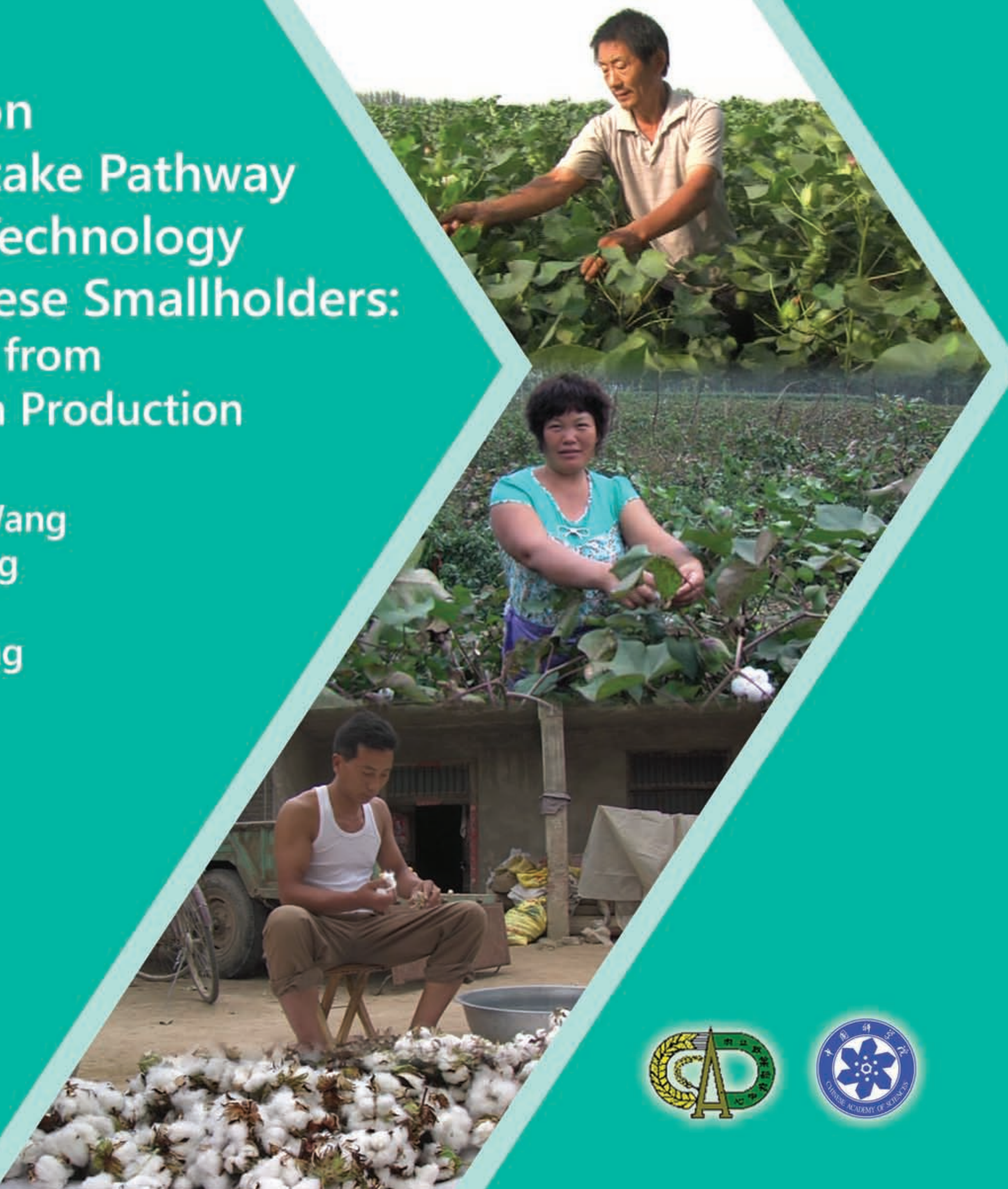
Adoption and Uptake Pathway of GM Technology by Chinese Smallholders:
Evidence from Bt Cotton Production

Xiaobing Wang
Jikun Huang
Huaiju Liu
Cheng Xiang
Wei Zhang



Adoption and Uptake Pathway of GM Technology by Chinese Smallholders: Evidence from Bt Cotton Production

Xiaobing Wang, Jikun Huang, Huaiju Liu, Cheng Xiang and Wei Zhang

Center for Chinese Agricultural Policy
Chinese Academy of Sciences

December 2013

Published by: Center for Chinese Agricultural Policy, Chinese Academy of Sciences

Citation: Xiaobing Wang, Jikun Huang, Huaiju Liu, Cheng Xiang, and Wei Zhang. 2013. Adoption and Uptake Pathway of GM Technology by Chinese Smallholders: Evidence from Bt Cotton Production. Center for Chinese Agricultural Policy, Chinese Academy of Sciences: Beijing, China.

Layout and cover design by Angela Mae Miñas

Table of Contents

List of Tables

List of Figures

Foreword

China is one of the first six countries that first commercialized a biotech crop – Bt cotton in particular. Although eight biotech plants (cotton, petunia, tomato, sweet pepper, poplar, papaya, rice, and maize) have been issued safety certificates for production, cotton remains to be the most successful crop with the greatest impact. First commercially released in 1997, Bt cotton has been rapidly adopted by small scale farmers estimated at over seven million to date. Nearly all farmers now plant the crop in North China and those along the Yangtze River. It is Bt cotton that enabled millions of farmers to go back to profitable cotton production after a breakout of a major pest, cotton bollworm, in the late 1990s.

Adoption and Uptake Pathway of GM Technology by Chinese Smallholders: Evidence from Bt Cotton Production provides empirical basis for understanding the phenomenal growth that triggered significant increases in cotton area, number of farmers, and adoption rate for over one and a half decades of cultivation. This research was made possible through the effort of students and staff of the Center for Chinese Agricultural Policy (CCAP), Chinese Academy of Sciences (CAS), as well as graduate students from agricultural universities. The substantial data obtained and interactions with farmer-beneficiaries have demonstrated that farmers have indeed benefitted from the technology as only the end users can attest to the value of any scientific product.

The research highlights the benefits that farmers gained from Bt cotton adoption. These include reduction in insecticide use, increased yield, savings in labor inputs, and ultimately improved farmers' income and livelihood. Feminization of cotton production in China was noted as less use of pesticide and savings in labor attracted women farmers.

We note the important role of seed companies and technology developers in farmers' use of Bt cotton. They conducted field trials in cotton production villages which provided opportunities for farmers to see first hand how Bt cotton compared with conventional varieties. Local extension staff and progressive farmers likewise encouraged a multiplier effect in motivating other farmers to try Bt cotton. So successful was the introduction of the technology that demand for seeds was higher than supply and information on its use was sought after. This scenario suggests the need for a model that encourages adequate participation of public and private sector players to assure seed availability, and knowledge and information sharing among farmers.

We hope that the results from this research will guide policy makers in facilitating avenues for the sustained interest and motivation of farmers to adopt biotech crops, not only of Bt cotton but other crops including those in the pipeline. In addition, other developing countries may also find the research and policy implications useful for understanding how best to introduce a technology to those who stand to benefit most.

The research team recognizes all the farmer respondents who participated in the survey and focus group discussions. We also appreciate the support provided by the International Service for the Acquisition of Agri-biotech Applications (ISAAA) and the John Templeton Foundation who strongly believe that the farmers' collective voice should be heard.

Xiaobing Wang
Jikun Huang
Huaiju Liu
Cheng Xiang
Wei Zhang

Abstract

China is one of the first countries that have commercialized GM crops. Bt cotton was commercially released in 1997 and had been rapidly adopted by farmers thereafter. Our survey shows that it takes only a few years for nearly all farmers to adopt Bt cotton in Huang-Huai-Hai region, a major cotton production area in China. Bt cotton is well reported as a successful case of biotechnology adoption in China.

