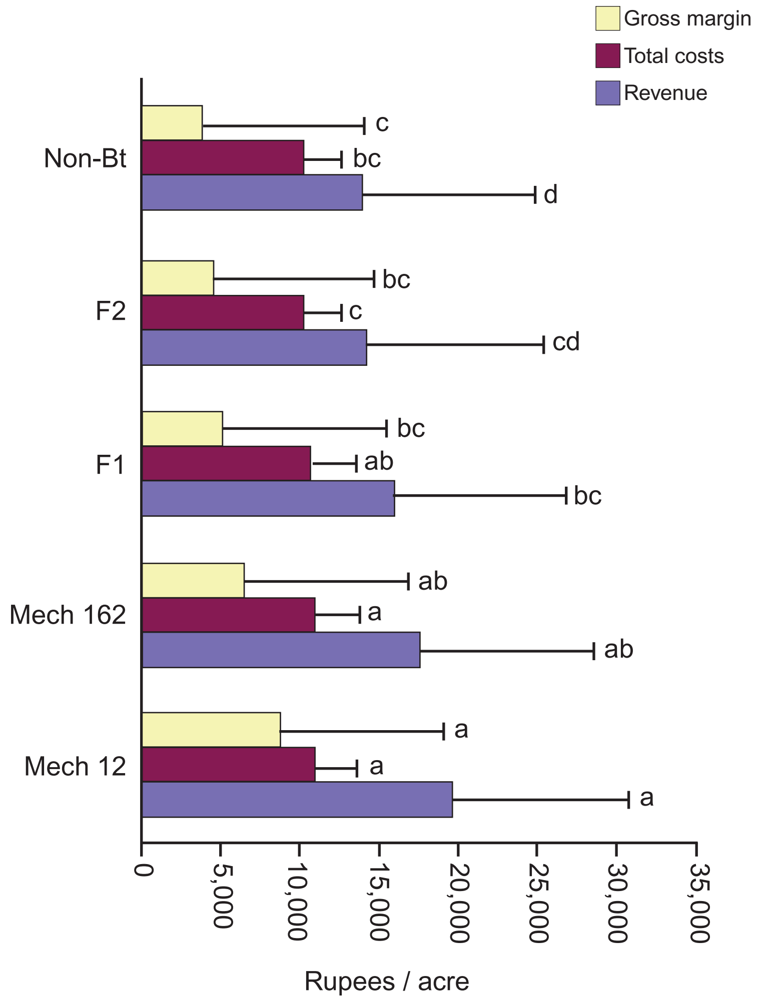

Figure 6.
Total costs, revenue and gross margin for the five cotton hybrids.
Note. Bars are mean values; error bars represent one standard deviation. Mean separation was via Duncan's Multiple Range Test. Means with a common letter are not significantly different at the 5% level.

Source: Morse et al. (2005a), p.5.

A DIFFERENT KIND OF FARMER?

Recently, the Reading group has returned to their analysis of the 2002 and 2003 cotton seasons in Maharashtra with a set of papers published in 2007, based on a survey carried out in the district of Jalgaon (Crost *et al.* 2007; Morse *et al.* 2007a, b). In different ways these papers addressed the problem of isolating the effect of the Bt trait from other factors that might influence the overall productivity of cotton cultivation, especially the characteristics of Bt adopting farmers.

Morse *et al.* (2007a) set out to examine whether Bt cotton might exacerbate inequality. Although the paper claimed to address the argument that Bt cotton could increase inequality between richer farmers able to take advantage of the new technology and poorer ones who could not, the analysis actually concentrated on measurements of equality *among* groups of adopters and non-adopters rather than *between* the groups. Finding that, on some measures, including income from cotton, there was less inequality among the adopting households, the authors then asked, 'So what has *resulted in* this greater equality of cotton income among the adopter group of [households] relative to the non-adopters?' (Morse *et al.* 2007a:47, emphasis added).

Unfortunately, there is no longitudinal data that could have enabled a comparison of inequality among the same group of farmers before and after adopting Bt cotton. Instead, Morse *et al.* (2007a) inferred a causal relationship between Bt cotton cultivation and greater income equality indirectly, from a static snapshot of data from two seasons, by looking for possible correlations between measurements of equality in different factors of production, especially between land ownership on one hand and income from cotton on the other.

At the farm level, they found that the distribution of income from cotton cultivation was more equal among Bt adopters than among non-adopters. At the aggregate level, on the other hand, they found that land was more evenly distributed among non-adopters than adopters, which led them to conclude, rather peremptorily, that that factor could not explain the greater equality of cotton income which they had observed among adopters. Morse *et al.* (2007a) then switched to an evaluation of differences in gross margin per unit of land between Bt cotton, a high-performing non-Bt hybrid called Bunny, and other non-Bt hybrids. They found that gross margins for Bt cotton were greater than for Bunny, whose gross margins were greater in turn than other non-Bt varieties.

These calculations led Morse *et al.* (2007a) to draw the conclusion that the degree of income equality observed for Bt adopters at the aggregate level must be attributable to the greater degree of uniformity in gross margins per unit of land for Bt cotton. But the two types of measurements they used cannot be compared directly. One was a measurement of the distribution of income across a sample of farm households of different sizes, while the other was a measure of the input—output performance of cotton on plots of land of the same size. One particular problem with such a comparison is that there may be efficiency effects associated with different sizes of farms or plots. Accordingly, the correlation found by Morse *et al.* (2007a) should be interpreted with great caution.

More importantly, Morse *et al.* (2007a) also neglected to consider the possibility that the more uniform harvests apparently achieved by the Bt cotton farmers in their sample may have been associated not only with the more dependable performance of Bt hybrids, but at least partly with the farmers' greater access to reliable irrigation, which is apparent from Morse *et al.'s* (2007a) statistics on the farmers' production costs. In other words, it seems distinctly possible that, had longitudinal data been available, it might well have shown that there was already greater equality in productivity among farmers having the benefit of irrigation before Bt cotton was commercialised.

The apparent difference in levels of irrigation by Bt adopters and non-adopters is surprising in view of Morse *et al.'s* (2007a:46) own assertion that: 'Only a few differences in terms of general background features of the farmer and household were discernible between adopters and non-adopters of Bt cotton'. In fact, looking more closely at their data, access to irrigation begins to look like just one of the dimensions of difference between Bt adopters and non-adopters. Part of the issue here is the important difference between 'statistical significance', which is a technical test used to check that a statistical finding is unlikely to have occurred merely by chance, and everyday significance, which is the size or importance of the effect that has been measured in social, economic or other meaningful terms (Ziliak and McCloskey 2008). Morse and colleagues did not address the statistical significance of the apparent difference in average levels of irrigation used by Bt adopters and non-adopters, but in relation to labour they did tell readers that they found 'some suggestion ($P < 0.1$) that adopters had more full-time and male labor available for agriculture than did the non-adopters' (2007a:46). It turns out, from looking at Morse *et al.'s* (2007a) tables, that the margin between the average expenditure on labour by Bt adopters and non-adopters was actually of considerable magnitude and showed up consistently in relation to both the adopters' Bt and non-Bt plots and in both seasons studied. The same can be said for irrigation. As one looks at these facts, one begins to suspect that there actually may have been some rather significant differences – in the everyday sense – between adopters and non-adopters of Bt cotton. While statistical tests of significance are of course important in avoiding the risk of over-interpreting data from a small sample, it is surprising and disappointing that Morse *et al.* (2007a) did not explore these contrasts more thoroughly.

It turns out that these indications that there may have been some important differences between the kinds of farmers adopting Bt cotton and those not adopting are actually borne out by the data revealed in another article, published in the *Journal of Agricultural Science (JAS)* (Morse *et al.* 2007b). Based on the same dataset, written by the same authors and published in the same year, this paper nevertheless reached some startlingly contrasting conclusions.

