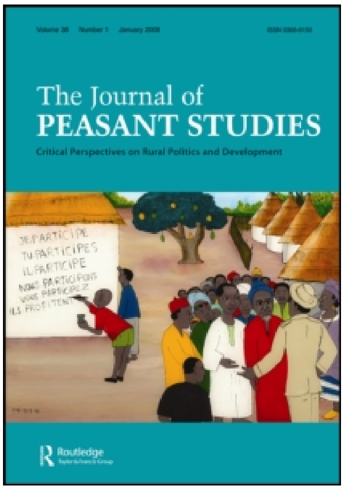

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Access and control of agro-biotechnology: Bt cotton, ecological change and risk in China

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Access and control of agro-biotechnology: Bt cotton, ecological change and risk in China

Peter Ho, Jennifer H. Zhao and Dayuan Xue

This article argues that if the introduction of genetically modified crops (GM crops) in developing countries is to be successful, we can and should not evade questions of access and control of technology. It implies probing into the experiences, perceptions and understanding of GM crops by the prime user: the farmer. Exactly in these respects the scholarly literature is remarkably silent. We know little about farmers' experiences and perceptions of GM crops' potential risks and benefits. This is evident when concentrating on a major GM crop – Bt cotton – and studying this in the context of China, its second largest producer in the world. Based on the results of a large survey, we demonstrate that Chinese farmers' awareness ('having heard of') and their understanding ('being able to explain') of Bt cotton is low. This may lead to ill-informed, distorted risk perceptions and a general inability to relate agricultural production problems to the specific nature of transgenic cotton cultivation. A great majority of the farmers find that the Chinese seed market was liberalised too early, in turn leading to a high incidence of 'stealth transgenics' or illegal seeds, the undermining of farmers' trust in private institutions, and a weakened biosafety regime. This finding points to the need for continued state intervention in the seed market, particularly in a developing context. Finally, we have discovered that farmers report a significantly lower reduction in pesticide use by Bt cotton than found in other studies. As suggested by recent research, we suspect that the higher pesticide use is necessary to control secondary pests – i.e. pests other than the cotton bollworm. We present empirical evidence that Chinese farmers perceive a substantive increase in secondary pests after Bt cotton was introduced.

Keywords: genetic modification; secondary pest; biosafety; poverty; pest management; biotechnology

Introduction

There is a fierce scholarly debate on the benefits and drawbacks of genetically modified crops (GM crops) in developing countries. Exemplary in this debate are the discussions on one of the main GM crops cultivated in the world: Bt cotton.[1] Some claim that due to its built-in pest-resistance Bt cotton leads to higher yields, lower

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[1]The global area of GM crops has increased from 1.7 million hectares in 1996 to 114.3 million hectares in 2007; over 10 percent of this is Bt cotton. Note that apart from Bt cotton, there are also other types of genetically modified cotton. Here we will only focus on Bt cotton. See International Service for the Acquisition of Agri-Biotech Applications (2007).

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labour input and higher income. Others point to its potential drawbacks, such as the increased dependence of farmers on seed suppliers, the development of resistance by its main pest, and unwanted environmental effects. A large number of studies have focused on measuring the economic and wealth effects of Bt cotton for farmers in different countries.[2] As much as a discussion on alleged or scientifically proven effects is vital for a balanced consideration of agro-biotechnological innovations, it should not neglect the wider role of technology in society, its governance and societal dynamics. We argue that the GM debate should also pay careful attention to 'issues of access and control of technology' as it is situated 'at the centre of the political economy of development' (Newell 2008, 345). This inevitably entails the inclusion of the experiences, perceptions, and participation of GM crops' primary user: the farmers. Only in this way can we prevent developing and emerging economies from becoming a testing ground for novel, insufficiently developed technologies. That these are by no means hypothetical concerns is proven by the case of China, one of the world's largest producers of Bt cotton.[3]

By narrowing down on the Chinese case, this article will explore the access and control of GM crops while centering on the question of how the introduction of Bt cotton is experienced by smallholders in socio-economic and ecological terms. Our study is based on a pilot and full survey. The pilot study consisted of 12 interviews and a survey of 50 randomly-selected households in three provinces, while the full survey covered five provinces and involved 1,000 randomly selected farm households, five focus group sessions, and 68 in-depth interviews using semi-structured interview lists with various stakeholders in the biotechnological field (farmers, local and national officials, scientists, and business and NGO representatives).

Bt cotton derives its name from the *Bacillis thuringiensis*, a bacterium of which a gene (or several genes) has been inserted into the cotton genome. As a result, Bt cotton produces biotoxins that can kill its primary pest – the bollworm. The biotoxins, however, have no significant effect on the secondary pests, such as lygus bugs, aphids, and mites. Since Bt cotton was first cultivated on an experimental basis in 1996, the area has risen explosively from around 16,700 hectares to 3.8 million hectares in 2007, equivalent to 69 percent of the total 5.5 million hectares sown to cotton.[4] Today the crop is grown in all major cotton producing areas of China – even in the allegedly 'GM-free zone' of Xinjiang (Zhao and Ho 2005, 371). Bt cotton has been cultivated in China for a little over a decade. Now it might thus be an appropriate time to evaluate the impact of Bt cotton cultivation as perceived by Chinese farmers. Before turning to the methodological section, and the presentation and analysis of the research findings, we will first discuss the relevant studies on Bt cotton.

[2]See the literature review in this article, in the section entitled 'Previous studies on Bt cotton'.
[3]For years, China accounted for the world's largest acreage in pest-resistant Bt cotton. For the first time since the introduction of Bt cotton, China was overtaken by India in 2006 (at the time the Chinese area of Bt cotton was 3.5 million ha, while India cultivated 3.8 million ha). China is the world's second largest grower of Bt cotton, and together with the number one, India, their area sown to Bt cotton accounts for 8.7 percent (respectively 3.8 and 6.2 million hectares) of the total area of GM crops in the world (International Service for the Acquisition of Agri-Biotech Applications 2007).
[4]For 2007 data on Bt cotton, see also footnote 3.