Introduction of Bt cotton helped Chinese farmers to recover their cotton production in the late 1990s. Even though China has a long history of cultivating cotton, breakout of cotton bollworm in the mid-1990s shrank its cotton production area. With the availability of Bt cotton for farmers, in majority of sampled counties, the share of cotton area to total sown area increased parallel with the diffusion of Bt cotton. The descriptive statistics and finding from focus group discussions (FGDs) show that the adoption of Bt cotton by farmers are mainly motivated by better traits of Bt cotton in the field such as the effective control of bollworm and reduced yield loss from bollworm attacks, reduction of pesticide usage, and being an environment-friendly crop.

In general, while Bt cotton technology is a neutral technology that benefited all farmers, there was an evolution in the spatial pattern of Bt cotton production. Farmers in our study areas were smallholders and they equally accessed the new technology. The spatial evolution was closely correlated with serious infestation of local bollworm, resistance of Bt cotton to bollworm, and biosafety regulation.

All farmers in Huang-Huai-Hai region were smallholders with average cultivated land area of less than one hectare. Field work for both Bt cotton and non-Bt cotton were mainly conducted by women as men were engaged in off-farm jobs more than women. Reduction in pesticide use and saving in labor due to Bt cotton adoption benefited women. There were no significant differences in household characteristics between Bt cotton adopters and non-Bt cotton adopters.

In the first stage of Bt cotton diffusion, both seed companies and the technology developers (e.g. research institutes or biotech companies) that conducted Bt cotton field trials and demonstration in cotton production regions played important roles in farmers' use of Bt cotton. Leading domestic seed companies working with technology developers sold Bt cotton seeds to some of the initial adopters.

Meantime, local public agricultural technology extension staff (or technicians) and leading farmers were invited to visit Bt cotton field trials or demonstration fields by technology developers to facilitate initial adoption of Bt cotton by farmers. In some villages coordinated by their leaders, training workshops on Bt cotton or visits to Bt cotton field trials were provided for farmers who became the first adopters of Bt cotton. Some village leaders also coordinated the Bt cotton seed generation and set up the seed purchasing contract with seed company, which helped their villagers become the first adopters and facilitators of the expansion of Bt cotton.

With the outstanding performance of Bt cotton by its first adopters, the other farmers in the same village followed them rapidly. Generally, farmers visited the Bt cotton fields of the first adopters and learned the advantages of the technology. The followers also learned and adopted Bt cotton from their neighbors, other farmers inside or outside their villages, or the hometown of the farmers' wives.

However, it is worth noting that when Bt cotton was first released, there were also serious constraints in its adoption. Many farmers wanted to plant Bt cotton but the supply of Bt cotton seed did not meet their demand. With the limited knowledge about biotechnology, some farmers also delayed their adoption. This study has several policy implications. To facilitate GM technology diffusion to farmers, seed companies, technology developers, local village leaders, and the first adopters of technologies can play important roles. Local technology extension service and training are also critical in disseminating appropriate information and knowledge to farmers so that they can fully benefit from the new technology.

Introduction

There has been rapid growth of genetically modified (GM) crop areas since the late 1990s. With a 100-fold increase from 1996 to 2012, the global accumulated GM crop area reached 170 million ha, distributed across 28 countries (James, 2012). China is one of the first countries that have commercialized GM crops. Bt cotton was commercially released in 1997 and had been rapidly adopted by farmers thereafter. The share of Bt cotton in total cotton areas exceeded 65% after 2004. Nearly all farmers planted Bt cotton in Northern China and Yangtze River basin after the middle 2000s. Bt cotton is well reported as a successful case of biotechnology adoption in China.

The rapid extension of GM technology also attracted the attention of agricultural economists to evaluate cost and benefit of major GM crops (Falck-Zepeda et al., 2000, Fernandez-Cornejo et al., 2002; Huang et al., 2002b; Qaim and de Janvry, 2003b; Huang et al., 2005b; Marvier et al., 2007).

Numerous results, both ex post and ex ante, documented that insect-resistant *Bacillus thuringiensis* (Bt) crops allowed significant reduction of pesticide resulting in positive impacts on welfare and environment. For example, Huang et al. (2003) indicated that Bt cotton, as the substitute of pesticide against the pest, appears to be a technology that improves both productivity and the environment.

The study of Bt cotton in India by Subramanian and Qaim (2010) also mirrored this conclusion. Compared to traditional cotton, smallholders benefit from saving pesticide, higher effective yields with less crop losses and poverty reduction (Ali and Abdulai, 2010). These contributions to agricultural production are also found in Bt maize production in the Philippines (Torres et al., 2012).

Despite the enormous uptake in GM crop cultivation in many countries, pathways and diffusion of a new biotech product to smallholders are different based on institutional and developmental interventions. There exists burning debates about their potential risks and direct and indirect effects on agronomic and socio-economic concerns for decades. As a result, negative attitudes seem to dominate in the European Union (EU) and thus GM technology is denied to European smallholders. For example, after cultivating herbicide tolerant (HT) GM soybean in Romania for some years (1999-2006) before its entry to the EU, farmers suddenly stopped planting it because HT GM soybean is not approved for commercialization in the EU. After the commercial release of Bt cotton in China and India for years, some smallholders did not adopt this technology even within the same community without the constraint of access to GM seeds (Qaim and Kouser, 2013; Huang et al., 2012). This could be explained by some factors such as the gap in marketing chain of seed companies, the functioning of technical extension system, and household's characteristics.

The adoption and diffusion of biotechnology is influenced by social-economic factors and not free of risk preference. Empirical results and evidences from focus group

discussion (FGD) suggest that smallholders are not going to pay for a specific seed unless they verify that it has real benefits (Torres et al. 2012). The study contributed by Huang et al. (2010) found that if smallholders can fully grasp and apply GM knowledge in production, the use of pesticide would decline 6.7 kg/ha by using Bt cotton. New technology, such as GM crop, is only "absorbed" by smallholders, it can make positive effects on pesticide reduction and yield. Even having adopted Bt cotton, the overuse of pesticide by leading smallholders definitely reduces the positive effects of biotechnology on welfare and environment, and also make fellow smallholders less likely to follow. By using an experiment to measure risk preference, Liu (2011) found that smallholders who are risk averse are more likely to adopt Bt cotton later when controlling for other constant variables.

Furthermore, literature showed that smallholders often vary substantially on adoption of new agronomic technology due to difference in resource endowment, which possibly dampen potential profit, and thus impede the introduction of advanced technology (Pemsl et al. 2005). With the scarce land resources of around 0.60 ha per farm, Huang et al. (2008) argued that smallholders were vulnerable to harvest risk from pest infestation, and hence inclined to overuse pesticide. Thus, study on adoption of GM and its knowledge effect is especially meaningful and valuable to other countries with the similar land/labor ratio like India.

Even though existing studies empirically analyzed the key factors that significantly influence the adoption decision of smallholders, there is little knowledge about the uptake process and the roles of different stakeholders.

To fill this gap, this report tends to answer the following questions:

- What are the institutional frameworks to offer biotechnology in China?
- Who are the leading adopters of Bt cotton in the local communities?
- What are the key factors that facilitate or constraint the adoption of biotechnology? What are the roles of different stakeholders in the uptake process of biotechnology?
- What are the significant changes that occurred as a result of GM crops adoption?
- What are the uptake pathways of biotechnology in a village?
- What are the perspectives of the stakeholders and smallholders to expand or adopt biotechnology?

Thus, the overall objective of this study is to analyze the adoption and uptake pathways of biotech crops among smallholders in China. The specific objectives are as follows:

1. Present the evolution of cotton production, with the special attention to the commercial release of Bt cotton in China.
2. Explore the factors including demographic and farm characteristics correlated with the adoption of Bt cotton.
3. Assess the impacts of the adoption on inputs and yield in production, and direct effects on smallholders' revenue.

4. Identify the development interventions from different stakeholders like leading farmers, technicians and seed dealers in the uptake pathway of Bt cotton in China based on the FGDs.

To meet the general and specific objectives, we used two datasets including national cotton production data and the several round of cotton production surveys, and the records from FGD. We conducted the descriptive statistics of the cotton production data and analyzed FGD by using Innovation Tree methodology. The latter is used to help visualize the pathway of a technology and the roles of participants in the diffusion of biotechnology in a village.