The *JAS* paper set out to examine the 'farmer effect' in Bt cotton cultivation. The paper revealed that the adopters and non-adopters of Bt cotton were rather different from one another, after all. The authors made more of the labour advantage enjoyed by Bt adopters: 'Given that crop cultivation in this area is dependent on human and animal labour, this is a major advantage' (Morse *et al.* 2007b:494). The Bt adopters also had much more credit and land than non-adopters, and devoted a bigger proportion of their land to cotton. Bt adopters were significantly more likely to be involved in livestock production and earned twice as much income on average from livestock as non-adopters. A higher proportion of non-adopters' household incomes came from farming. Interestingly, however, the non-adopters typically earned more than adopters from similar areas of non-cotton cultivation and overall the average household income of non-adopters was actually higher than that for adopters, albeit with a wider range of variation. It was also clear (as in their previous paper) that Bt adopters also showed a preference for a particular hybrid, Bunny, for their non-Bt plots. As the authors noted:

> This suggests that the categories of adopter and non-adopter may reflect two quite different types of farmer. Adopters concentrate more on cotton, and have more land and higher incomes from livestock. Non-adopters are generalists in terms of the crops that they grow, and have less land and less of an emphasis on cotton (Morse *et al.* 2007b:494).

In the light of these conclusions, Morse *et al.'s* (2007a) own previous discussion of inequality among adopters and non-adopters seems very odd. The clear differences between adopters and non-adopters during the 2002–03 and 2003–04 growing seasons in Maharashtra have in fact been confirmed by Ramasundaram *et al.* (2007). For instance, they found that the average land-holdings for adopters during those first two seasons of official Bt cotton cultivation were 6.26 hectares and 3.28 hectares, respectively, whereas the average land-holding per capita in rainfed areas of the region was less than one hectare; Bt adopters were also more literate (see also Shah 2005, 2008 on Gujarat).

Nevertheless, although the *JAS* paper confirmed that adopters and non-adopters 'are indeed quite different' (Morse *et al.* 2007b:499), the authors' conclusions emphasised their finding of a 'farmer effect'. They calculated that this effect accounted for about half of the observed advantage of growing Bt cotton – thus significantly downgrading their own and other analysts' previous claims about the magnitude of benefits from cultivating the new Bt varieties. In other words, a substantial proportion of the better results achieved by Bt cotton adopters was attributable to the pre-existing differences that distinguished them from non-adopters, such as better access to labour and irrigation. That conclusion was confirmed by another paper that used the Jalgaon dataset (Crost *et al.* 2007). Crost *et al.* (2007) also offered a much more explicit acknowledgement than previously of the degree to which farmers also differed in their decision making about pesticides. In this aspect, however, the differences did not correspond neatly with the categories of adopters and non-adopters of Bt cotton, or other measurable features. As the authors noted, 'at least a portion of the farmers use pesticides in a very inefficient way… generally, the efficiency with which farmers use inputs seems to vary widely and is not explained well by their observable characteristics' (Crost *et al.* 2007:33). That conclusion should lead to questions about what factors might provide a better explanation for the wide variability in farmers' behaviour and attitudes, for which simple econometric methods might be insufficient.

It is a pity that Morse *et al.* (2007b) did not give more space to an examination of the implications of the clear differences they had identified, between farmers who had adopted Bt cotton and those who had not, because it is a fascinating and important observation. In fact, Morse *et al.'s* (2007b) data suggests rather strongly that the kind of farmers who first adopted Bt cotton in Maharashtra were not only wealthier, having more land as well as better access to the key resources of irrigation and credit, but they also appeared to be more commercially oriented farmers, for whom farming represented a smaller proportion of their economic activity, who allocated more of their land to cotton and livestock and were actually less productive in their cultivation of non-cotton crops. Not only did the non-adopters lack the resource advantages of their richer counterparts, it seems distinctly likely that they may have been pursuing a different kind of livelihood strategy, one which was more dependent on agriculture as a whole but less dependent on cotton in particular. That could help to explain why Bt adopters also showed a preference for a particular hybrid, Bunny, on their non-Bt plots, whereas non-adopters planted some Bunny but also chose a range of other varieties. It may be that these non-Bt varieties, though they may have been less productive than Bunny or the Bt hybrids, nevertheless had other advantages that the non-adopters valued. For instance, perhaps they were preferred by farmers because they performed better in rainfed conditions or produced a more dependable, though less spectacular, yield from season to season (see Ramasundaram *et al.* 2007). Morse *et al.'s* (2007b) data could be a timely and important reminder that not everyone wants a thoroughbred racehorse; sometimes a sturdy, reliable mule is what you really need.

A key point to notice here is the implicit assumption, in this and similar research, that the more commercial farmers were 'better' farmers (Morse *et al.* 2007a:44), a factor that supposedly drove their preference for 'improved' varieties and also helped to explain the higher levels of productivity they achieved with all kinds of cotton. The corollary of this assumption is that their example is one for the non-adopters to emulate; and also that it should be a goal for agricultural policy makers to encourage all farmers to be more like the Bt adopters – not merely in their choice of crop varieties, but in their commercial orientation. But it is hard to sustain the assumption that Bt adopters were more competent farmers in the face of the contrary evidence that some non-adopters clearly achieved better results on their non-cotton plots, even though they had fewer resources at their disposal (Morse *et al.* 2007b). Meanwhile, the fact that non-adopters in Morse *et al.'s* (2007b) sample actually had a higher average household income than Bt adopters, which they apparently generated from smaller areas of land and in spite of a lower income from cotton cultivation, ought to raise questions about whether encouraging them to make a transition to a more commercial style of farming would necessarily make those households better off. That possibility cries out for further research and analysis. Besides, it should be a vital question whether agricultural development policy should aim to encourage farming households to conform to an imposed normative model of agriculture or seek to support them in achieving the developmental goals they themselves wish to achieve.

5. BT COTTON IN SOUTH AFRICA

Bt cotton was commercialised in South Africa in 1998. About 1.8 million hectares of GM crops were grown in South Africa in 2007, including varieties of Bt cotton and maize, and herbicide-tolerant varieties of soybeans and cotton (James 2007). Small-scale cultivation of Bt cotton is concentrated in the Makhathini Flats region of KwaZulu–Natal province, where about 3,000 black smallholders grew the crop on about the same number of hectares in 2000–01 (Thirtle *et al.* 2003). Smallholder cotton production in the region has since fallen back, however, as will be discussed below (Fok *et al.* 2007; Gouse *et al.* 2005).

YIELDS, PROFITS AND RISKS

As in China and India, a number of impact studies have been published since Bt cotton was commercialised in South Africa. Some of these studies were carried out by the Reading group of researchers, but other studies have been contributed by researchers from King's College, London, South Africa itself, Germany, France and the USA. The history of impact studies on Bt cotton in South Africa resembles the stories in China and India, where early studies were interpreted as showing that farmers were reaping significant benefits from adopting Bt cotton, while later research has revealed a more nuanced and differentiated picture.

Early studies by the Reading group, based on a survey of 100 farmers and covering the first two seasons of commercial cultivation (1998 and 1999), concluded that 'Bt cotton adopters experience significant benefits from the new technology' (Ismael, Beyers *et al.* 2002:348), including better yields and reduced expenditure on pesticides, leading to a higher gross margin (Ismael, Bennett *et al.* 2002a, b; Ismael, Beyers *et al.* 2002). A smaller study by Bennett *et al.* (2003), which involved in-depth interviews with 32 farmers, endorsed these conclusions and added the observation that reported incidents of pesticide poisoning at the local hospital had declined alongside the spread of Bt cotton. These results were broadly confirmed by Thirtle *et al.* (2003), who supplemented the data from the same original questionnaire survey of 100 farmers with data from the detailed farm records held by the local cotton company, Vunisa. They found that Bt adopters had actually been financially slightly worse off than non-adopters during the first season, when growing conditions were favourable for cotton, but that they were more efficient than non-adopters in their use of inputs during both seasons. Gouse *et al.* (2003) broadly confirmed these findings, although they found indications that the early adopters were generally more efficient farmers in the first place.