Studies on Bt cotton: a critical review

A part of the scholarly discussion on Bt cotton revolves around the danger of smallholders' dependence on seed suppliers, as well as on farmers' economic risks because of consumers' resistance. The latter question will not be taken up in this article, as consumers' concerns over, and their potential resistance against, GM crops generally relate to food crops. The case of Bt cotton in China underscores this, as it is an absolute non-issue among Chinese consumers.[5] However, the first issue is surely of relevance here, not because Chinese smallholders are overly dependent on GM seed suppliers, but because the Chinese case illustrates the importance of continued government intervention in the market. For one thing, the Chinese government has actively prevented the monopolisation of the seed market. In contrast to, for instance, northern Mexico,[6] Canada, and the US, where Monsanto is the predominant provider of Bt cotton seed,[7] China features a different situation, with a wide variety of domestic producers and traders. Bt cotton is officially produced by two companies in China – Monsanto/Delta Pine Land (hereafter Monsanto)[8] and Biocentury, established by the Chinese Academy of Agricultural Sciences (CAAS). Yet, after the liberalisation of the seed market in 2000, a multitude of domestic private traders and biotech companies have become active in the cotton sector. Chinese farmers are also not bound by contracts, but can save and replant the harvested seed on their own accord, although only a minority actually do.[9]

Several studies on Bt cotton in developing countries claim that its use brings benefits to smallholders because it reduces the number of pesticide sprayings (e.g., Pray *et al.* 2001, Bennett *et al.* 2003, Thirtle *et al.* 2003). Although these studies have been contested on methodological grounds,[10] and on the claimed positive economic returns,[11] we argue that the criticism should not be solely directed towards whether or not Bt cotton leads to a reduction in pesticide use, costs, and labour input. In fact,

[5]In a recent survey conducted among 1,000 urban consumers, we found that few of them are aware that there is such a crop as Bt cotton. When asked to mention one or more GM crops, only a minor proportion mentioned cotton. Chinese consumers' low awareness of Bt cotton stands in stark contrast with the fact that China is the world's second largest producer of it. Of the 1,000 respondents, 32 percent could mention one GM crop, of which only five percent mentioned cotton (Ho and Vermeer 2006, 251).

[6]As is the case in the Comarca Logunera cotton-producing area in northern Mexico.

[7]In northern Mexico, the US, and Canada, Monsanto requires farmers to sign seed licensing contracts in return for the right to purchase and use Bollgard. Through the contracts farmers forfeit rights to replant their own harvested seed, while they are obligated to deliver the cotton to Monsanto-authorised gins. See Eaton *et al.* (2003). For instance, by buying Brazil's largest seed corporations, the previously domestic hybrid seed industry became 82 percent owned by Monsanto in one single year (Paarlberg 2001, 70).

[8]Monsanto/Delta Pine Land works through joint ventures in China: Andai company in Anhui and Jidai company in Hebei province.

[9]Of the interviewees only 25.3 percent save their own seed. The overall majority of the respondents stated that they do not keep Bt cotton seed, interestingly, not because the company requires this (in only 11 percent of the cases) but because of the decrease in seed quality (84.8 percent). Findings come from this survey.

[10]For a review of the critique, see Shantharam *et al.* (2008).

[11]Jost *et al.* (2008) found that the use of transgenic cotton does not provide increased returns to the farmer. This is the conclusion of a 4-year study using different transgenic and non-transgenic cultivars of cotton grown under exactly similar conditions at two locations in the state of Georgia.

smallholders around the world have welcomed Bt cotton, because of its pest-resistant properties – a trend also confirmed through our study.

However, the crux is that most studies categorically overlook issues of access and control. None of the aforementioned studies delved into farmers' experiences, perceptions *and* understanding of GM crops. However, without a thorough understanding of the primary user of GM crops, we fortify mechanisms by which state, business, and the scientific community in developing countries portray farmers as 'ignorant, ill-informed and only able to engage in issues of science and technology on ''emotional'' grounds' (Newell 2008, 365). It explains the paradoxical dynamics of the political economy of biotech in the South, aptly described as a situation in which farmers 'do not really have an idea of what GM crops are and are mobilised on other issues' while 'very often the very same farmers mobilised by organised farmer movements – whether KRRS in Karnataka or the MST in Brazil – are the same farmers planting pirated GM crops' (Scoones 2005, 18).

Failing to account for the 'farmers' factor' is a miscalculation of what ultimately determines the benefits and drawbacks of GM crops for smallholders. Farmers regarded as ignorant and ill-informed are often justified to be left ignorant and ill-informed, and thus uninteresting as an object of analysis *per se*. Such reasoning reinforces processes by which farmers will be unable to relate potential agricultural production problems to the nature of transgenic crops. Especially when the environmental dimension is brought into the agro-biotechnological equation, this becomes crucially clear. As a scholar noted:

> There is uncertainty related to the question of the sustainability of crop protection through Bt technology. Comparatively little is known about secondary effects on insect populations, and resistance development might occur when large-scale use of Bt cotton leads to high selection pressure. (Qaim 2003, 2126)

The high uncertainty of the environmental impact of Bt cotton lies in the fact that ecological change may take many years to manifest.[12] Ecological effects of Bt cotton can appear in three ways: (i) the development of the bollworm's resistance against Bt cotton; (ii) a negative impact of Bt cotton on the bollworm's natural predators; and (iii) the increase of secondary pests.[13] Laboratory tests have provided evidence for the bollworm's potential to build up resistance against Bt cotton, and resistance development has also been confirmed in the field (Li *et al.* 2007).[14] However, there

[12]The case of DDT is a classical example. Its insecticidal properties were discovered by the Swiss chemist Paul Hermann Müller in 1939, leading to its widespread use to control insect-born diseases (malaria and typhus) during the second world war. In 1948, Müller was awarded the Nobel Prize in Medicine for his research on DDT. Not until 1962, almost a quarter of a century after his discovery, when American biologist Rachel Carson published the book *Silent Spring*, did the realisation arise that DDT could lead to environmental damage. DDT was not banned in the US until 1972.

[13]Another ecological problem associated with GM crops is its impact on biodiversity through gene flow. This issue is less problematic for cotton as it is an annual plant and self-pollinator. However, in the case of maize, gene flow has already been verified (Quist and Chapela 2001).

[14]The laboratory findings apply to China, Australia and India (Downes *et al.* 2007, Gujar *et al.* 2007, Wu 2007). To avoid the development of resistance against Bt cotton, it is advised to plant 20 percent of Bt cotton acreage with non-transgenic varieties as a refuge area to avoid resistance development, because the population of bollworm that has become resistant to Bt cotton will then continuously cross with the population of non-resistant bollworm feeding on non-transgenic cotton (and thus has had no chance to develop resistance). But in developing countries with weak regulatory structures and small, fragmented agricultural plots, the enforcement of such refuge areas has been very problematic; China is no exception to this.

are no confirmed findings of negative effects on natural predators (e.g., parasitic wasps).[15] Finally, it is suspected that when farmers spray less (as the bollworm is controlled by Bt cotton), secondary pests – that would normally have been killed by heavier insecticide applications – have a chance to emerge. In the long run, some of these pests might develop into primary pests. The issue of secondary pests in Bt cotton has gradually received greater scientific attention since its first report in the mid 1990s (Turnipseed 1995, Cannon 2000, Head *et al.* 2005, Wang *et al.* 2006, 2008).