For this study, Bt cotton is used as a case crop. After the diffusion of biotechnology globally for more than a decade, major crops like GM soybean, cotton and maize with single or stacked traits have been cultivated by smallholders. However, Bt cotton is the only biotech crop in the field in China while other biocrops like Bt rice are only in the pipeline. Better understanding of the uptake of Bt cotton will be of important policy implication to expand other food biocrops like GM maize in China.

The rest of this report is organized as follows:

Section 2 summarizes the main findings from literature review about the development and adoption of Bt cotton and its impact on production and smallholders' welfare. Furthermore, we present the biosafety regulations in China.

Section 3 presents the data source and instrument for both of the survey and FGDs.

Section 4 documents the evolution of Bt cotton in China. In addition, we present the descriptive statistics of our national cotton survey between those who adopted Bt cotton and those who did not.

Section 5 presents the results of Innovation Tree based on FGDs in eight counties. The last section concludes and discusses policy implications.

Literature Review

The development of Bt cotton in China

In spite of concerns on potential environmental and health risks, an enormous growth in the diffusion of GM crops in terms of crop varieties, acreage and the approved countries has been observed (James, 2012). GM varieties cover crops like maize, fruits like melon and papaya, and flowers like carnation with improved adaptation to local agronomic conditions. The unprecedented growth of GM varieties indicates that it might be a new driving force for agricultural development and a potential solution to global food security issues (Pray et al., 2001, Huang et al., 2002a; Qaim and David, 2003a; Beyers, 2003; Huang et al., 2005a; Wang et al., 2009).

To raise agricultural productivity and ensure national food security through GM technology, China has injected great investment in research and development (R&D) and human capacity building (Huang et. al., 2002; Hu et al., 2012). Unlike many other countries, Chinese government invested substantially in the public sector in order to develop its own technology since the 1980s. The investment was accelerated after China initiated its new National GM Variety Development Program (GM program) with about US$3.8 billion in 2008-2020.

While smallholders in most GM crop growing countries are adopting GM technologies from multinational companies (MNCs), China's public sector did generate impressive GM technology. Bt cotton is one of the most cited examples of R&D progress of GM technology in China. In 1997, two varieties of Bt cotton with different sources of Bt genes could be obtained by Chinese smallholders in certain provinces: one variety patented by Chinese Academy of Agricultural Science (CAAS)[1] is competitive with the one (NC33B) integrating the Monsanto *Cry1Ac* gene developed by Monsanto company. The Ministry of Agriculture (MOA) simultaneously approved these two varieties for commercialization: one owned by CAAS was allowed to cultivate in Shanxi Anhui, Shandong and Hubei provinces while the other developed by Monsanto company was grown in Hebei province.

In fact, Bt cotton was approved for the commercial release step by step by Ministry of Agriculture (MOA), China. The country has a long history of cultivating cotton in three regions including Huang-Huai-Hai, Yangtze river and Xinjiang cotton production zones. After the commercial release of Bt cotton in Huang-Huai-Hai cotton production zone, it was proved that Bt cotton requires less pesticide use, is labor-saving and increases yield (Huang et al, 2002). As a result, the approval of new varieties was accelerated after 2000 (Huang et al, 2002). From regional dimension, China's government expanded the commercial release of Bt cotton beyond Huang-Huai-Hai to Yangtze river and Xinjiang cotton production zones. Table 1.1 indicates that in 1999, one and two varieties were allowed to cultivate in Jiangsu province (Yangtze river production zone) and Xinjiang, respectively. Since 2004, four varieties adapted to the agronomic condition were commercially released in Yangtze river production zone.

[1] The variety is not specified as to its genetic strain.

Table 1.1 Approval of commercial release of Bt cotton in China by the start year and by province

Province	Cotton Production Zone	Starting Year	Variety	Affiliation
Anhui	Huang-Huai-Hai	1997	Bt cotton[a]	Biotechnology Research Institute, CAAS
Shanxi	Huang-Huai-Hai	1997	Bt cotton[a]	Biotechnology Research Institute, CAAS
Shandong	Huang-Huai-Hai	1997	Bt cotton[a]	Biotechnology Research Institute, CAAS
Hubei	Huang-Huai-Hai	1997	Bt cotton[a]	Biotechnology Research Institute, CAAS
Hebei	Huang-Huai-Hai	1997	NC33B	Monsanto
Henan	Huang-Huai-Hai	1999	GK12, GK95-1	Biotechnology Research Institute, CAAS
Liaoning	Huang-Huai-Hai	1999	GK95-1	Biotechnology Research Institute, CAAS
Jiangsu	Yangtze River Valley	1999	GK-12	Biotechnology Research Institute, CAAS
Xinjiang	Xinjiang	1999	GK-12, GK95-1	Biotechnology Research Institute, CAAS
Shaanxi	Huang-Huai-Hai	2004	GKz1, GKz2	Biotechnology Research Institute, CAAS
Jiangxi	Yangtze River Valley	2004	DP410B	Monsanto
		2004	GKz18	Biotechnology Research Institute, CAAS
Hunan	Yangtze River Valley	2004	DP410B	Monsanto
			GKz17	Biotechnology Research Institute, CAAS
Sichuan	Yangtze River Valley	2004	DP410B	Monsanto
		2004	GKz34	Biotechnology Research Institute, CAAS
Zhejiang	Yangtze River Valley	2004	GKz18	Biotechnology Research Institute, CAAS

From temporal dimension, since 2000, the number of new varieties approved every year increased dramatically in all three cotton production zones (Table 1.2). In 2005 and 2006, there were more than 20 new varieties available to smallholders in provinces located either in Huang-Huai-Hai or Yangtze river production zones every year.[2] From 2008 onwards, the approved varieties were released subject to the production zones, rather than by province.

This suggests that the Bt cotton trait has been improved to adapt to more diversified agronomic condition. Furthermore, given more varieties in the market, Chinese smallholders have less constraint to access Bt cotton seed.

The results in Table 1.2 show that more varieties have been approved and targeted to smallholders in Huang-Huai-Hai cotton production zone. Chinese smallholders are growing Bt cotton developed by the domestic public research institutes as well as those from multinational companies (MNCs) including Monsanto company (Huang et al., 2002).

[2] We only reported the new varieties approved every year. Even though some of the varieties approved earlier could be expired according to GM technology regulation, it is reasonably assumed that the actual numbers of varieties offering to smallholders are more than those approved every year.

Table 1.2 The evolution in number of newly commercialized varieties by cotton production zones and by provinces, 1997-2012

Year	Huang-Huai-Hai								Yangtze river					Xinjiang
	Anhui	Hebei	Henan	Shandong	Shanxi	Hubei	Liaoning	Shaanxi	Jiangsu	Jiangxi	Hunan	Sichuan	Zhejiang	Xinjiang
1997	1	1	-	1	1	1	-	-	-	-	-	-	-	-
1998	0	0	-	0	0	0	-	-	-	-	-	-	-	-
1999	3	1	2	1	1	0	1	-	1	-	-	-	-	2
2000	1	2	0	1	0	0	0	-	0	-	-	-	-	0
2001	1	0	0	0	0	0	0	-	0	-	-	-	-	0
2002	2	2	7	4	1	1	0	-	1	-	-	-	-	1
2003	0	0	0	1	0	0	0	-	1	-	-	-	-	0
2004	19	18	28	28	0	10	0	2	18	2	2	2	1	0
2005	72	22	33	36	3	11	0	8	31	2	5	2	3	1
2006	74	29	61	44	24	26	0	5	20	1	18	4	4	0
2007	27	50	53	30	7	14	0	11	24	5	10	3	2	0
2008	180								53					0
2009	141								90					0
2010	92								72					0
2011	31								10					0
2012	54								69					0

The impacts of biotechnology in China

Since 1997, China has commercialized various GM crops and thus the investment has received high return (Huang, 2004; Pray et al., 2002). By 2013, eight biotech plants (cotton, petunia, tomato, sweet pepper, poplar, papaya, rice, and maize) have been issued safety certificates for production, among which Bt cotton was the most successful case and widely adopted by smallholders. Benefit from Bt cotton and potential roles of biotechnology boost agricultural productivity and improve the national food security (Huang et al., 2002). One of the proven traits of Bt cotton is its remarkable ability to reduce the usage of pesticide (Huang et al., 2002a and 2003). Compared with conventional cotton, the single trait of Bt raises effective yield by reducing the crop loss and its variation of yield. By using damage control models, Bt cotton adopters on average save pesticide by around 56%, and the yield increase by around 8% in China (Huang et al., 2002). Compared with the findings in India, Bt cotton yield increased much more than that in China but the pesticide saving is a bit less (Sadashivappa and Qaim, 2009). Even though Bt rice is still in the pipeline, the study based on the trial production data showed that the yield of Bt rice increased by around 6-9% by using less than 17kg/ha pesticide and less labor 8.4 days/ha (Huang et al., 2005).