Later studies, involving larger samples across three seasons (1998/99, 1999/2000 and 2000/01), appeared to confirm the success story of Bt cotton (Bennett, Ismael, Morse *et al.* 2004; Bennett, Morse *et al.* 2006; Morse *et al.* 2004, 2006). The following summary of these studies' conclusions is fairly typical:

> The results show significant, substantial and consistent benefits of adopting Bt cotton for resource-poor smallholders in the Makhathini area of South Africa over the first three significant years of adoption. Benefits were largely in the form of increased yields, reduced pesticides and labor for spraying that, despite higher seed and harvesting labor costs, resulted in substantial improvements in gross margin. Results also suggest that those benefiting most from the technology were the smaller and more intensive cotton growers (Morse *et al.* 2004:380).

Further, Bennett, Ismael, Morse *et al.* (2004) found that inequality had increased between adopters and non-adopters, but declined among adopters as time passed. They also calculated that reduced pesticide spraying by Bt cotton-adopters had resulted in a reduced toxic load to the environment, a claim that was confirmed, using a slightly different method, by Morse *et al.* (2006). Using the same dataset, Bennett, Morse *et al.* (2006) further argued that Bt cotton reduced risk for adopters, on the grounds that the technology helped to prevent crop losses in years with unfavourable weather.

Together, these studies appeared to provide convincing evidence that Bt technology in the Makhathini Flats was a success story. However, beneath the surface of the generally positive conclusions reached by these studies were other, more complex stories. For one thing, it became increasingly evident that there was a wide degree of variability in the results experienced by different Makhathini smallholders and between seasons. Also, as in the Chinese and Indian cases, none of the studies succeeded in establishing a convincing causal link between the adoption of Bt cotton and observed reductions in pesticide use. In fact, Bennett, Ismael, Morse *et al.* (2004) showed that the reduction in toxic load attributable to Bt cotton plots was partly due to the fact that Bt adopters had reduced their use of non-bollworm pesticides, even though the Bt trait provides no protection against pests other than bollworms. They also showed that that the overall toxic load to the environment from all types of cotton agriculture had actually increased over the first three seasons since Bt cotton had been commercialised, largely because non-adopters were using more pesticides against non-bollworm pests. As the authors commented, these observations placed question-marks over the mechanisms driving pesticide use, farmers' comprehension of the pest-control technologies they were using and the sustainability of the environmental benefits that Bennett and colleagues had identified. On the basis of a separate survey, Hofs *et al.* (2006) confirmed that the adoption of Bt cotton had not led to the adoption of a substantially less hazardous or more environmentally friendly pest management regime by farmers in the Makhathini Flats.

Claims by Bennett, Morse *et al.* (2006) and Zilberman *et al.* (2007) that transgenic insect-resistant crops reduced risk for smallholders have also been called into question. Their argument rested on the contention that Bt cotton reduces risk because it smoothes out the variability of crop output and profits from one season to the next, making farming more predictable. However, Bt technology functions primarily as a form of crop insurance. It only confers a substantial economic advantage in seasons where there is a serious outbreak of the target pest. In other seasons, adopters of insect-resistant crops have to carry the additional costs of transgenic seed but gain no particular yield advantage over non-adopters who have paid much less for their seed. Furthermore, the Bt trait protects the crop against only one kind of threat. A different kind of threat, such as a major outbreak of secondary pests or severe adverse weather conditions, such as a prolonged drought, could still wipe out the crop, destroying the investment in the more expensive Bt seeds. Hence, depending on the circumstances, spraying pesticides may remain a more sensible strategy of risk management than adopting Bt cotton (Pemsl *et al.* 2004).

Hofs *et al.* (2006) and Fok *et al.* (2007) were in no doubt that the high technology fee attached to Bt cotton seed increased financial risk for Makhathini farmers, particularly in the light of persistently low yields and wide variability in outputs and revenues from one season to the next. A key problem with the study by Zilberman *et al.* (2007) is that the authors did not seriously evaluate the magnitude of the downside risk. Resource-constrained smallholder farmers are well-known to be risk-averse, having good reason to be so (Shankar *et al.* 2007; cf. Ramasundaram *et al.* 2007, for India). Shankar *et al.* (2007) stated unequivocally that Bt cotton increased production risks for Makhathini smallholders, because of the lack of benefits in unfavourable years. Nevertheless, they still concluded that the superior average performance of Bt cotton (the same feature which led Zilberman *et al.* to label the technology 'risk-reducing') made it preferable, even for risk-averse smallholders. Ultimately, however, it is impossible to draw general conclusions about Bt cotton's impacts on risk, since they depend critically on the local context; for instance, Crost and Shankar (2008) found that the technology reduced risks for cotton farmers in India, but there was no clear effect in South Africa.

More generally, it has been made increasingly clear that institutional factors have played a central role in the recent history of cotton production in the Makhathini Flats, positively and negatively, to a degree that eclipses the role played by the Bt technology *per se.* Whereas the early impact studies created the impression that there had been a pattern of steady growth and improving returns from cotton cultivation in the Makhathini area, production actually collapsed in the 2002/03 growing season and continued to fluctuate dramatically, upwards and downwards, in the following seasons. It is now very clear that the initial 'success' of Bt cotton in the Makhathini Flats depended heavily on the joint support of the local cotton company, Vunisa, and the local credit agency, the Land Bank. Between them, these two agencies provided the farmers with a ready supply of inputs, information and credit, backed by loan guarantees, as well as a market for their cotton output. Since the breakdown of this supportive institutional framework in 2002, cotton production has become a much more precarious venture for smallholders, especially for those who lack irrigation. Without irrigation, the yields of both Bt and conventional cotton remain low (Fok *et al.* 2008; Fok *et al.* 2007; Gouse *et al.* 2005; Witt *et al.* 2006).

These institutional factors were evident from the earliest studies and even recognised as 'a critical component of the farming system in Makhathini' (Ismael, Bennett *et al.* 2002b:108), but their implications were typically not explored in significant detail. Later studies, such as those by Bennett, Morse *et al.* (2006) and Zilberman *et al.* (2007) have, more centrally and explicitly than before, acknowledged the key importance of the institutional context. But it is unfortunate that the special institutional characteristics of the Makhathini case did not receive greater attention in some of the early studies. They were clearly evident from an early stage, and a more rigorous analysis of their implications might have restrained some of the more exaggerated inferences that were drawn about the likely impacts of GM crops in other smallholder farming contexts elsewhere in the developing world. For instance, as early as 2003, Thirtle *et al.* acknowledged that:

> Makhathini Flats was a special case … as it was a large smallholder development scheme that was something of a show-piece for the international community. As a result, the Makhathini Flats Scheme has an experimental farm and an extension service that is far better than in other areas and this must be taken into account when considering the wider applicability of the results (Thirtle *et al.* 2003:719, citation deleted).

This review of studies on the impacts of Bt cotton in China, India and South Africa shows that there is clear evidence of selectivity in the way that partial, ambiguous and equivocal data has been interpreted and represented. In all three cases, the story of success that has been highlighted on the surface has been shown to be, if not untrue, certainly only part of the story. Of course, few have been foolish enough to claim that Bt cotton has been a resounding, unqualified success. But in a number of different, subtle but identifiable ways, encouraging results have been emphasised, while negative ones have been downplayed. For instance, analysts have focused on the positive story told by average values, while glossing over the very wide variability that has been observed in the impacts of Bt cotton between different farms and farmers. Clear indications of differences between Bt adopters and non-adopters have been found, but apparently not found interesting or important, as if Bt technology rendered underlying socio-economic differentiation irrelevant. Economic analysis has been used to show that Bt adoption is a rational choice, without sufficiently considering whether the real resource constraints faced by smallholders might prevent them from affording the up-front costs or bearing the downside risks of an expensive technology. Observed reductions in pesticide use have been attributed to the adoption of Bt cotton, without troubling to examine the issue of causation and despite the overwhelming evidence that farmers' pesticide decision making is often economically irrational and shaped by obscure and complex institutional, economic, technical and cognitive factors. Bt cotton has been constructed as a technology that reduces risk because it smoothes out the variability in cotton production from one season to the next, rather than one that amplifies risk because the higher cost of the seeds increases the potential for economic losses in a season where cotton yields are seriously affected by drought or 'secondary' pests.