Methodology: pilot and full study

The research covered three main aspects: (i) an evaluation of farmers' perceptions of the strengths and shortcomings of Bt cotton;[16] (ii) farmers' understanding, awareness and risk perception; and (iii) their views on processes of privatisation and market liberalisation. The research was carried out from the fall of 2003 until the spring of 2005.[17] Initially, we intended to test farmers' awareness of genetic modification ('have you heard of'), to be followed by a series of specific questions on knowledge ('can you explain').[18] For this purpose, we intentionally avoided the phrases 'Bt cotton' or 'genetically modified cotton'. Instead, we used the term 'pest-resistant cotton' (or *kangchong mian* in Chinese), by which most farmers know Bt cotton. However, during the pilot survey (in Anhui, Jiangsu, and Xinjiang) we found that few farmers had heard about the Bt gene and were able to link it to toxic substances that kill the bollworm. The overall majority (71 percent) had never heard about Bt cotton, let alone the Bt gene.[19] As a smallholder worded it:

> Don't know about transgenic cotton. For me pest-resistant cotton simply means that there are fewer bugs. The agricultural extension station never told us about its workings. They have even never bothered to tell us when and how we should spray insecticides.[20]

[15]As Men *et al.* (2004, 247) write: 'Transgenic cotton ... did not reduce numbers of predators considerably'.

[16]More specifically, our study compares non-transgenic cotton with cotton of which the genome contains the Bt gene. As will be described in the section on the seed market, there are a wide assortment of Bt cotton seed varieties. Moreover, Chinese farmers generally experiment with different seed varieties at the same time. Therefore, it is methodologically impossible to compare farmers' views and experiences on different Bt cotton varieties through a sociological or an economic study. To be methodologically fully sound a controlled experiment should be carried out with various groups of farmers only cultivating one type of Bt cotton, and a control group only cultivating conventional cotton. However, it is not the purpose of our article to make a full-fledged comparison of different Bt cotton varieties as that could be better left to biologists. Instead, we intend to get a sense of farmers' personal experiences with GM crops. It should be noted that none of the previous studies on Bt cotton reviewed here in this article have properly accounted for the differences in Bt cotton seed.

[17]The village sites and farm households were randomly selected. For reasons of space, the full details of this research, in terms of persons interviewed and research sites, have not been included, but are available from the authors upon request.

[18]We had employed similar questions for a survey of urban consumers. For instance, 'Is it false to say non-GM soybeans do not have genes?' and 'Is it false to say eating GM food may change one's genes?'. See also the survey methodology used in Ho and Vermeer (2006, 253).

[19]Of the respondents 10 percent had heard of Bt cotton and had some understanding about it; another 19 percent of the farmers knew the term, but were unaware of its linkage with human-made changes in the cotton plant (Zhang 2004, 27).

[20]Farmer interview, Nanshenzao Town, Jiangsu Province, 30 April 2004.

On the basis of these results, we decided to leave the more complicated questions on knowledge aside and limit ourselves to measuring awareness only.

The environmental part of the research was originally focused on the *perceived* effectiveness of Bt cotton to see if there would be reason to suspect a possible build-up of bollworm resistance. Yet, as we conducted the pilot research we heard on several occasions from farmers and agricultural officials that secondary pests had increased over the past years. In addition, research reports by some provincial bureaus of agriculture also noted this phenomenon.[21] For this reason, we devoted the perception of environmental change entirely to farmers' perception of secondary pests.[22] Lastly, the part on risk perception included knowledge questions on a possible negative environmental impact of Bt cotton (e.g., gene flow and effects on biodiversity). But again, the results of the pilot survey did not warrant such specific questions.[23] Instead, we looked into farmers' risk perception of Bt cotton through another angle: as consumers of an important cotton by-product, cotton oil.

The full study was carried out in four provinces and one autonomous region (Hebei, Shandong, Anhui, Jiangsu, and Xinjiang). The research sites were selected to reflect the climatic and agricultural differences between China's three main cotton regions: (1) the Yellow River region (concentrated in the three provinces of Hebei, Henan, and Shandong); (2) the Yangzi River region (Hubei, Hunan, Jiangsu, and Anhui); and (3) the Northwestern region (the Xinjiang Uygur Autonomous Region). The Yellow River region is the largest cotton-producing area of the three. It produces close to 40 percent of the nation's total, while Xinjiang and the Yangzi River region respectively account for 24 and 30 percent (China National Bureau of Statistics 2003, 426). The most important differences between the three regions are the climate and the scale of cultivation. Due to the cold winters in the arid northwest, infestations by the bollworm are less severe in Xinjiang. The Yellow River and Yangzi River regions, however, are more seriously affected by the bollworm. In these regions cotton is cultivated with little mechanisation on plots that are on average smaller than a half hectare. The cotton fields are interspersed with fields planted with other crops, such as wheat, maize, potatoes, and vegetables. By contrast, Xinjiang features large-scale mono-cultivation of cotton on military state farms, known as the *bingtuan*.

In the first part of the full survey, where we examined farmers' experiences with Bt cotton in comparison with conventional cotton, farmers were provided with hypotheses that could be rated from 'definitely agree' to 'fully disagree'.[24] In the

[21]See, for instance, Hebei Bureau for Agriculture (2003).

[22]There is debate on farmers' ability to identify agricultural production problems in relation to the environment (Heisey 1990, Trutmann *et al*. 1996). Bentley (1992) posited that agricultural production problems that are relatively easy to observe and have a high perceived importance (e.g., weeds or termites) have a higher probability of being reflected in farmers' knowledge. Against this backdrop, it can be posited that Chinese farmers are likely to link the incidence of secondary pests (both easily detectable and accorded with a high importance) with the cultivation shift from conventional cotton to Bt cotton.

[23]Through the pilot survey it was found that 67 percent of the sampled farmers think that Bt cotton does not impose any negative impacts on the environment, and 33 percent do not know. These results are not very surprising as the great majority of farmers have no understanding of genetic modification at all. See Zhang (2004, 27).

[24]These categories have been formulated to falsify hypotheses by forcing the respondents away from affirmative answers if they were not fully sure. The hypotheses were designed on the basis of the most common answers during the in-depth interviews of the pilot study.

second part of our survey, farmers were asked to indicate for eight different types of secondary pests (see Appendix 1 for the scientific pest names) whether they experienced any changes in the pests prior to and after the introduction of Bt cotton.[25] The final part of the interviews and survey was geared to farmers' experiences with the liberalisation of the Chinese seed market. During the Mao era the seed market was a centrally planned, state-dominated market. To boost private enterprise development and better services, the central authorities liberalised the seed market in 2000. Although with the best intentions, liberalisation soon led to a sort of 'wild West capitalism' with a multitude of new companies and seed varieties entering the market. To date little has been written about the effects of the seed market liberalisation on Chinese farmers' lives. What advantages do they see in the market liberalisation, e.g., improvements in seed prices, better seed varieties, access to market information? What are the shortcomings in their view, e.g., counterfeit seed, non-transparent market structure, unclear after-sale services? And how did the entry of so many new commercial entities affect farmers' trust in state and market institutions? These are the guiding questions of the last part of the survey.