After the commercial release of Bt cotton for years, other evidences beyond its promises on yield and reduction of pesticide still make Bt cotton a valuable option for smallholders (Pray et al., 2011). Even though the price of conventional cotton is lower, higher yields of Bt cotton combined with less usage of pesticide and labor inputs outweigh higher seed costs in the developing countries. This suggests that adopting Bt cotton also improve the smallholders' welfare through its positive effects on income. By measuring the consumption expenditure, the long-term impacts on Bt cotton adopters' welfare turns to be positive compared to counterparts in India (Kathage and Qaim, 2012). Due to the limitation of the consumption data, this issue is not yet explored for Chinese Bt cotton adopters.

Despite debates on its environmental effects, its direct and indirect positive effects on environment have been obtained given its unique mechanism of pest control. For example, with the obvious advantage of controlling bollworm, either cotton smallholders (Bt or Non-Bt) and other smallholder benefit from the reduction of bollworm population where agricultural production is susceptible to bollworm (Wu et al., 2012). Recent study by Zhang et al. (2013) also proves the positive impacts of Bt cotton on the improvement of biodiversity in the field. Positive environment effects on water, energy use, and soil could be obtained from the reduction of spraying pesticide as well.

Factors influencing the adoption of biotechnology in China

Economics theory explicitly state that as a rational producer, the production decision is subject to the analysis of cost and benefit. It is no exception for adopting a new technology, like biotechnology. All of the existing studies make us conclude that either the smallholders in developing countries or the big farmers in US, Canada or those in South America will not adopt biotechnology without its proven traits such as the reduction of inputs and increased yield (James, 2012). This is true for all GM crops such as Bt cotton, Bt maize, HT GM soybean, and GM papaya in the field.

Empirical evidences show that keeping other variables constant, the extent of new technology adoption is influenced by demographic characteristics. Compared with conventional cotton, Bt cotton is a labor-saving technology. Thus, households with less laborers or comparative advantage in off-farm employment will cultivate Bt cotton. Education and experience also correlate with the adoption decision. Smallholders with higher educational attainment are more likely to be the leading farmer to adopt Bt cotton. Furthermore, farmers with more training are more likely to fully adopt it or even expand cotton production after seeing its traits performance in a demo farm.

Even though there appears the feminization and aging in Chinese agricultural production, male and young household heads have higher probability of adopting Bt cotton compared to counterparts (Huang et al., 2012). Studies by Liu (2012) and Liu and Huang (2013) also show that risk preference is statistically important to influence the adoption of biotechnology. Risk-averse smallholders adopted Bt cotton later than their counterparts.

The adoption decision is also influenced by information and extension, intellectual property right (IPR), and access to seed markets. Some reports and the findings from our own FGDs indicate that at the initial commercial release, the availability of the seeds to some extent hamper the rapid diffusion of Bt cotton due to the poor marketing chains of seed companies including the MNCs in developing countries. IPR issue of the better varieties is precondition

of diffusing a new variety across countries and within a country (region) (Pray et al., 2012). After the adoption of biotechnology, some of the leading smallholders still overuse pesticide in production, due to the limited knowledge on this technology. This definitely dampened the incentive of fellow smallholders to follow, as the positive effect of this technology is only marginal (Hou et al., 2012).

Last but not the least, biosafety regulatory is of importance to diffuse biotechnology across countries and within a country. For example, the case of HT GM soybean in Romania indicates that the institution is a barrier for the diffusion even though the adopters are eager to re-cultivate it. Before Romania had access to EU, HT GM soybean was adopted by Romanian farmers from 1999 to 2006. However in 2006, GM soybean was not approved for planting, and thus farmers in Romania had to stop planting HT GM soybean even though it was earlier welcomed by farmers.

Biosafety Regulations in China

In response to the emerging agricultural biotechnology, China has established and improved its legal and regulation system for agricultural biosafety since early 1990s. The first biosafety regulation on the measures for safety administration of genetic engineering was issued by the Ministry of Science and Technology (MOST) in 1993. Following MOST's guidelines, the Ministry of Agriculture (MOA) issued the implementation measures for safety control which are specific for agricultural GM organisms in 1996. With continued development of agricultural biotechnology, rising GM product imports and consumers' concerns, China has periodically amended its biosafety regulations since 2001. Currently, biosafety regulations covers management, trade, and labeling of GM products.

Furthermore, China formally institutionalized the National Biosafety Committee (BC), which is in charge of biosafety management. The BC consists of mainly scientists in relevant majors including agriculture, medicine and health as well as representatives of officers from different ministries. The BC is in charge of approvals of the intermediate trial, the environmental release, the pre-production trials and biosafety certificates of GM crops. MOA makes decision on the commercial release of biocrops after the BC's recommendations for commercialization. In the past 15 years, even though the world acknowledged China's government-issued biosafety certificates for Bt cotton, Bt rice, Ring Spot Virus Resistant Transgenic Papaya, Phytase maize, and other GM plants (e.g., GM petunia, tomato, sweet pepper, and poplar trees), Bt cotton is the only major crop in the field.

However, with the fast development of GM technology domestically and abroad and the rapid commercial release of GM crops, the present biosafety regulation of GM crops will cause new challenges for the trade of GM crops, which are manifested from the dimensions of export and import. Though China has commercialized many GM crops and others still in the pipeline, it has never proposed safety application of GM crops to foreign supervision department regarding the GM crops to be produced, which makes the exporter of rice and other related processed products of special concern. The practice of only applying safety license domestically instead of to the importing country will bring in unauthorized GM product among the exports, which is highly possible to cause the issue of low level presence (LLP) of GM product and trade disputes or suspension.

China is one of the most important importing countries of GM crops in the world. It is becoming the biggest importing country of GM soybean and increasingly also that of GM maize in the past five years. However, the biosafety regulations of China's agricultural imports require that GM products should

apply for import safety approval only after the approval of the exporting country, which leads to remarkable asynchrony in examination and approval of GM products. Meanwhile, the zero threshold LLP standard adopted by China for the imported GM products that have not gotten safety license makes the agricultural merchants and international biotechnology R&D companies exporting to China worry a lot about the consequent trade risks.

Data and Methodology

This study aims to analyze the pattern and dynamics of adopting GM technology by Chinese smallholders in cotton production. We further identify the uptake pathway of GM technology among a selected segment of Chinese cotton smallholders. To meet the specific objectives, we conducted descriptive statistics from the national cotton production data and dataset recorded on the random selected samples and organized focus group discussions within the selected sampled villages.

Sampling strategy and instruments for *China national cotton survey*

The sampling strategy is subject to cotton area, the commercial release of Bt cotton and its varieties patented by company or institutes. First, we chose four provinces including Hebei, Shandong, Anhui, and Henan provinces located in Huang-Huai-Hai cotton production zone (Figure 3.1). The commercialization of Bt cotton in all of the four provinces were either in 1997 or in 1999 when Bt cotton was first released in China (Table 2.1).