Above all, evaluation of the merits of Bt cotton has rarely addressed the question of how Bt technology compares with other technical interventions or alternative approaches, despite the strong indications that, for example, the choice of background variety or the availability of irrigation has a much more significant impact on cotton yields than Bt technology itself. Equally, effective farmer training can lead to major beneficial changes in yields and productivity without resorting to the expense of an inflexible technology like Bt cotton. In other words, the often strenuous and sophisticated effort to evaluate the technical and economic performance of Bt cotton has usurped the place of a different, more dispassionate, and ultimately more rigorous, kind of evaluation, that would begin with the complex problems faced by smallholder cotton growers and explore the multiple possible solutions that might help to overcome those problems. A genuinely open-ended assessment of those options and alternatives, taking the farmers' problems and the socio-technical context rather than a particular technology as the starting point for the analysis, would leave all possibilities open – including that of abandoning cotton cultivation altogether.

A misleading impression has been created that Bt cotton has already proved its value as part of a sustainable, productive agricultural livelihood for poor farmers in China, India and South Africa. That conclusion carries with it the strong implication that there is a *prima facie* case for presuming that Bt cotton and other GM crop technologies would be similarly beneficial for other small-scale farmers in other poor countries. But, as the discussion in the three preceding sections has shown, there is another side to the story, one which highlights the contingency, limitations and problems of the Bt cotton 'success'. As time has gone by, even the authors associated with the most enthusiastic early endorsements of Bt cotton as a success have begun to acknowledge those factors more frankly and explicitly than before. Those factors reaffirm the need for careful, case-by-case, contextual analysis of the likely effects of GM crops. However, as I described at the beginning of this paper, those nuanced messages have, to date, had less of an impact on public and policy debates. The next section turns to an exploration of why the implications of Bt cotton's widely variable and highly contingent impacts appear to have been resisted and are struggling to have any impact on the public and policy debate about GM crop technology.

6. THE RESILIENCE OF THE 'PRO-POOR GM CROPS' NARRATIVE

As discussed in the introduction, the narrative of GM crops as a pro-poor, developmental technology has shown a remarkable resilience over time, in spite of the gradual accumulation of evidence that calls for a more sophisticated and nuanced response to the impacts of GM crops. As the previous three sections have begun to show, this resilience can be seen in the ways that the very researchers who have been responsible for collecting data and analysing the results have chosen to frame their research questions and present their findings. But identifying those choices sometimes requires a very close, careful scrutiny of the methods used and of the gap between the stories emerging from the data and the ways in which those stories are selectively told, framed and highlighted in researchers' own discussions of their findings.

Sometimes, the reluctance to deal frankly with the evidence is more obviously on view. A good example of this arose in the case of a paper first presented at a conference in 2006 by a team of researchers from Cornell University, USA, which included Per Pinstrup-Andersen. Pinstrup-Andersen is a former Director General of the International Food Policy Research Institute (IFPRI) and recipient of the prestigious World Food Prize in 2001, who has been a passionate advocate for the use of GM crop technologies in the developing world (e.g. Pinstrup-Andersen and Schioler 2001).[9] The paper, entitled 'Tarnishing Silver Bullets', reported data from a survey of cotton areas of China which clearly indicated that the early benefits of Bt cotton cultivation in that country were being undermined by the emergence of secondary pests (Wang *et al.* 2006, 2008). The outbreak of sucking pests, especially mirids, meant that Bt cotton was proving uneconomic for farmers, just a few years after they had adopted it; the study found that the net revenue of Bt farmers was actually lower than that of non-Bt farmers in 2004, because they had to spray additional pesticides, as well as paying the higher price for Bt cotton seed. The authors also warned that the Bt cotton system also threatened to lead to the rapid evolution of insect resistance to the Bt toxin itself.

Commenting on these findings, Pinstrup-Andersen said: 'These results should send a very strong signal to researchers and governments that they need to come up with remedial actions for the Bt cotton farmers. Otherwise, these farmers will stop using Bt cotton, and that would be very unfortunate'.[10] In the light of the paper's

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[9] Pinstrup-Andersen has recorded a powerfully emotive video appeal on behalf of GM crops for Monsanto's 'Conversations about plant biotechnology' website, available at http://www.monsanto.com/biotech-gmo/asp/experts.asp?id=PinstrupAndersen (16/01/09).

[10] 'China's GM cotton profits are short-lived, says study', SciDev.Net, 26/07/06, http://www.scidev.net/en/news/chinas-gm-cotton-profits-are-shortlived-says-st.html (12/11/08).

findings, this was a rather surprising comment. It was as if the performance of Bt cotton technology could somehow be dissociated from its effects. It was as if Pinstrup-Andersen wished to disembed the technology from the social and even agronomic context of its use. Wang *et al.'s* (2006) main recommendations were for farmers to change their behaviour, which would involve adopting a complicated set of secondary pest-control methods that might be expensive in the short term and whose implementation would, in any case, depend on the questionable ability of agricultural extension workers to raise farmers' awareness and convince them to adopt new practices. Against that background, Pinstrup-Andersen's insistence that it would be 'unfortunate' if farmers abandoned Bt cotton betrays his reluctance to see the abandonment of a technology which, it appears, is simply not well-adapted to the capacities of smallholder farmers or the dynamic agricultural systems and constrained institutional contexts in which they operate.

'Tarnishing Silver Bullets' actually raised fundamental questions about the Bt cotton model of pest management and about the grounds on which the technology has been recommended for use by Chinese smallholders. The authors pointed out that official and commercial encouragement to embrace Bt cotton has been based in part on economic models of the technology's impact that have been based on the obviously false assumption that cotton farmers only need to take account of one pest. That assumption necessarily biased the results of such models by overstating Bt cotton's likely benefits for farmers (Wang *et al.* 2006, 2008). Contrary to the assumptions of economists' models, cotton farmers actually have to contend with a large number of different cotton pests – about 150 different species in India, for instance (Murugkar *et al.* 2006; Venugopal 2004) – of which, the Bt toxin protects against just a handful. Seen in this light, the categories of 'primary' and 'secondary' pests are seen as merely historically contingent constructs. It is entirely predictable that farmers' success in selectively attacking the primary pest will stimulate the expansion of secondary pest populations. In a technical sense, Wang *et al.'s* (2006; 2008) recommendations, which included the advice that Bt cotton farmers should plant a significant 'pest refuge' of conventional cotton and spray it with pesticides, may well be correct; but implementing such measures would mean that the simplicity and ease of management that were among the supposed advantages of the Bt cotton pest-control model begin to look rather more complicated.

Strangely, Wang *et al.'s* (2006; 2008) papers had implicitly recognised the need for a socially embedded analysis of Bt cotton technology in the context of the wider socio-technical system. Tacitly rejecting any claim that 'the technology is in the seed', they pointed out that the 'working' of Bt cotton technology requires specific knowledge and awareness – typically inculcated through education and training – that leads to changes in practice. They illustrated their case with the finding that most of the Chinese farmers they sampled were completely unaware of the concept of a refuge, an ignorance that threatens the sustainability of the benefits of growing Bt cotton. Further, the authors concluded that, in the absence of adequate education and training, 'new technologies may only serve to exacerbate problems associated with poverty and scarcity' (Wang *et al.* 2006:8).

What we seem to be encountering here is a powerful desire to isolate the technical performance of Bt technology from its socio-economic and environmental effects, leading to a repeated failure to learn the lessons provided by impact studies. Another, striking example can be found in the article by Gouse *et al.* (2005), discussed above, in which they went so far as to label Bt cotton in the Makhathini Flats explicitly as a ‘technological triumph but institutional failure’. As discussed above, there is in fact strong evidence to suggest that it was the institutional framework that helped to create whatever degree of ‘success’ was seen at first in KwaZulu–Natal – a conclusion which is only strengthened by the knowledge that cotton cultivation collapsed when the institutional framework broke down and has been unstable ever since.