Results of the full study and pilot

Pros and cons of Bt cotton: primary versus secondary pests

As mentioned earlier, during the pilot study we regularly encountered farmers who stated that secondary pests had increased. Also officials at the agricultural extension stations and county agricultural bureaus mentioned this problem. A local cadre in Anhui stated:

> The bollworm has decreased, but now aphids and spider mites have become the main pests. In September farmers must spray at least seven to eight times against aphids and spider mites, and it appears they are increasingly becoming pesticide-resistant. In the past these pests were not problematic, but now they are rising.[26]

The findings of the pilot study were confirmed during the full study a year later. The period reviewed by farmers covers approximately eight to nine years because Bt cotton cultivation started between 1996–2000 in the studied provinces.[27] During this time span, farmers in all provinces, except for Jiangsu,[28] have experienced a strong increase of two or more pests.[29] In Shandong farmers even perceived an increase in

[25]The change could be rated on a five-point scale from 'strong' or 'slight' decrease and 'no change' to 'slight' or 'strong' increase.
[26]Interview with official of the Agricultural Service Centre of Zougou Town, Anhui Province, 27 April 2004.
[27]Bt cultivation started in 1998 in the provinces of Jiangsu, Anhui, and Shandong. The only exceptions are the GM-free zone, Xinjiang, where the cultivation of Bt cotton started illegally in 2000, and Hebei province, where Bt cotton was introduced on an experimental basis for the first time in China in 1996.
[28]In Jiangsu an increase in only one type of pest, the lygus bug, was reported by 31 percent of the farmers.
[29]For Anhui, 46 percent stated they saw an increase in spider mites, 33 percent in the beet army worm, and 57 percent in cotton leaf worm; for Xinjiang the figures for spider mites and aphids are 27 percent and 59 percent, respectively.

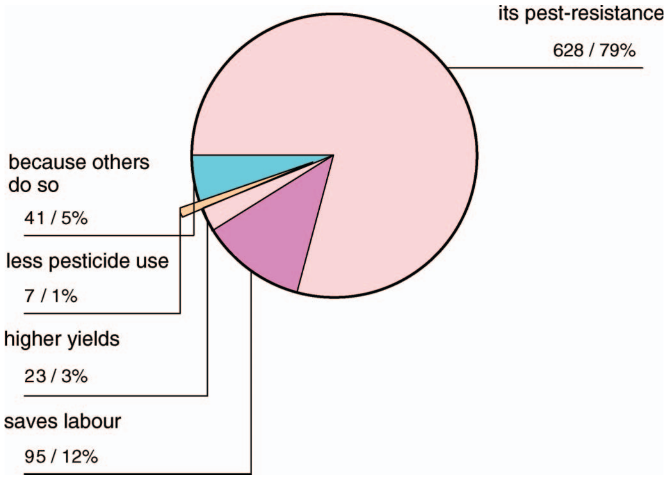

Figure 1. Main reason to choose pest-resistant cotton (one answer possible).
Source: Authors' survey.

four different pests, with 93 percent seeing a rise in pink bollworm and over half (54 percent) in cotton leaf worm.[30] Also, in Hebei the situation is serious as almost all (97 percent) of the respondents mentioned they saw a 'strong' increase in lygus bugs, while spider mites and aphids were also experienced as problematic.[31] Although the percentages, the type, and the number of pests rated as increased differ by province, there is no doubt that farmers have perceived a rise in secondary pests after the introduction of Bt cotton.

The perceived rise in secondary pests has not caused farmers to stop growing Bt cotton. In fact, Bt cotton remains popular among the Chinese farmers because of its pest-resistant qualities. When farmers were asked to state the main reason why they preferred Bt cotton over conventional cotton varieties, the overall majority said that it was Bt cotton's resistance against the bollworm. Other benefits identified in international studies, such as higher yields and less labour input, scored significantly lower (see Figure 1),[32] while surprisingly, less pesticide use was mentioned only by one percent of the farmers as their reason to choose Bt cotton. We asked farmers to tell us the average number of sprayings before and after the introduction of Bt cotton. In general, the number of sprayings had decreased by five to six times. It is important to note that the overall decreases in pesticide use are

[30]The other percentages for Shandong are 18 percent for spider mites and 15 percent for aphids.
[31]The percentages of Hebei farmers seeing an increase in spider mites and aphids are respectively 22 percent and 25 percent.
[32]However, in Xinjiang where the incidence of the bollworm is less serious due to the climatic conditions, we see that more farmers – namely 56 percent – indicate 'higher yields' as the main reason for choosing Bt cotton. In Xinjiang pest-resistance as a reason for Bt cotton cultivation scored lower: 34 percent.

substantially lower (by approximately a factor of two) than the figures reported by other studies.[33]

Our results – a rise in secondary pests and a concurrent higher application of pesticides – seem to confirm recent research on the long term sustainability of Bt cotton. The most significant study in this regard is probably that by Men *et al.* (2004), who, based on field data collected over three years, concluded that there is no difference in the pesticide use between conventional and transgenic cotton because of the need for additional pesticide sprayings to control emerging secondary pests in Bt cotton. In their words:

> Although insecticides were not applied against the main pest cotton bollworm on transgenic cotton, the total number of insecticide applications in 3 years was no less than the total applied on nontransgenic cotton, because additional applications were required against sucking pests on transgenic Bt cotton.[34] (Men *et al.* 2004, 247)

Easily manipulated? Low awareness and risk perceptions

Some scholars maintain that farmers' low awareness of GM crops implies it is of little use to probe into their risk perceptions. However, we contest such a view. Exactly because of their low awareness and understanding, farmers can be easily misguided or manipulated by state, private, scientific, and even non-governmental actors. As a commentator noted, movements such as

> the MST and Vía Campesina do not have any informed social groups backing the political rhetoric of their leaders when dealing with GMOs or agricultural biotechnology per se. The fact is that when landless families and workers participate in any action sponsored by the movement, they can even carry banners attacking trade and so on, but when you talk to them there is deep ignorance about these issues. (quoted in Newell 2008, 368)

In fact, the main objective of the MST is not to mobilise its rank and file members over the issue of GM crops, but to 'raise their international (and so local) profile and forge links with the hall of fame of international anti-GM activism' (Scoones 2005, 22). The result of such a political-economic constellation is a debate that shirks away from issues of access and control, as well as from one of the prime potential drawbacks of Bt cotton: its environmental impact. It is against this backdrop that the second part of our survey specifically looked into farmers' awareness ('have you heard of . . .?') and risk perception ('what is your attitude towards . . .?').