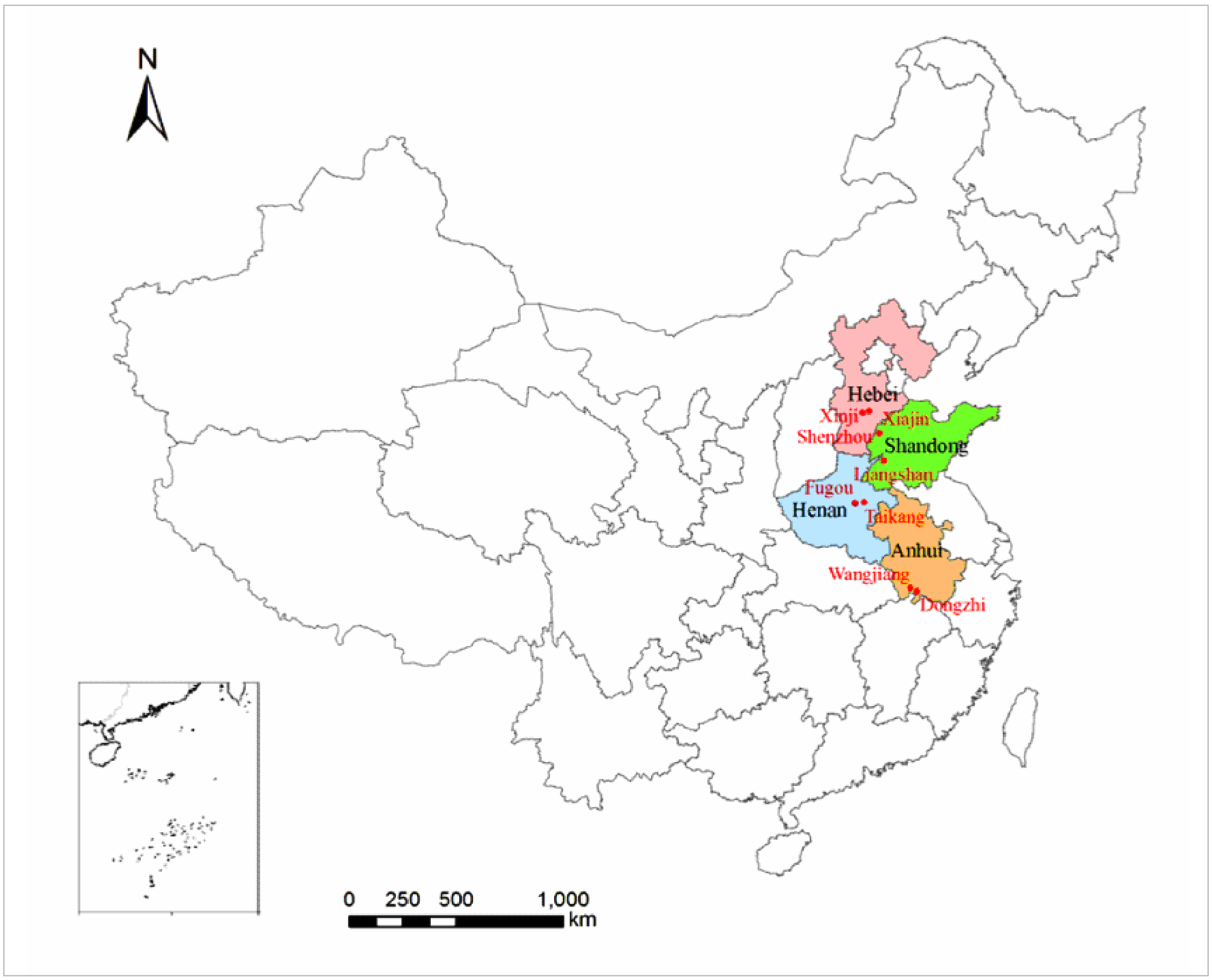


Figure 3.1 Map of survey sites

In 1998 two varieties of Bt cotton from two sources of Bt genes were available to smallholders in three sampled provinces (Table 1.1): one variety diffused by CAAS could be accessed in Anhui and Shandong provinces; simultaneously, the other variety (NC33B) integrating the Monsanto *Cry1Ac* gene was approved for commercialization only in Hebei province. One year later, smallholders in Henan province were able to access three varieties (GK12, GK95-1and sGK321) developed by CAAS. In 2000, Monsanto company also successfully commercialized their varieties including PM1560BG, NC32B and DP410B in Anhui and NC33B in Shandong following the first release of NC33B in Hebei province. Compared to other cotton production regions, more varieties have been offered to smallholders in the sampled province with improved adaptation to local agronomic condition and better traits against bollworm (MOA, 2007).

Secondly, in each province, two counties were chosen because of different varieties of Bt cotton and cotton area. In a common annual two-crop rotation, cotton is harvested in autumn. This suggests some regions where some risks like early frost exist, hence, the smallholders are less likely to produce cotton. Thirdly, we randomly selected four villages in each of the county. Finally, in a village, we relied on the household roster to randomly select 20 cotton smallholders.

Before introducing the procedure of organizing focus group discussion, we would present more details about our unique dataset. We conducted the survey in the sampled counties of Hebei and Shandong provinces as early as 1999 (Table 2.1). In 2000, the second wave of this survey includes the samples in Henan after one year of the official commercial release of Bt cotton. In 2001, the third wave of this survey expanded the survey sites to include some counties in Anhui province. In the years 2004, 2006, 2007 and 2012, we revisited the sampled farmers. Among the waves of the survey we tried to revisit the same households. This facilitates us to set up an unbalanced household-level panel data. Henceforth, we call this dataset the China National Cotton Survey. To identify the factors correlated with the adoption of Bt cotton, we analyzed the production between Bt cotton and non-Bt cotton production dated back to the period when Bt cotton was not completely adopted by farmers. We also present the descriptive statistics of household's and farm's characteristics that influence the adoption decision of smallholders on Bt cotton.

Table 2.1 The survey sites used for this study, 2012

Province	County	1999	2001	2004	2012
Hebei	Xinji	1	1	1	1
	Shenzhou	1		1	1
Shandong	Xiajin	1	1	1	1
	Liangshan	1	1	1	1
Henan	Fugou		1	1	1
	Taikang		1	1	1
Anhui	Dontgzhi		1	1	1
	Wangjiang		1	1	1

During the survey process, we also interviewed the village cadres. Village cadres recollected the data on cultivated area and its cultivation pattern with the special attention to cotton area and Bt cotton area in the past five years. This facilitated the presentation regarding the trend of adoption of Bt cotton from the year of initial commercial release.

We made great effort to ensure the quality of the datasets. The data collection effort involved students and staff from the Center for Chinese Agricultural Policy, Chinese Academy of Sciences and a group of master's students from agricultural universities. All of the enumerators were trained together and conducted some rounds of the pretests to ensure the understanding of the survey form before every wave of the survey. During each of the wave, households were paid 20-50 yuan and given a gift compensated for the time that they spent with the survey team. The enumerators interviewed either the household head or the respondents who understood the cotton production within a household and recorded their answers in the protocols.

The project team gathered detailed information on a wide number of variables covering cotton production activities. In particular, there were several blocks of the survey that focused on recording information by variety and by plots: the adoption of Bt cotton, yield, inputs with special attention to pesticide because the traits of Bt cotton is to reduce the use of pesticide targeted to bollworm. Furthermore, we also designed a block of questions to better understand the knowledge of GM technology. Finally, there was a section of the survey form that collected data on demographic characteristics. Data were collected on characteristics including gender, age and educational attainment and training. Since the surveys were conducted right after the commercial release of Bt cotton in certain provinces, we could identify who had been cultivating Bt cotton; if they cultivate Bt cotton, and the share of Bt cotton area to total cotton area.

Answers were sought to the following questions:

- What are the important factors that facilitate or constrain the diffusion of GM technology?
- What are the impacts of GM technology on yield, inputs, and smallholders' welfare?

Instruments and procedure for focus group discussion

To generate the Innovation Tree pathway, we organized one focus group discussion in one village of each county. Innovation tree is a participatory rural appraisal (PRA) tool by Van Mele and Zakaria (2002). This methodology is well accepted in academics as "a useful tool to distinguish between different types of innovators, but also to better understand the psychological and social dimensions underpinning the decision-making process, which would be difficult to disclose in other ways". During the survey process in 2012, we conducted eight focus group discussions to complement the *China National Cotton Survey*. Figure 3.2a-3.2b are the pictures taken during the Innovation Tree exercise.