It is hard to shake the impression that the authors of many of the Bt cotton impact studies have gone to excessive lengths to exaggerate the importance of their favourable conclusions. A particularly extreme example is provided by Qaim (2003) in his early report of beneficial impacts from cultivating Bt cotton in India, which was based on pre-release field trial data. Qaim claimed that Bt cotton was responsible for a yield increase of 80% in a year of high pest pressure, as well as significant reductions in pesticide use. The extraordinary magnitude of these supposed benefits should have encouraged a healthy scepticism, followed by a careful reassessment of the evaluation methods used. On the contrary, however, Qaim went on to argue that his findings could be taken as a robust foundation for predicting the likely impacts of Bt cotton under normal farming conditions. He repeatedly asserted that the value of his results was not entirely mitigated by having been drawn from field trial data because, he claimed, the farmers involved were left alone to manage their cotton plots. However, his account of the design and conduct of the trials made clear that that assertion was seriously misleading. The field trials had actually been closely supervised by agronomists from the Indian seed company Mahyco, who visited the trial farms frequently, where they carried out regular monitoring of pest pressure and supplied that information to the farmers.

Apart from the obvious fact that most farmers do not have the benefit of receiving frequent, detailed bulletins about the fluctuations of pest pressure on their own land, it stretches credulity to breaking point to believe that the farmers did not ask for the agronomists’ advice and guidance, or that the agronomists, who had a vested interest in ensuring the trials were successful, did not give it to them. Qaim (2003) even acknowledged that, left to their own devices, farmers often overuse pesticides. However, instead of drawing the obvious inference that there must be more to understanding what drives farmers’ pesticide use than assuming that it is simply a function of pest pressure or economic calculation, Qaim asserted: ‘Thus, the trial results rather underestimate the technology’s potential for pesticide savings’ (Qaim 2003:2123). By saying so, it is as if Qaim believes that Bt technology could be responsible for changing farmers’ irrational spraying behaviour as well as tackling bollworms.

Overstating the weight of evidence in this way occurs in various other articles and papers. For instance, in the introductory part of one of their articles on Bt cotton in South Africa, Bennett and colleagues made the following unequivocal statement: 'With regard to the health and environmental benefits resulting from the use of less insecticide, there are a number of studies which *prove the causal link* between the growing of insect-resistant GM varieties and the use of less insecticide' (Bennett, Ismael, Morse *et al.* 2004:666, emphasis added). As I have argued above, that statement is seriously misleading because, if there is one thing that the studies referred to[11] have consistently failed to do, it is to establish any kind of causality in relation to observed changes in pesticide use. Moreover, as discussed in the last section, Bennett *et al.* (2004) also demonstrated that the toxic load to the environment in the Makhathini Flats actually rose over the first three seasons of Bt cotton adoption. They added:

> Therefore, it should not be assumed that the introduction of Bt cotton will inevitably reduce toxic load to the environment arising from insecticide…. Care needs to be taken in extrapolating assumptions of environmental benefit from an apparently logical stance that the introduction of Bt-based resistance must reduce pesticide use. Much depends upon the type of pesticides being used in the regime as a whole, and how farmers perceive their pest problems (Bennett, Ismael, Morse *et al.* 2004:673).

This is perhaps the clearest statement acknowledging that fluctuations in pesticide use depend on both institutional factors and farmers' knowledge, not merely on observed fluctuations in pest pressure. In a fascinating way, it also comes close to acknowledging that many people have simply assumed that insect-resistant cotton would be found to have reduced pesticide applications, just because it was expected to do so.

The finding that the spread of Bt cotton cultivation had been accompanied by an increase in the environmental toxic load from pesticides in the Makhathini Flats is a good illustration of the unexpected, unintended, perhaps counter-intuitive and sometimes perverse consequences of technological interventions in agriculture. But it appears in a paper that is entitled 'Reductions in pesticide use…', a title that would appear to be at least a selective interpretation, if not a direct misrepresentation, of what the paper showed was actually happening in the Makhathini Flats. The prior framing which is implicit in that title suggests that Bennett and colleagues' analytical approach had been influenced by the very prior assumptions that they then warned against when they pointed out that the consequences of technical change might not be the ones that were intended or expected.

Two more illustrations of this kind of prior framing can be found in papers by Yang and colleagues (Yang, Iles *et al.* 2005; Yang, Li *et al.* 2005). As described above, Yang, Iles *et al.* (2005) made some fascinating observations about Chinese

[11] In fact, Bennett *et al.* (2004) did not cite which specific studies they were thinking of.

smallholder cotton farmers' perceptions about the pest-control technologies available to them and, in particular, their propensity to over-estimate the damage caused by bollworms and to over-use pesticides against the bollworm complex. Meanwhile, Yang, Li *et al.* (2005) found evidence which clearly indicated that the performance of Bt cotton was a relatively unimportant factor in improving farm-level productivity or producing beneficial effects on pest populations, when compared to other interventions, especially farmer training on IPM methods. In other words, Yang and colleagues' work suggested that Bt cotton technology is actually of rather marginal importance to Chinese smallholder farming systems. Nevertheless, the authors of both papers framed their discussions so as to emphasise the potential value of IPM and farmer education strategies in making Bt technology work better, rather than questioning whether Bt technology represented an effective investment for Chinese agriculture and smallholder farmers. Why formulate their analysis in that way and not, for example, the other way around?

7. POSITIONS AND POLARISATION

The effort to discover whether Bt cotton 'works', in a technical sense, has come to overshadow consideration of the complex role it may perform in a farming system or, more pertinently, a focus on the original problems farmers actually face and the types of technical, institutional and socio-economic interventions that might help them overcome those challenges. It is as if Bt cotton has been put 'on trial'. Supporters and opponents of GM crop technology must share the blame for that fact, since both sides have conspired in depicting Bt cotton as a technology that must be either a source of evil or a saviour of farmers, both sides distorting the discussion in the process (Stone 2002). A great deal of effort has been invested in proving the case one way or the other, as though proclaiming Bt cotton's individual guilt or innocence were the only vital question. In that respect, both supporters and critics can be accused of an excess of technological determinism, for implying that Bt cotton technology bore sole responsibility for either the positive or negative outcomes of smallholder farming and failing to embed the technology in its necessary context.

The extreme polarisation of debates about Bt cotton can be seen in relation to the negative experiences reported by some farmers in Andhra Pradesh and Maharashtra, India. Indian campaigners and commentators have claimed that many farmers in certain districts of these two states experienced poor yields and crop failures after planting Bt cotton, and some have sought to link Bt cotton to an alleged surge in farmer suicides following the commercial release of the new varieties (Qayum and Sakkhari 2005; Sainath 2005, 2007). Such reports are, of course, easy to dismiss for not having the scientific credibility of peer reviewed journal articles. Their claims of crop failures were fiercely denied by the seed industry and obviously represented a stark contrast with the stories of success that were being reported by agricultural economists such as Bennett *et al.* (2004). A typical reaction to this situation has been to assume that NGOs and farmers in these areas must have conspired to distort the truth of Bt cotton's success for reasons to do with ideology and pecuniary interest (Herring 2007b). It turns out, however, that certain Bt cotton varieties really did perform poorly in particular areas of Andhra Pradesh and Maharashtra, especially during the first and third seasons after the technology was commercialised, which coincided with spikes in the number of farmer suicides in those states (Gruère *et al.* 2008; Qaim *et al.* 2006). Naturally, Bt cotton could not be solely responsible for the seasonal increases in farmer suicides, but the high price of the technology, combined with the manner in which it was promoted to farmers and its failure to produce good yields undoubtedly contributed to some farmers' indebtedness and distress, as critics of the technological treadmill and neoliberal agricultural reforms have long argued (Gruère *et al.* 2008). Hence, while academics may criticise the NGO studies for lacking the dispassionate rigour of peer reviewed research, the humanitarian can only applaud them for drawing attention to the very real problems that were being experienced by some farmers.