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[33]For instance, a study of Zulu smallholders at the Makhathine Flats in South Africa by Bennett *et al*. (2003) revealed that there had been a reduction in the average number of pesticide sprays per season (from 11.2 to 3.8 sprays) for farmers who adopted Bt cotton. As a result, there were cost savings in the form of lower inputs for pesticide and labour (Bennett *et al*. 2003, 128). See also Thirtle *et al*. (2003). Pray *et al*. (2001) have conducted similar research in China. Their results concur with the reports on Bt cotton in India and South Africa. They report that the reduction in pesticide sprayings ranged from 12 to 3 times (Bennett *et al*. 2003, 814).

[34]In July 2006, a research group headed by Per-Pinstrup Andersen presented similar findings at the annual American Agricultural Economics Association. However, these findings have not been published yet. See Lang (2006).

When farmers were asked how they first learned about *pest-resistant* (thus avoiding the term 'transgenic') cotton, over one-third said that they had got the news through the agricultural technology and extension station (or *nongji tuiguangzhan*), followed by news through neighbours (close to one-third), and family and friends. There were no great regional differences, and the state – through its agricultural technology and extension stations – is still the main source for news about seed varieties (see Figure 2 below).[35]

It was not until this stage of the survey that farmers were confronted with the term 'transgenic cotton' or *zhuangjiyin mianhua*. As Table 1 shows, an overwhelming majority had never heard about transgenic cotton, let alone about the Bt gene. A

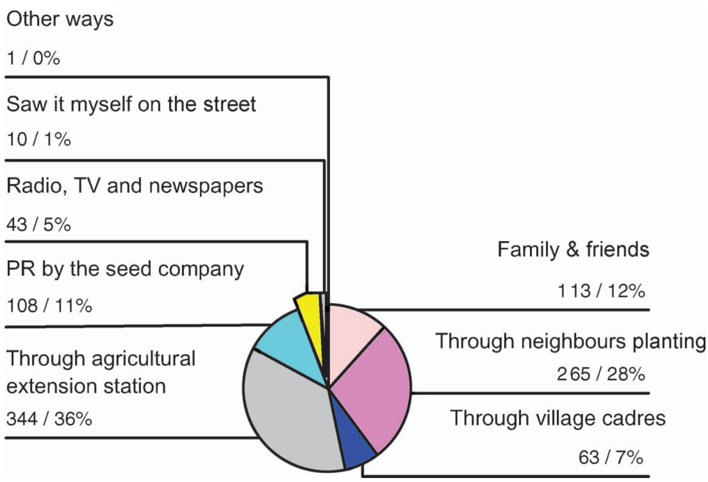

Figure 2. How did you first learn about pest-resistant cotton?
Source: Authors' survey.

Table 1. Farmers' awareness of Bt cotton.

Province	Question: Heard about ...	Yes	No
Hebei	transgenic cotton?	3.5%	96.5%
	Bt gene?	2.0%	98.0%
Shandong	transgenic cotton?	14.1%	85.9%
	Bt gene?	2.5%	97.5%
Anhui	transgenic cotton?	24.7%	75.3%
	Bt gene?	16.3%	83.7%
Jiangsu	transgenic cotton?	3.0%	97.0%
	Bt gene?	0%	100.0%
Xinjiang	transgenic cotton?	29.9%	70.1%
	Bt gene?	7.1%	92.9%
Total	*transgenic cotton?*	*14.9%*	*85.1%*
	Bt gene?	*5.5%*	*94.5%*

Source: Authors' survey.

[35]The only exception was Hebei province, where news through neighbours accounted for 44 percent and news through the agricultural technology and extension station for 32 percent.

striking illustration of this is the following conversation recorded with an Anhui smallholder:

> *Do you plant 'pest-resistant' cotton?*
> Yes, most of us do in this township.
> *Have you ever heard of 'transgenic' cotton?*
> Silence, then:
> No, never heard of it. They don't sell that kind of seed here.[36]

To assess farmers' sense of risk of GM crops, we posed a series of questions related to their role as *consumers* instead of their role as *producers*. In a previous study amongst urban consumers we found that low levels of understanding might easily lead to extreme reactions against GM food that have little to do with the risks identified by scientists (Ho *et al*. 2006). The problem for our study is that Chinese farmers do not grow any transgenic food crops of importance. The crop that can be most closely related to farmers' perception on food safety is derived from what they already grow: cotton. The cotton seed is traditionally used for extracting cooking oil, and one might say that cotton oil is truly the Chinese farmers' oil. Farmers like it because it is cheap,[37] it is fragrant (like sesame oil), and it adds a nice golden color to deep-fried foodstuff.[38] The only disadvantage mentioned by farmers is that it easily catches fire, so one must be careful when using cotton oil for cooking and frying.

To date there is no scientific consensus about the potential toxicological effects of the Bt protein on human health.[39] Under these circumstances, it is all the more important that there is an uninhibited flow of information on GM crops in relation to food safety, as our study also demonstrates. The case of Bt cotton oil is mostly neglected in issues of food safety, risk, and GM crops. Approximately two-thirds of China's cotton oil is nowadays produced in Xinjiang and sold to other provinces. While farmers retain a portion of the extracted oil as a payment for selling cotton seed to the oil mills, cotton oil is not readily available for individual consumers. Instead, it is sold in bulk to private traders, who in turn sell the oil to restaurant owners or petty shopkeepers. Many of the snacks and fried dumplings that make up a typical Chinese meal are actually prepared with cotton oil. Furthermore, a substantial portion of cotton oil is mixed and sold as salad oil, popularly known as 'hygienic oil' or *weishengyou*. As a result of the specific marketing structure of cotton oil, it is not labelled as containing or made of GM material, such as, for example, GM soybean oil. This is in striking contrast with the growing importance of Bt cotton and the oil extracted from it.

During the survey, we first asked farmers whether they had eaten cotton oil before, and eight of ten indicated that they had (see Table 2). When they were

[36]Interview with farmers during a focus group session in Xifeng township, Anhui province, 27 April 2004.

[37]The cheapest cooking oil in China is cotton oil, which sold for around 6,000–6,200 RMB per kg at the wholesale market in 2004. By comparison, sesame oil, the most expensive cooking oil, sold for 24,000 RMB per kg in the same year.

[38]In some regions it is even said that cotton oil has certain medicinal properties and is a remedy against greying hair.