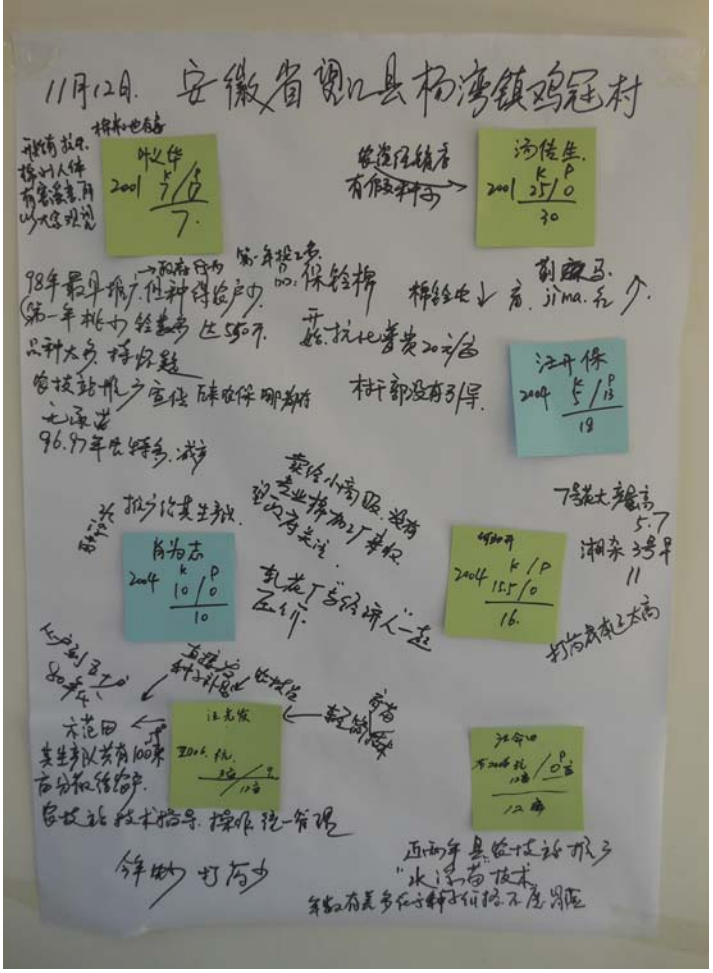


Figure 3.2a The innovation tree exercise

To identify the respondents in the focus group study, we interviewed the village cadres and the technicians at the township.

The focus group consisted of the technician in the village, village cadres, the smallholders who adopted Bt cotton first in the village, fellow smallholders, and the smallholders who sell pesticide and chemical fertilizer in the village. The procedure of the focus group study is as follows:

1. All of the respondents were gathered in a specific place;
2. The leader of survey team explained the research protocols and the purpose of this group discussion;
3. Respondents were given one piece of colored paper to record personal characteristics;
4. Smallholders and fellow smallholders were asked about adoption of Bt cotton including: the starting year, the area of Bt cotton and non Bt cotton at the first year of adopting Bt cotton, the seed varieties and its source as well as the availability, the inputs and output, and the marketing scheme;
5. Questions about the barriers and driving forces to expand GM technology within the village were designed for village leaders and technicians;
6. Dialogues were organized to figure out the impacts of GM technology in cotton production and smallholder's welfare; and
7. Smallholders' perspectives on GM technology were asked.

The questions for the FGDs are presented in Appendix A.

Figure 3.2b Focus group discussion

Adoption of Bt Cotton and its Impacts in China

The evolution of cotton production and adoption of Bt cotton in China

With a long history of cultivating cotton in China, the commercial release of Bt cotton is due to the traits adapted to the local agronomic and pest conditions. After the introduction of household responsibility system, the trend of cotton area shows that cotton production reached historical records once in 1984 and 1992. Yield increased from 550 kg/ha in 1980 to 880 kg/ha in 1991 with an average yearly growth rate of 4.8% even though there is some fluctuation of the yield in the latter part of 1980s (Figure 4.1). Some researchers attributed the growth of cotton production to the institutional reform and the introduction of hybrid varieties (Huang and Rozelle, 1996; Fok and Xu, 2011). However, with the continuous infestation of pests especially cotton bollworm since 1992, cotton production stagnated (Figure 4.1-4.2). Before the introduction of Bt cotton in 1998, cotton production shrank to 3,726 thousand ha, which was around half of the historical record.

Cotton production recovery paralleled with the commercial release of Bt cotton. Even though at the initial stage of offering Bt cotton mainly in Huang-Huai-Hai cotton production zone, cotton area increased from more than 35% to 5,110 thousand ha from 1998 to 2003 (Figure 4.1). After the further expansion of Bt cotton to Yangtze river cotton area, the area was more than 5,500 thousand ha in 2006-2008. However, cotton area decreased to less than 5000 thousand ha recently. Our field observation suggests that this reduction of cotton production is that smallholders tend to save labor inputs in organizing agricultural production given the increased opportunity cost of farming. Compared to other cereals in China, cotton is a labor-intensive crop. The trend of cotton yield kept increasing even though there appeared a sudden drop in 2003 (Figure 4.1). Yield reached the summit in history at more than 1300 kg/ha in 2006.