Regrettably, however, it has taken a long time to arrive at a more sober and balanced assessment of Bt cotton's impacts in a proper context. Recently, there has been a welcome moderation of the earlier, over-enthusiastic assessments of Bt cotton. Belatedly, the authors of some of the early studies have acknowledged the limitations and systematic biases of the methods they and others had used previously (Crost *et al.* 2007). Others have acknowledged that there is a lot that we do not fully understand about farmers' reasons for adopting new technologies or selecting particular seeds (Qaim 2005). Qaim (2005) has noted that farmers have adopted, disadopted and sometimes readopted Bt cotton from one season to the next, an observation which gives the lie to the assumption that Bt cotton's benefits are always apparent to farmers and undermines claims that the technology can be presumed a technical success simply because large numbers of farmers have adopted it. In fact, as many as 60% of farmers in one Maharashtra sample were found to have disadopted Bt cotton after the first two seasons, although there were also signs of later readoption (Ramasundaram *et al.* 2007). Meanwhile, as Stone (2007) and Shah (2008) have shown, the widespread adoption of Bt cotton varieties in some Indian communities appears to have been only obliquely connected to the farmers' evaluation of their superior technical performance.

Meanwhile, Qaim *et al.* (2006) have acknowledged, more frankly and directly than ever, that Bt cotton has had widely variable impacts across locations and seasons and, more particularly, that its performance depends heavily on factors like the background germplasm into which the Bt trait is inserted as well as other agronomic, socio-economic and institutional factors. In the past, some analysts have highlighted the importance of background germplasm merely to excuse the Bt trait itself from guilt. But that is an absurdity: the Bt trait has no performance, no effect, except in association with the background variety, not to mention through interaction with soil, water, temperature, pests and other factors.

But the effort to insulate the evaluation of the Bt cotton trait from the performance of its background variety is persistent. In their recent study on the possible link between Bt cotton and suicide in India, Gruère *et al.* (2008) kept the Bt trait at arms length from blame by highlighting the fact that some cases of poor yields could be attributed to the poor performance of some of the cotton hybrids into which the Bt trait was first back-crossed for commercial release, which were not well adapted to all of the locations where they were marketed and grown – as if inappropriate marketing and distribution practices, which were under the control of the technology's owners, could properly be dissociated from the case-history of Bt technology. Conceptually isolating the performance of the 'Bt gene' from other factors is exactly what the biotechnology industry strives to do, in order to be able to represent the transgenic Bt trait as an effective product and preserve the justification for their technology fee.[12] Disinterested academic analysis, however, should be concerned to understand the functioning of the technology in its wider socio-technical context. By isolating the technical performance of the Bt trait from the context of its use and performance, scholars have overlooked important and consequential stories about the dynamics of Bt cotton adoption and use. Their failure to address these issues is regrettable, because it fuels speculation that much of the Bt cotton impacts literature has been influenced by a corporate agenda.

Much has been made, by supporters of GM crop technology, of the supposed baleful influence of a European anti-GM lobby in debates about transgenic crops in developing countries (e.g. Herring 2008; Paarlberg 2008). With a few exceptions (e.g. Lipton 2007), GM crop advocates have apparently been much more relaxed about the pro-GM hype produced by the biotechnology industry's well-resourced and sophisticated international public relations machine. The routes through which corporations have sought to influence global- and national-level biotechnology politics are diverse and pervasive, often working indirectly through informal channels and behind-the-scenes lobbying, as well as in more transparent ways (Glover 2008; Glover and Newell 2004; Newell 2003a; Scoones 2005b; Yamin 2003).

Evidence of the influence of corporations behind studies into the impacts of GM crops is necessarily partial but highly suggestive. For instance, Monsanto has directly funded at least some of the work of the Reading group of researchers and evidently supported a great deal of it. It is difficult to assess exactly how much of the group's work has been directly funded, since the published articles have not explicitly acknowledged such support. However, Monsanto has claimed the credit for financing the research reported by Ismael *et al.* (2001) in one of the earliest conference papers on Bt cotton adoption in South Africa (Monsanto 2001:13). That funding was part of a USD $6m budget disbursed by Monsanto between 2000 and 2002, to finance third-party research on the impacts of GM crops around the world; the company expected to continue funding such work 'through 2002 and beyond' (Monsanto 2001:13). The research reported in that early paper by Ismael and colleagues was subsequently published in peer-reviewed journals (Ismael, Bennett

[12] Interview, Monsanto manager, St Louis, MO, USA, 20 June 2005.

et al. 2002a, b). In addition, Professor Richard Bennett's website discloses that his work on 'livelihood impacts of Bt cotton and Bt maize in South Africa' in 2005–06 was funded by Monsanto and his work on 'economic impacts of the uptake of Bt cotton in India' in 2004–05 was funded by a 'commercial sponsor'.[13]

A number of the Reading group's articles on Bt cotton in India have acknowledged the assistance of Mahyco and AC Nielsen ORG–MARG, a market research company that has carried out impact assessments on Bt cotton on behalf of the joint venture Mahyco–Monsanto Biotech Ltd. (MMB) in the past (e.g. Morse *et al.* 2005a, 2007a). Some of the articles also offered personal thanks to Mr. Jagresh Rana, who is (or was) an employee of Monsanto India, for his 'logistic support' (e.g. Morse *et al.* 2007a, b). Reading researcher Yousouf Ismael has said that Mr. Rana was very helpful in organising the group's access to their research areas (Ismael, pers. comm., 2004). In some cases, questionnaire surveys were administered by Mahyco personnel (e.g. Bennett, Kambhampati *et al.* 2006; Kambhampati *et al.* 2006). In other studies, the researchers analysed existing data collected by Mahyco and AC Nielsen (e.g. Morse *et al.* 2007a; Morse *et al.* 2007b). The Reading group also used Mahyco's sales data to select the areas in which to carry out their research (e.g. Bennett, Kambhampati *et al.* 2006).

Research by the Reading group and others in South Africa also appears to have relied on logistical support and facilities offered by Monsanto and Vunisa (e.g. Morse *et al.* 2006; Thirtle *et al.* 2003). It is hard to believe that the involvement of Mahyco, Monsanto and Vunisa personnel in the process of selecting research locations, facilitating the researchers' access to the field and directly in the data collection process did not have some impact on the data collected, and perhaps also on the way it was analysed and interpreted. In the absence of full disclosure of the degree of the companies' involvement, together with an account of what measures may have been taken to isolate the research from possible influence by interested parties, it is only reasonable to treat the findings of such studies with caution.

8. LEARNING FROM THE BT COTTON IMPACT STUDIES

The mixed results from Bt cotton cultivation should have been anticipated. The findings of the Bt cotton impact studies discussed in this paper are essentially similar to those one would expect to see after the introduction of any new crop variety, where experience shows that the results are typically highly variable and outcomes depend on many technical, social, economic and institutional factors (Smale *et al.* 2006). It follows that the excessive simplification of the early studies

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[13] http://www.reading.ac.uk/apd/staff/r-m-bennett.asp (22 October 2008).

should have been avoided and that it really should not have taken so long for the excessive optimism of those early studies to be replaced by a more sober and reasoned assessment.

However, the story of that belated step forward teaches us important lessons about the processes of knowledge creation, contestation and synthesis in the context of a highly controversial policy setting. In the conclusion of their thorough review of the methodologies used in econometric impact studies on GM crop cultivation in the developing world, Smale *et al.* (2006) have laid out what they regard as a set of benchmarks for designing the kind of thorough and rigorous analysis that would enable researchers to account for all of the different dimensions and factors that are relevant to any assessment of the impacts of GM technology in the developing world. The increasing complexity of the analytical tools required tells its own story of the difficulty of parsing the many different factors that contribute to the profitability or productivity of agriculture and rural livelihoods. The efforts of analysts have been largely confounded, though, not only by the sheer complexity of the factors involved, but because the external variables they have struggled to control and exclude are actually essential to understanding the impacts of new crop varieties on farms. In other words, the strenuous efforts to rule out the effects of ‘externalities’ can be seen as a reflection of a basic failure to recognise the fundamental importance of contextual factors in complex socio-technical systems.