[39]As Kuiper *et al*. (2001, 503) concluded in a review: 'the digestibility of [the Bt, PH] protein preparations under simulated conditions is of limited value, as questions can be raised as to whether these assays do mimic the physiological state of human beings . . . more extensive toxicity testing with the pure protein at exaggerated doses may be required'.

Table 2. Farmers' views on cotton oil.

Province	Percentage who have eaten cotton oil	Percentage who would **not** eat oil extracted from Bt cotton	*Of those who would not eat oil from Bt cotton*, percentage who would choose not to eat it because it is toxic or unhealthy
Hebei	100.0	18.2	75
Shandong	97.5	76.1	71
Anhui	65.4	76.4	59
Jiangsu	36.4	100.0	2*
Xinjiang	97.7	10.6	75
Total	*79.1*	*58.0*	*43*

Notes: * 92 percent of the respondents do not consume cotton oil because they eat rapeseed oil instead.
Source: Authors' survey.

subsequently asked whether they would eat oil extracted from Bt cotton, almost two-thirds said they would not. Of this group close to half stated they thought Bt cotton oil was either toxic or unhealthy.[40] In the words of a farmer: 'If pest-resistant cotton can kill bugs, it must not be healthy for people to eat the oil from it'. While another farmer feared that the use of Bt cotton oil might have adverse effects on human reproductive health and could even result in miscarriage.[41] A cadre of a town agricultural service centre voiced concerns:

> Nobody knows whether Bt cotton oil has any influence on humans. It might have. In the 1950s nobody knew that DDT was harmful, it was only much later that it was discovered. That's why the state should label it. People have the right to know and to choose between products.[42]

However, a CEO of one of the largest oil processing companies in Anhui province was considerably less concerned:

> GM cotton is the main type of cotton cultivated in China today and its seed is mainly used for oil extraction. Some people have concerns about food safety, but I believe that oil from GM cotton has no influence on the human body.[43]

[40]Shandong, Anhui, and Jiangsu provinces have high proportions of farmers who refuse to consume oil from Bt cotton seed (respectively 76.1, 76.4, and 100 percent). Jiangsu is an exception with only two percent. We discovered that at the turn of the century, Jiangsu province was shaken by a food scandal involving contaminated (non-Bt) cotton oil. This food scandal started in Qidong County. The contamination was most likely caused by phenol in cotton oil, the result of improper processing during oil extraction. After the incident few Jiangsu farmers continue to use cotton oil for cooking. This is also reflected by our data: 92 percent of the respondents stated that they would not eat oil extracted from Bt cotton because they consume rapeseed oil. Although the percentages of farmers who indicated that they thought Bt cotton oil was toxic or unhealthy are high for Hebei and Xinjiang (75 percent in both cases), both provinces score substantially lower on the proportions of those who refuse to consume Bt cotton oil (respectively 18.2 and 10.6 percent). We could find no plausible explanation for this phenomenon. Therefore, only for Anhui and Shandong could a solid relation be established between farmers' perception of food safety and Bt cotton.

[41]Farmer interviews, Zougou Town, Anhui Province, 27 April 2004.

[42]Interview with official of the Agricultural Service Centre of Zougou Town, Anhui Province, 27 April 2004.

[43]Interview with Wang Guangming, CEO of the Guangming Grain and Oil Industry Limited Company of Anhui Province, Wuwei County, Jiangba Township, 22 September 2004.

Our research was limited in time and resources with respect to conducting a sectoral analysis of the Bt cotton oil industry. However, we believe that the developments sketched here warrant further research.

Market liberalisation: pro-poor development or weakened biosafety?

Scholars have wondered whether seeds produced through informal, or even illicit, channels could provide a way for farmers to avoid dependency on large agricultural, transnational biotech corporations. The results from our survey on the liberalisation of the Chinese seed market tap straight into this question, and the discussions on 'stealth transgenics' or the possibilities of a pro-poor development enabled through 'Robin-hood Bt seeds' (Roy *et al.* 2007, 169). Some maintain that a situation in which 'stealth transgenics are saved, cross-bred, repackaged, sold, exchanged, and planted in an anarchic agrarian capitalism' not only 'defies surveillance and control of firms and states', but that it also results in outcomes 'more pro-poor than alternative modes of diffusion' (Herring 2007, 130). The Chinese case, however, demonstrates that pro-poor development – or a market catering to small-scale farmers, for that matter – does not revolve around 'stealth transgenics', but around access to and control of technology, which in this case relates to the pace and timing of market reform. In fact, the Chinese seed market has been liberalised too rapidly, resulting in insufficient control over product quality and biosafety regulations.

During the Mao era the agricultural seed market was strictly controlled by the state to ensure cheap and good quality agricultural inputs for farmers. The system reached well into the countryside through county seed companies and town/township agricultural technology and extension stations. As occurred in other sectors of the economy, the state attempted to dismantle the former socialist planned economy in gradual steps, thus allowing for the development and maturation of the domestic market before opening it up to foreign capital (Sachs and Woo 1996, Pei 2007). For instance, the biotech company Monsanto has repeatedly accused the government of deliberate delays in biosafety application procedures to allow Chinese companies to enter the seed market first.[44] At the time of writing, there are only two Bt cotton seed varieties that have been officially approved for commercial release by the China National Biosafety Commission: one developed by Biocentury and another by Monsanto.

With the development of domestic seed companies over the second half of the 1990s and China's gradual opening up to transnational corporations (e.g., Monsanto, Aventis, and Syngenta), the government faced increasing pressure to liberalise the seed market. This led to the new Seed Law, which passed the National People's Congress in July 2000 and allowed private traders on the market. The liberalisation led to two contradictory trends. On the one hand, there was an

[44]As a Monsanto representative stated: 'These things [frustration of Monsanto's activities in China] go back to 1996 when Guo Sandui [of CAAS] started his research on Bt cotton. Monsanto started in 1998 in Hebei province, which made the ministry rather anxious. Officials wanted to ensure that Chinese Bt cotton would come on the market soon. Later, the Ministry of Agriculture said we missed certain data for the biosafety approval, but others told us this was not the real reason. I believe the Chinese Ministry of Agriculture has held back our biosafety approval in favour of local Bt cotton research to catch up'. William Deng, Technical Representative responsible for Bt cotton and former general manager of Andai Company, 4 May 2004, Beijing.

avalanche of new seed companies and transgenic cotton varieties on the market, providing farmers with a hitherto unknown freedom and a virtually unlimited choice of seeds. On the other hand, the flood of the new transgenic seeds – some officially approved for biosafety, but the majority sold in flagrant contradiction of the law – caused confusion and market distrust among farmers, as well as immediate production problems. Even more, the widespread sale of stealth seeds implied their complete escape from the state's control over biosafety.