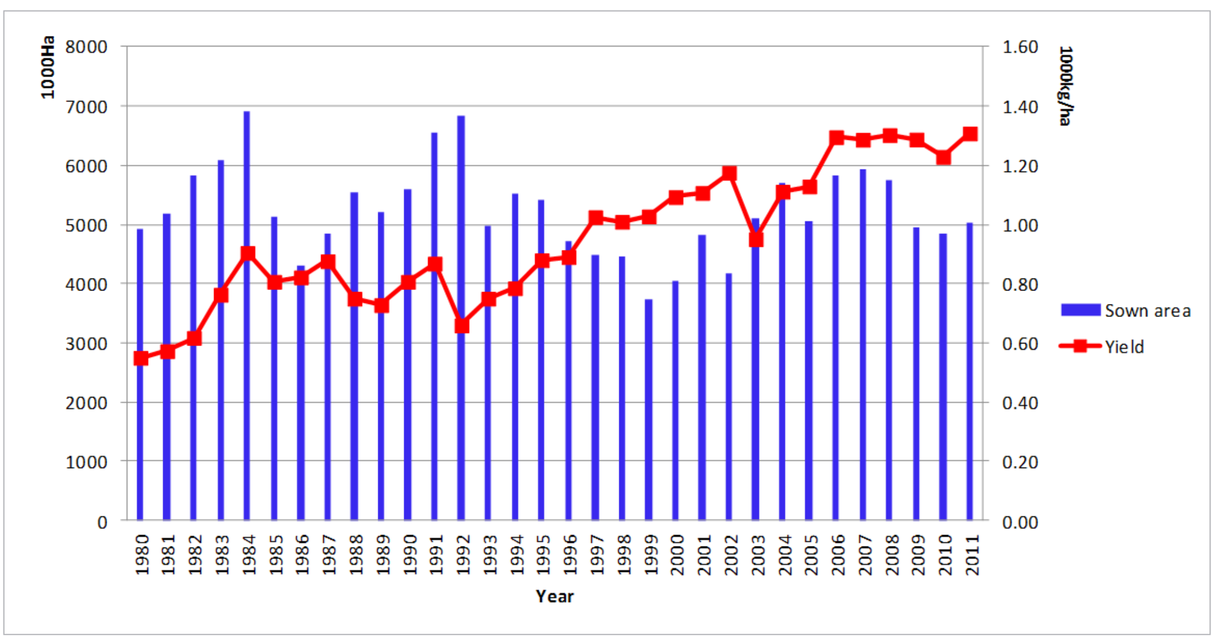
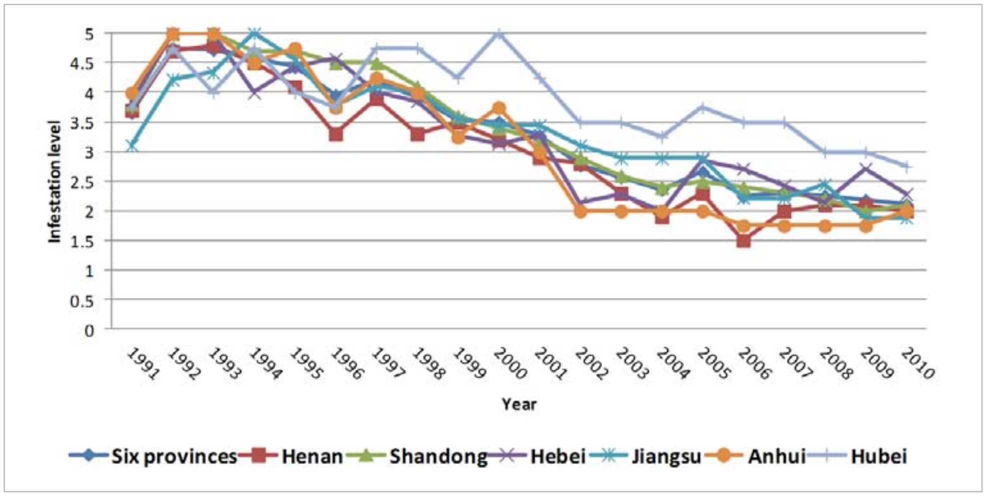
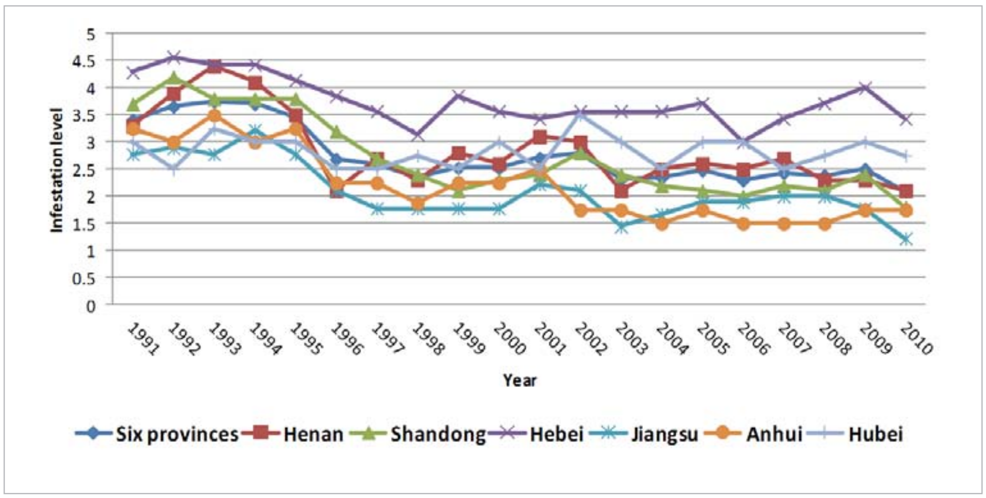


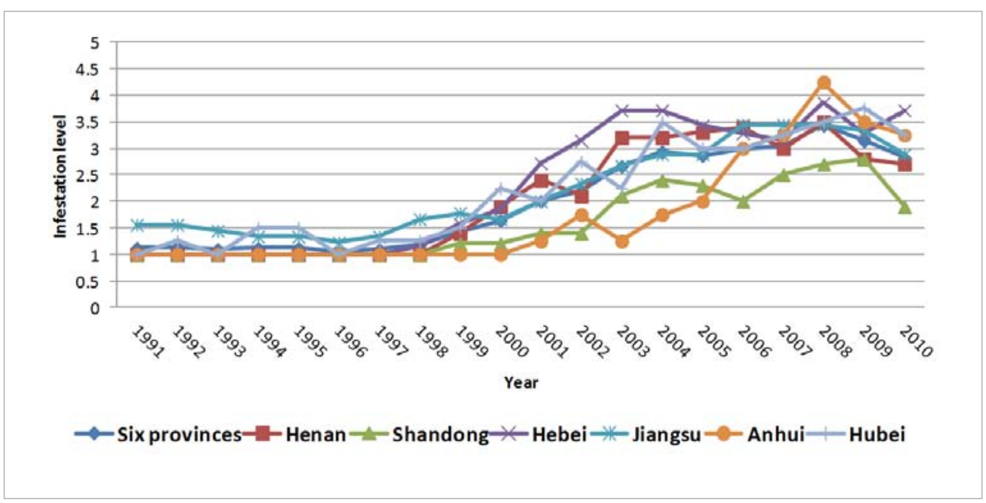
Figure 4.1 Cotton area and yield in 1980-2011
Source: Chinese Agricultural Statistics Yearbook (various issues)



Panel A Infestation level of cotton bollworm



Panel B Infestation level of cotton aphid



Panel C Infestation level of cotton mirids

Figure 4.2 The infestation of bollworm, cotton aphid and cotton mirids, 1991-2010
Source: Chinese Agricultural Sciences (2011)

Figure 4.3 indicates that the expansion of cotton area is driven by the rapid adoption of Bt cotton in China (Pray et al., 2002). Since Bt cotton was introduced in the market, the area of Bt cotton has increased more than 12 times from 260 thousand ha in 1998 to 3831 thousand ha in 2008. Here, the adoption rate is defined as Bt cotton area to total cotton area. The adoption rate indicated that until 2008 around two-thirds of cotton area was Bt cotton with improved traits adapted to local production conditions.

Decomposing the adoption rate at provincial level also presents three important characteristics (Figure 4.4). First, there exists the regional variation of adoption. In 1997, the share of Bt cotton in Huang-Huai-Hai cotton production zone was only 5% and none in Yangtze river and Xijiang zones. One year later, the share of adopted area increased to 42.9% in Huang-Huai-Hai zone and 2.6% in Yangtze river zone (Huang et al., 2010). Even though Bt cotton has been commercialized in Xinjiang since 1999, the adoption rate there was still low at 13% due to the less pest pressure in 2008. The adoption of Bt cotton mainly happened in Huang-Huai-Hai and Yangtze river cotton production.

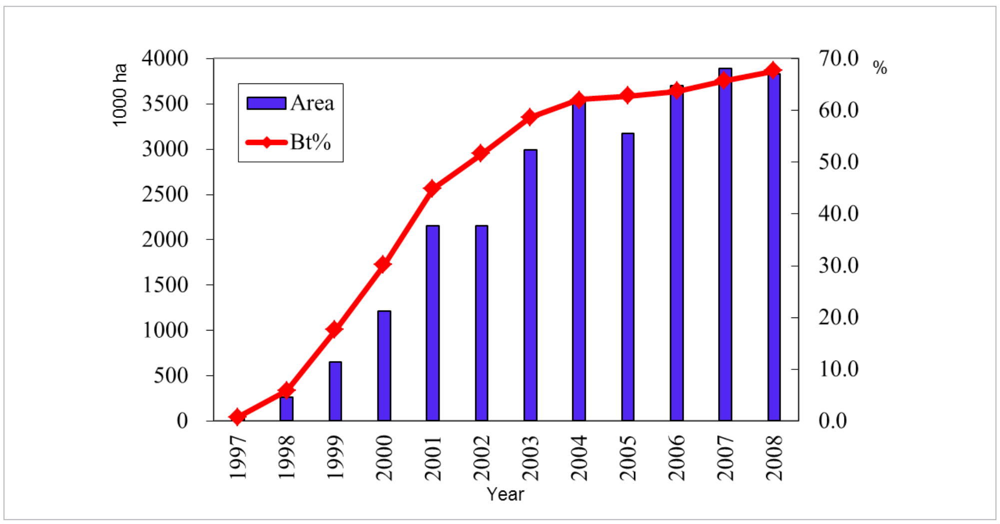


Figure 4.3 The trend of Bt cotton areas and the adoption rate of Bt cotton in China, 1997-2008
Source: Huang et al (2010)