As the analytical methods applied become more and more refined, analysts have in fact succeeded in attributing some percentage gain to the specific transgenic trait in question. The value of that benefit has been revised downwards in successive steps, from the extreme optimism of projections extrapolated from controlled field trials, to the early studies of commercial Bt cotton, to the later studies that have finally taken account of some of the key contextual factors that have helped to determine the impacts of Bt cotton. But, in the process, the findings have actually become rather less useful to farmers and policy makers, who need to know how the trait fits into a farming system and a livelihood context. The reductionist focus on a single technological intervention or strategy is incapable of grasping the complexity, diversity and riskiness of smallholder agriculture as a socio-technical system. All that we can know from ex post econometric analyses of the impacts of Bt cotton is that the trait contributed to a certain slice of productivity in the particular conditions that prevailed in a particular growing season in the past. But each new farming season is different in its weather, its market conditions, its pest and weed pressure, in the farmers’ family circumstances and so on. Farmers face a complex array of decisions and choices about which crops to grow, which seeds to buy, when to plant, how much water to use, when – and dozens more. Each season brings with it a range of new seeds to choose from, each promising a certain performance but fundamentally an unknown quantity until it has been tried out in farmers’ fields. It is only when seeds are in the hands of farmers that they can reveal their performance characteristics in a meaningful context (see Roy *et al.* 2007). While careful econometric analysis of input—output relationships can tell us something about broad averages or the aggregate performance of particular types of technology over recent seasons, it is largely incapable of providing farmers or policy makers with detailed guidance to inform their decisions for the future.

The separation of the technical performance of GM crop technology from its socio-economic and institutional context helps to explain the remarkable unwillingness of some scholars and commentators to let go of the hope and promise of Bt cotton. It is as if the technology has been preconceived in advance as effective and successful. Problems and limitations have been explained away by referring to factors from the socio-economic or agronomic context, which must have been unfavourable and thus acted as obstacles to the fulfilment of the technology's promise.

This kind of technological reductionist analysis completely overlooks the degree to which seed choices, pest-management strategies, cropping patterns and farming systems are embedded in a particular household's or farmer's wider livelihood strategy, which in turn is embedded in a set of social and institutional relationships and processes. Reductionist analysis reflects a bias in much of the contemporary thinking about agricultural development, which attempts to deconstruct developing-country farming using a modernist–industrial lens, in which agricultural systems are envisaged as a collection of independent building blocks, each of which may be optimised individually and then combined with each of the others in order to produce a whole system that approaches an optimum level of productivity that is the sum of its separate components. Such an approach downplays the scope and depth of the risks and uncertainties which small farmers and their households face. Indeed, it assumes that the existing livelihoods of smallholder farmers are an obstacle to be swept aside. Modernist, industrial assumptions about how to manage agriculture ignore the long-standing recognition that, in the midst of uncertainty and complexity, farming for many people in developing countries is not a rationally planned and pre-organised commercial project but a skilful 'performance', in which the farmer uses judgement, skill and experience and draws on a repertoire of options as each season unfolds (Richards 1989).

BT COTTON IN THE DEVELOPING WORLD: AN ASSESSMENT

The realisation of GM crop technology's potential contribution to poverty alleviation will depend on whether a delicate balance can be achieved between the technology's various potential technical, economic and social effects for different groups of people (see Lipton 2007). Bearing that caveat in mind, on the basis of the Bt cotton impact studies reviewed above, what do we now know about the performance and impacts of Bt cotton in smallholder agriculture in the developing world? The picture is complex and differentiated, since impacts depend not only on the technical performance of the technology and its local adaptedness, but also on the nature of the pre-existing circumstances and problems in the farming systems of different countries and regions of the world (see Lipton 2007).

On the positive side, there can now be little doubt that Bt cotton technology has been shown to work – in the limited, technical sense that cotton plants transformed with the Bt gene do express the Bt toxin and that the toxin provides some protection for the plant against bollworm pests. In seasons where bollworms cause a serious problem, the technology can help to prevent major crop losses and there is some evidence that, consequently, the technology helps to smooth out the seasonal fluctuations in cotton yields. Those features are potentially useful tools in a crop–pest management system and not to be underestimated.

Beyond that, however, the messages emerging from the Bt cotton impact studies are much more equivocal and constrained. The performance of Bt cotton varieties depends critically on the local suitability of the background germplasm and is also heavily dependent on favourable rainfall or reliable irrigation. Cotton yields in rainfed agriculture remain low, even with Bt. Because the Bt trait protects cotton plants against just one type of pest, Bt cotton is just as vulnerable as non-Bt cotton to outbreaks of so-called secondary pests, as well as other threats such as drought. Largely because of the higher prices charged for Bt seed, Bt cotton also increases the magnitude of the potential downside risk if the crop is destroyed. On the other hand, for farmers who are able to afford the additional cost of the seeds without taking on excessive levels of debt, the insurance function provided by the Bt trait and its smoothing effects on yields can provide a substantial advantage.

The relationship between Bt cotton and pesticide consumption, as the paper has discussed, is complicated. In China, India and South Africa, changes in pesticide consumption have been observed that coincided with the adoption of Bt cotton. However, those changes happened against a background of economically irrational and often excessive pesticide use. It is not clear that observed reductions in pesticide use are attributable to farmers' adoption of Bt cotton varieties or to other factors, such as the manner in which the technology was promoted, the information provided alongside seeds or advice received from seed dealers and sales representatives. However, many Bt cotton farmers still spray excessive quantities of pesticides and dramatic reductions in pesticide use, as well as effective and economical pest control, have been achieved without Bt cotton. Compared to farmer training and the adoption of IPM methods, in some situations Bt cotton has been shown to have a minor impact on pesticide use and pest populations.

Significant question-marks therefore remain over the medium- and long-term effectiveness of Bt technology as a method of pest control, because of the risk of the emergence of pest-resistance to the Bt toxin and because of the probability that controlling one family of pests will create an ecological niche for other pests to multiply. Long-term management of pest-resistance to the Bt toxin depends on the technical effectiveness of stacked Bt varieties (that is, transgenic Bt plants expressing more than one version of the Bt toxin) as well as the practical effectiveness of pest refuges (see, e.g. Ibargutxi 2008; Kannan and Uthamasamy 2007; Sisterson *et al.* 2005).

Finally, the evidence suggests that different kinds of farmers, or different kinds of livelihood strategies, create different kinds of preferences in relation to Bt cotton technology. It may be that those differences disappear – or may already have disappeared – as Bt adoption becomes more widespread and the Bt trait becomes available in a wider variety of the cotton varieties farmers like to plant. But that possibility should not deflect our attention from exploring the possibility that Bt technology, and other similar kinds of plant improvement, may, perhaps unwittingly, be prioritising the interests of particular kinds of farmers and livelihood strategies at the expense of neglecting others (see Soleri *et al.* 2008). That observation suggests that there is a need to consider whether technology development strategies, in both public and private sectors, could be retuned to address the preferences and priorities of diverse types of farmers and livelihoods.

The evidence clearly indicates that the performance of one or two traits inserted into a crop variety depends critically on the local suitability of the background germplasm, on seasonal rainfall, irrigation, soils, pest attacks and diseases, and that the overall productivity and profitability of agricultural livelihoods depend on a range of socio-economic, political, institutional and infrastructural factors. The arguments of the Nuffield Council in 1999 were prescient: social and economic factors matter, as do the structures of ownership and the direction of research and development. Politics and technology cannot be separated. Yet, these important observations, made a decade ago, have been largely ignored, with study after study framing the problem – and then the solution – solely around the efficacy of the GM technology in isolation. But the political-economic and institutional contexts for commercialisation of GM crops in, for instance, China (Keeley 2005, 2006) and India (Scoones 2005b) are very different, despite these two countries' superficial similarities (Newell 2003b, 2008; see also Scoones 2008 for an exploration of the contrasts between India, South Africa and Brazil). Against this background, where context is all important, it is not in the least surprising that impact studies on GM crop technology in developing contexts have found such varied and complex outcomes.