When farmers were asked what they saw as the most important advantage of market liberalisation, close to two-thirds (64 percent) mentioned an increased freedom to buy their own seeds. At the same time, when they were asked what they regarded as the main drawback, over one-third stated that the market had become more chaotic because of 'fake' seeds (*jia zhongzi*). On average 15 percent of the respondents had personal experience with buying fake seeds, while almost a quarter knew direct neighbours or friends who had had this experience.[45]

It must be noted that 'stealth seeds' are not automatically tantamount to seeds of inferior quality. In China, there is illegally copied seed by which the Bt gene is unlawfully appropriated by companies or research institutes that have the technological capacity to insert it into conventional cotton. These varieties are sold on the market under their own brand, for instance, Lumian-15 and NAU-3 (produced by a commercial offspring of the Nanjing Agricultural University). But these seeds are practically identical to the legitimate seeds of Monsanto and Biocentury as they contain the same gene. The packaging of these varieties seldom mentions that the seed contains the Bt gene, as that would require going through strict biosafety assessment procedures. To circumvent biosafety regulations, illegitimate seed are simply sold as 'pest-resistant' instead of transgenic cotton.[46] Another type of illegal Bt cotton seed is seed produced in breach of the production contract. Monsanto and Biocentury have signed agreements with seed production bases for specified production quotas. However, there is little that prevents these seed production bases from producing more than the agreed quotas and selling the surplus on the market against a lower price. These seeds are illegitimate, but genetically fully identical to the Monsanto and Biocentury seeds.

The majority of illegally copied seeds, however, are hybridised varieties by which Bt cotton is crossed with conventional cotton varieties. This type of seed is highly labour-intensive in production (as fertilisation of the cotton plants can only be done manually), although it needs little technological know-how. The hybridised seed, however, can not be saved for cultivation in the next year, because of the decrease in quality. This is compensated for by a higher yield than the parent generation – the so-called F0 generation. The higher yield of

[45]The sale of fake seeds was limited in Hebei (3.5 percent had direct experiences with fake seed and 3 percent knew neighbours or friends with that experience), while Anhui farmers encountered serious problems with an overwhelming 44 percent of the respondents having personal experiences with fake seed and 44 percent personally knowing people who had bought fake seed.

[46]As a Monsanto representative maintains: 'We estimate that there are over 100 different kind of illegitimate seed varieties, of which 80–90 percent are in fact 33B. However, they are sold on the market as "American Bt cotton No. 1" or something fancy like that. In this way, biosafety procedures are evaded'. William Deng, Technical Representative responsible for Bt cotton and former general manager of Andai Company, 4 May 2004, Beijing.

hybridised plants (the F1 generation) is a well-known biological effect known as the 'heterosis effect'.[47] Problematic for Chinese farmers is that corrupt seed traders also sell seed of the F2 progeny (hybrid cotton that has been reproduced) as genuine pest-resistant seed. Apart from an unstable productivity – due to the loss of the heterosis effect, which only occurs with the F1 generation – this seed may or may not contain the Bt gene, and thus has uncertain pest-resistant properties. This last type of seed is thus the seed that Chinese farmers refer to as 'fake seed' as it fails to control the bollworm, is lower in yield than conventional cotton, or might even not germinate at all.[48] Although the law provides for legal redress if agricultural production fails due to faulty seeds,[49] the overall majority of farmers stated they received no (financial or in-kind) compensation in such cases.[50] Close to a quarter of the farmers complained about bad after-sales services on the part of the seed companies. Confronted with the problems in the seed market, almost all interviewees (95 percent) deemed immediate government action necessary.

Contrary to the aims of the state to devolve its functions as a seed supplier to the market, close to half of the farmers (48 percent) continue to buy cotton seeds from the county seed companies, while one-third still turn to the township agricultural technology and extension stations. Over the past years, the county seed companies and the agricultural technology and extension stations at the townships have in fact been privatised. Yet, placed in a volatile market with insufficient information, farmers overwhelmingly put their faith in what they perceive as state institutions, rather than trusting the new private companies. A cotton farmer stated:

> There are many fake seeds, and I only feel reassured when I buy from the county seed company. There are farmers who bought from private shops, and their seed did not germinate. They went back to the shopkeeper and fought to get compensation. Some of them got some money, 40 RMB per mu, which included the costs for seed. But many did not receive a single penny.[51]

It is not surprising that farmers' trust in the state remains high; close to 80 percent believe that the government has the capacity to regulate the market.[52]

[47]Local Chinese officials have reported the heterosis effect for hybridised Bt cotton. Under similar production conditions, it is estimated that Bt cotton has a productivity of around 400–500 kg per mu (1/15 ha), while hybrid Bt cotton can reach 500–600 kg/mu. Interviews with officials of the Bureau for Agriculture of Wangjiang and Dongzhi County, Anhui, 23–26 September 2004; Dafeng City, 28 April 2004, Jiangsu; and the head of the Agricultural Technology and Extension Station, Hua Jianhuang, Dazhong Town, Jiangsu, 28 April 2004.
[48]The official Chinese standard for the germination rate has been set at 72 percent of the seed.
[49]As the law stipulates: 'If the seed user undergoes loss because of the seed quality, the seed supplier should compensate for it, and the compensation includes the money number used to buy the seeds, related expense and the available profit loss.' (Article 41 of the 2000 Seed Law).
[50]Only 27 percent obtained some kind of compensation either financially or in kind from the concerned seed company.
[51]Farmer interview, 30 April 2004, Nanshenzao Town, Jiangsu province. At the time one RMB had a value of 0.0994 Euro.
[52]Of the respondents, 78.8 percent thought that the state could regulate the market, 16.9 percent had some or serious doubts about it, while 4.3 percent did not know.

Ironically, however, if there is one area in which the Chinese state has lost much of its former control, it is the regulation of the seed market. This is painfully evident when it comes to issues of biosafety. A county official said that,

> according to the Seed Law, seed should be assessed and approved. But our law enforcement team can not cope with the work. Every village has its own seed outlet, in one county alone there are over a thousand shops . . . And there are just too many transgenic varieties – probably up to 70 or 80 percent of these have not been officially approved.[53]

In this sense, the Chinese situation underscores similar experiences in India and Brazil: state control over the market is vital, particularly in a rapidly developing context.[54]

Judging from the other objectives of the Seed Law – to 'control the selection, production, business operation and use of seed; protect the legal rights of the producers, business operators and users of seed; promote seed quality . . .' [55] – the restructuring of the domestic seed market has also failed. Even in terms of the economic benefits for farmers, government policy did not achieve what it had intended: almost all farmers (95 percent) did not agree that liberalisation had caused free market competition and better prices for seed. When asked to react to these findings, a deputy Director General at the Chinese Ministry of Agriculture answered:

> We had hoped that market competition would weed out the small and mala fide companies. However, such companies managed to survive because farmers are an easy victim. They lack the education and information to make sufficiently informed judgments about companies and their products. The situation is hard to control now, and perhaps we have been too early in liberalizing the market.[56]

Rethinking time and context for agro-biotechnology and GM crops

In the scholarly discussions on GM crops in general, and Bt cotton in particular, substantive attention has gone to their potential socio-economic benefits and drawbacks. However, much less has been said about problems of access and control. In other words, who has access to agro-biotechnology, and how can it be governed in such a way that its adoption can be economically viable, socially acceptable, and ecologically sustainable? Agro-biotechnological innovations might hold a wide array of potential benefits for poor, small-scale farmers in developing countries. However, to realise these benefits it is critical that questions of access and control are not shirked, but are continuously assessed and reassessed; that new technologies are introduced with ample consideration and caution; and that we sufficiently improve and test GM crops prior to commercial release – the period for this might need reconsideration in light of the length of time in which ecological changes occur.