9. CONCLUSION

Despite the growth of conflicting evidence, the promise of GM crops as a pro-poor, developmental technology has not died. Why has it proved so sticky and resilient to change? In part, the story told here is a familiar one from studies of technological futures (Brown *et al.* 2000): it is quite typical that predictions about new technological developments underestimate the technical and practical obstacles that will need to be overcome and overestimate the speed with which progress will be made, so that the initial promises of a technology are usually overblown and need to be scaled back in the light of experience (Geels and Smit 2000). In truth, though, neither innovation processes nor processes of political change can do without promises

(Fortun 2005; Selin 2007). Expectations about technological developments play a vital role in driving innovation processes, helping to create and sustain a momentum that is shaped by, and shapes, the behaviour of various social actors involved in the process (Deuten and Rip 2000; Michael 2000; Rosenberg 1976; Sanz-Menéndez and Cabello 2000; Selin 2007; van Lente 2000). The problem with discourses of technological promise, however, is that future advantages are typically emphasised at the expense of downplaying possible risks and disbenefits (Fortun 2005). This phenomenon, the 'future benefits argument', has been abundantly evident in the political claim-making that surrounds the promise of GM crops (Burkhardt 2001). Often, reasonable doubts and qualms about whether current technologies and near-term innovations will deliver the societal or environmental benefits that have been claimed for them are suppressed, because of the expectation that novel technologies that will emerge further into the future – provided that research and development is not slowed down in the present – will indeed deliver those kinds of benefits (Holmes 2006; Levidow 2001). But acceptance of the future benefits argument implies that innovators must also accept responsibility for ensuring that risks are assessed and controlled and that benefits are indeed both forthcoming and shared (Burkhardt 2001).

Promises of future benefits have driven scientific and commercial investments in biotechnology for many years but, in the process, technical risks and social concerns have often been downplayed within a regulatory framework designed to give the appearance of having brought them under control (Bud 1993; Newell 2002; Scoones 2002b; Wright 1994). Perhaps part of the explanation for the resilience of the 'pro-poor GM crops' narrative lies here. It may in part have to do with the need of biotechnology and agribusiness companies like Monsanto to sustain a key part of the dynamic that helped to drive their technical and commercial strategy for biotechnology (Glover 2008). In that respect, it may be that we can best understand the survival of the 'pro-poor GM crops' narrative as a consequence of its having been inscribed into a broader set of expectations and promises about the necessary evolution of agricultural biotechnology and agriculture, which perform the role of a script that does not allow for flexibility or deviation (Akrich 1992; van Lente 2000).

Narrative analysis (Roe 1994) may also help to explain why debates about GM crop technology have not moved beyond the narrative of promise and the contestation of that promise. The narrative of GM crops as a 'pro-poor technology' has, as we have seen, a very simple structure. It begins by identifying a cluster of serious, intractable problems, especially those of hunger and poverty at both macro and micro scales, as well as the technical and political challenges of feeding an expanding global population in an environmentally sustainable way. This launching point for the narrative implicitly – sometimes even explicitly – downplays the known, complex and difficult socio-economic, political, institutional and even technical causes of hunger and poverty (Jasanoff 2005). Poverty becomes merely 'the stage on which moral assertions about the value of biotechnology are made' (Jansen and Gupta 2009).

Next, the narrative proposes that GM technology holds the key to resolving these problems. Many of the papers and public statements that formulate this narrative do little more than recite a list of potential applications of GM technology that have been conceived by microbiologists, agronomists, plant breeders and nutritionists. The mere enumeration of these opportunities typically takes no account of the range of technical obstacles that may need to be overcome, let alone the social and institutional contexts that need to be taken into account, in order for benefits to be realised, even if the technologies are technically effective. The narrative merely assumes, in its final step, that the natural unfolding of genetic engineering's potential will inevitably address the problems identified in the narrative's premise (Jasanoff 2005).

Far from merely challenging the pro-GM narrative point by point, the opposition to GM technology has articulated its own, alternative 'counter-narrative' (Roe 1994). This storyline has a radically different diagnosis of the causes of hunger and poverty and a different vision of what needs to be done about them, including a different perception of the types of technologies that will be required. Crucially, the counter-narrative has a vision of technology that is much more socially embedded. It does not pretend that it is meaningful to envisage the impacts of technology in isolation from the social and institutional contexts in which it is applied. It is, indeed, a rather sophisticated conceptualisation of biotechnologies as social-technical ensembles in which certain kinds of social relations may be encoded (Ruivenkamp 2005; Shah 2008). This leads it to have a radically different complexion from the 'pro-poor GM' narrative: instead of focusing narrowly on how to make GM technology a success, it demands to know how technologies can be incorporated into sustainable, productive livelihoods (Scoones 2008).

This fundamental disagreement about the embeddedness of technology – in other words, a disagreement over whether one's starting point should be the technical performance of the technology or the social problems it is supposed to solve – represents the key to a hidden 'meta-narrative' (Roe 1994) that sustains the ongoing disagreements over the relevance and value of GM crops for small-scale farmers in the developing world, without bringing the dispute closer to a resolution (see Bernauer and Aerni 2007).

From this perspective, it is clear that the shortcomings of Bt cotton impact studies have done a serious disservice to both the public debates and policy discussions that surround the benefits, risks, social purposes, human values and trade-offs involved in pursuing the GM route towards crop improvement and attacking hunger and poverty. Widespread assurances that GM crops have been demonstrated to be good for the poor are not well supported by the evidence. In this respect the NGOs and anti-GM campaigners in places like India and South Africa, though they have been vigorously criticised for the lack of academic rigour in their reports, have undoubtedly done a great service in compelling the advocates of crop biotechnology for the developing world to sharpen their focus on the real, situated impacts of GM crops and to hone their arguments in support of the technology.

What is needed from policy advice is not a monomaniacal fixation with the performance of one particular technology, but a radical shift of attention towards the mechanisms and systems that will help farmers to respond and adapt to dynamic change, manage risks and cope with uncertainty. It requires attention to the institutions and systems that can enable farmers to reduce their vulnerability and improve their resilience. These are very different kinds of policy questions from the ones that have informed the design of Bt cotton impact studies. They do not lend themselves to simple narratives and they are difficult to turn into a sound-bite, but they are the kinds of analytical approaches smallholder farmers really need.

It has only been by scrupulously isolating Bt cotton from its socio-economic, agronomic and institutional context that it has been possible to keep the technology pristine. But, in fact, the efforts to do so have merely succeeded in demonstrating that the performance and impacts of Bt cotton depend on a range of contextual factors. In their efforts to rescue Bt technology from the attacks of its critics, its would-be saviours have simply reinforced one of the critics' most potent claims: that a single technological intervention in a landscape of diverse and complex agricultural systems is a hopelessly narrow and mechanistic approach to resolving profound and difficult socio-technical problems in agriculture.

The title of this paper is meant in two ways. 'Undying Promise…' can be read ironically, as a way of drawing attention to the lingering after-life of the 'pro-poor biotech' narrative. Zombie-like, the over-hyped promise of GM crops refuses to die, in spite of both the strength of conceptual critiques against it and the accumulating evidence that a sober reassessment is in order. Hasty economic analysis and a lack of thoughtful reflexivity on the part of some academics have helped to drag out its restless after-life. A greater self-awareness should have enabled these researchers to avoid the risks of appearing to pander to the political agendas and economic interests of the biotechnology industry, not to mention the Malthusian catastrophism and Panglossian techno-optimism of certain commentators.

It is high time that the heroic simplification of the 'GM crops are good for the poor' storyline is finally laid to rest. Only when we have driven it out can we hope to give due attention, more calmly and carefully, to the other aspect of biotechnology's undying promise – undying, in this case, because it has never been given a chance to live. The extravagant hype of GM crop advocates (and not only the alarmism of anti-GM campaigners) has unfortunately suffocated debate about this important new technological field. It is a field which, in truth, does indeed hold the potential to help address some important developmental challenges of the twenty-first century, whether through genomic techniques, marker-assisted selection or indeed some transgenic applications. But, to realise this potential, it is not enough to pay lip-service to the idea that GM crops will not be a silver bullet against hunger and poverty, while simultaneously designing impact assessments around the implicit assumption that such a magical effect is indeed possible. We need to think about how technologies may work in the dynamic and complex agricultural systems and institutional frameworks of the real world. We need to understand how farmers actually use technology. And we need to focus on problems to be solved and challenges to be overcome, in all their complexity, rather than focusing on particular types of technologies and looking for opportunities where they might be deployed. Hopefully, the promise of biotechnology is really not dead. But a realistic assessment of both its promise and its pitfalls requires a new set of research questions, different research methods and a rigorous focus on the problems to be solved rather than a fascination with a quick technological fix.

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