[53]Interview with official of the Agricultural Committee of Wuwei County, Anhui Province, 27 April 2004.
[54]Biosafety regulations are also hard to enforce in India and Brazil. As Herring (2007, 130) noted: 'the ability of seeds to move underground . . . undermines widely-assumed biosafety-regime capability'.
[55]As stipulated in article one of the 2000 Seed Law.
[56]From an interview with respondent 29/82008MoA. For reasons of privacy the name and department of this official cannot be given here.

Given its highly technical, multi-disciplinary core, the multitude of scientific uncertainties that surround it, and the novelty of its policy arena, industrialised countries deem it critical to monitor, plan, and control the adoption of GM crops. In a developing context, however, this might be substantially more difficult given the weaker institutionalised channels for civic participation, the limited or actively restricted access to information,[57] and less effective enforcement of laws and policies. Due to these parameters, developing countries might not be up for the transgenic challenge (see Paarlberg 2001), although they already account for almost half of the global acreage of GM crops.[58]According to Kydd *et al*. (2000, 1137) this may lead 'to lower standards for food safety and environmental protection' and a 'genetic Bhopal', while Zhao and Ho (2005, 370) note that some developing countries might evolve into: 'a "developmental risk society" – a society in which government and science confronted with major development issues, disregard technological risks due to the absence of sufficient countervailing forces'.

In a rapidly emerging developing economy such as the Chinese one, the adoption of GM crops has already proven problematic. China can command sufficient financial and human resources and, more importantly, also boasts the scientific and technological capacity to launch its economy well into the biotechnological age. In fact, the State Council's recent announcement of a large research and development package for GM crops, worth over US$3.5 billion, is a testimony to the state's resolve in this. To many foreign and Chinese observers the new government initiative might pave the way for the commercial release of another important GM crop, long halted but anxiously awaited by the biotech companies: Bt rice (*Newsweek Science and Technology* 2004, Stone 2008).

On the other hand, however, China is still in the midst of setting up regulatory biosafety structures and has encountered serious difficulties in enforcing biosafety rules and controlling the seed market (Zhao and Ho 2005, Gupta and Faulkner 2006). The liberalisation of the seed market has led to the Chinese state's increasing loss of control over biosafety issues and has caused a flood of illegal or 'stealth' seeds and a subsequent distrust of farmers in the new private seed companies. In a developing context, and China is no exception, farmers are often regarded as *passive recipients* of new technology that supports them in solving agricultural problems, rather than as *critical buyers and producers*, which entitles them to balanced, uninhibited information about that technology. We have found that an overwhelming majority of the Chinese farmers have no inkling about genetic engineering. For most of them, Bt cotton is simply a new seed variety, just like many others introduced to them over the past decades. At the same time, farmers have a strongly felt need for information: one-fifth of our respondents indicated that they wanted more information and training about Bt cotton cultivation.

[57]This problem is also noted by Tripp (2002), although he regards the lack of information as a managerial problem rather than a rights problem. Yet, an important difference between GM and conventional crops is their level of public contestation, which may affect their marketing. In this context, farmers should have a 'right to know' the potential risks of GM crops.

[58]Of the global area sown to GM crops, 43 percent (49.4 million hectares) were cultivated in developing countries where growth between 2006 and 2007 was 'substantially higher (8.5 million hectares or 21 percent growth) than industrial countries (3.8 million hectares or 6 percent growth)' (International Service for the Acquisition of Agri-Biotech Applications 2007).

It is also critical to recognise that the current time span over which transgenic crops are assessed and found sufficiently mature for commercial production might not concur with the time span at which ecological change is manifested. We have presented empirical findings that might support such a reading. First, the reduction in pesticide use in Bt cotton cultivars as compared to conventional cotton varieties is significantly lower than that reported in studies conducted several years before ours (e.g., Pray *et al*. 2001, 2002, Huang *et al*. 2003). Second, over the past years Chinese farmers have perceived a substantial rise in secondary pests, i.e., pests other than the bollworm, such as spider mites, aphids, and lygus bugs. The results were identical for farmers from all sample provinces representative of China's three main cotton regions: the Yellow River area, the Yangzi River area, and the Northwest. These findings are in line with recent research suggesting that over time more pesticides are necessary to control the rise of secondary pests in Bt cotton (Men *et al*. 2004, Wang *et al*. 2006, 2008).

Regardless of whether certain risks might prove to be scientific reality, it is vital that farmers become aware and knowledgeable about the principles of genetic modification and its implications. It will support them in making better-informed decisions about agricultural production, as well as helping them relate potential production problems more effectively to the specific nature of transgenic crop cultivation. Ultimately, this will benefit a more pro-poor adoption of GM crops in developing nations (Scoones 2002, Pingali and Traxler 2002). The Chinese case should remind us that the success of technology lies in embedding it in an appropriate institutional, political, and socio-economic constellation. In itself, technology can never and should never be a solution for problems of development.

Appendix 1. Overview of secondary pests tested in the survey.

English term	Scientific term	Chinese term
Cotton bollworm	*Helicoverpa armigera*	棉铃虫
Cotton aphids	*Aphis gossypii*	棉蚜
Cotton spider mites	*Tetranychus cinnabarinus*	红蜘蛛
Cotton pink bollworm	*Pectinophora gossypiella*	红铃虫
Beet armyworm	*Spodoptera exigua Hubner*	甜菜夜蛾
Cotton leafworm	*Prodenia litura Fabricius*	斜纹夜蛾
Sweetpotato whitefly	*Bemisia tabaci*	烟粉虱
Greenhouse whitefly	*Trialeurodes vaporariorum (Westwood)*	白粉虱
Lygus bugs	*Adelphocoris saturalis, A. fasciaticolls, Lygus lucorum*, etc.	盲蝽蟓

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