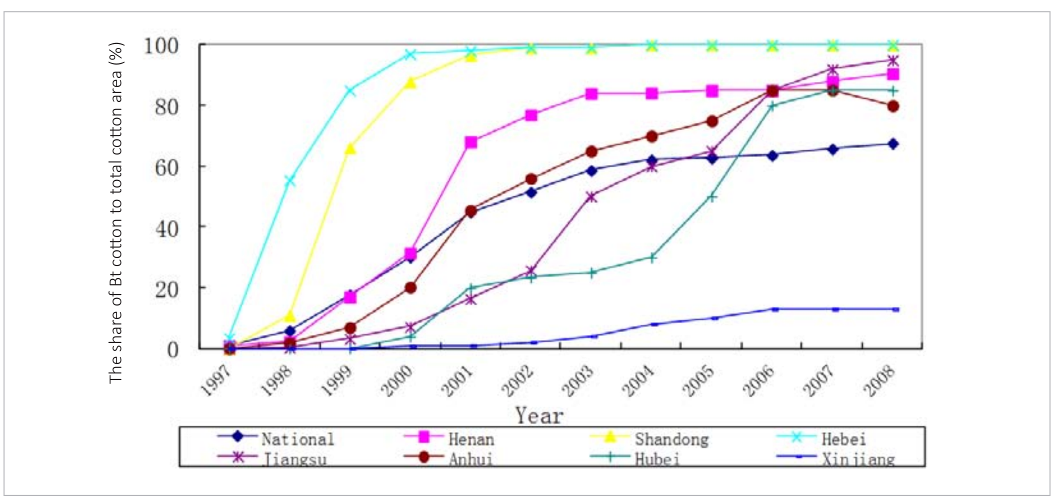


Figure 4.4 The adoption rate of Bt cotton by provinces, 1997-2008
Source: Huang et al (2010)

Secondly, the heterogeneity of regional adoption rate could only be partially explained by the rate of commercial release. Even though five provinces were allowed to cultivate Bt cotton at the same time, the adoption rate in Hebei and Shangdong provinces was faster than those in other provinces. Until 2000, the percentage of Bt cotton area to total cotton area was only 20% and less than 5% in Anhui and Hubei province. The commercial release of Bt cotton in Henan was one year behind that in the first region, however, adoption grows at a faster rate than the average adoption rate at national level. The almost complete adoption of Bt cotton also happened in Hebei and Shangdong provinces dated back to 2003.

Thirdly, combined with Figure 4.2 (Panel A) and Figure 4.4, there appeared the inverse correlation of adoption and the infestation level of cotton bollworm after the commercial release of Bt cotton in China – the higher the infestation level of cotton bollworm, the faster adoption of Bt cotton, and vice versa. That is true across provinces. However, the adoption of Bt cotton is not correlated with the infestation levels of cotton aphid and cotton mirids (Figure 4.2 Panel B and C, Figure 4.4).

Given the nature of Bt cotton adoption in China, those interested in the diffusion of technology, including those engaged in the debate about biotechnology should be interested in obtaining the answers to the following questions:

- Who are the leading farmers who adopted biotechnology and their roles in the diffusion?
- What are the important factors that facilitate or constrain the adoption of Bt cotton?
- What are the roles of different stakeholders in the uptake process of Bt cotton?

Findings from national cotton survey in China

Socio-demographic profile

Whether and to what extent the households adopt new technology including biotechnology is correlated by the social characteristics, demographic composition and working experiences. Table 3.1 presents the social-demographic profile of the household head and farm size tabulated with the adoption decision on Bt cotton at the early stage of commercial release of Bt cotton in China.

Age

The age of household head ranged from 22 to 68 years old in 1999. The mean age was 44 years old. Around 40% of household heads were in the 41-50 age range in all four provinces. However, the age of household heads was distributed heterogeneously for the rest of the three age levels (30 and below, 31-40 and 50 and above) across four provinces. For example, more than one-third of the heads belongs to 31-40 age level in Hebei while less than a quarter of counterpart in Anhui province. The percentage of the heads over 50 years old in Anhui doubled those in Hebei province. This suggests that the heads were younger in Hebei province than those in Anhui province. However, all farmers adopted Bt cotton across the provinces, suggesting that age levels are not correlated with the uptake pathway of Bt cotton.

Table 3.1 The characteristics of household head, family and farm by province at the early stage of commercial release of Bt cotton in 1999

	Hebei	Shandong				Henan			Anhui		
	Bt (n=99)	Total (n=183)	Bt (n=161)	Non-Bt (n=3)	Bt&Non-Bt (n=19)	Total (n=80)	Bt&Non-Bt (n=28)	Non-Bt (n=52)	Total (n=121)	Bt&Non-Bt (n=22)	Non-Bt (n=99)
Age											
30 and below	8.16%	7.65%	8.07%	0	5.26%	16.25%	14.28%	17.31%	5.79%	9.09%	5.05%
31-40	34.69%	28.96%	30.43%	0	21.05%	28.75%	32.14%	26.92%	23.14%	27.27%	22.22%
41-50	41.84%	39.34%	37.88%	33.33%	52.63%	38.75%	39.29%	38.46%	41.32%	54.55%	38.38%
50 and above	15.31%	24.04%	23.60%	66.67%	21.05%	16.25%	14.29%	17.31%	29.75%	9.09%	34.34%
Gender											
(1=male, 0=female)	0.94	0.95	0.94	1.0	1.0	0.96	1.0	0.94	1.0	1.0	1.0
Education attainment											
(year)	8.55	6.91	6.95	5.33	6.79	7.4	7.11	7.58	6.31	6.0	6.37
Attending training program on Bt cotton											
(1=yes, 0=no)	0.46	0.30	0.30	0	0.37	0.24	0.32	0.19	0.12	0.50	0.03
Cadre											
(1= yes, 0=no)	0.06	0.09	0.09	0	0.16	0.10	0.14	0.08	0.14	0.32	0.10
Employment											
Mainly farming (1=yes, 0=otherwise)	0.91	0.89	0.88	1.0	1.0	0.95	0.96	0.94	0.94	0.95	0.94
Family size (person)	4.0	4.0	3.97	4.33	4.16	4.5	4.53	4.48	4.41	4.68	4.35
Farm size (ha)	0.98	0.62	0.59	0.78	0.87	0.65	0.68	0.62	0.47	0.55	0.46
Cotton area (ha)	0.45	0.37	0.34	0.58	0.60	0.61	0.65	0.58	0.30	0.17	0.33

Gender

The latest study suggests feminization in Chinese agricultural production (de Brauw et al., 2013). The observation in the survey also suggests that field work of both Bt cotton and non-Bt cotton were mainly conducted by women as men engaged in off-farm job more than women. The evidences from FGDs indicate that reducing pesticide use and saving labor due to Bt cotton adoption benefited women.

The descriptive statistics indicate that the households who produce cotton including Bt cotton were dominated by the male head. Almost all of the household heads in our sample were male whether Bt cotton adopter or non-Bt cotton farmer. This trend is true across all the four provinces.

Education attainment

On average, the educational attainment of the head is between 6 to 9 years. This indicates that household head only finished elementary or secondary schooling. Education attainment of the head varied significantly across provinces. The average years of schooling of the heads in Hebei was 2 years more than that in Anhui province. Furthermore, majority of the heads in Shandong, Henan and Anhui provinces did not finish secondary schooling. Within a province, there was no statistical difference between Bt cotton adopters and their counterpart.

Attending training program on Bt cotton

The percentage of family heads who attended a training program on Bt cotton varied significantly across provinces. In Hebei, among all of the Bt cotton adopters, 46% of the heads attended the training program on Bt cotton. However, in Shandong province, less than one-third of the heads learned Bt cotton from the seminar or workshops organized either by technicians or seed companies. In Henan province, one quarter of the heads attend the training program while the percentage decreased to only 12% in Anhui province.

Our results also suggest that those who attended the training program have higher probability of adopting Bt cotton. In Shandong province, all of the heads who learned about Bt cotton during the seminar completely or partially adopted Bt cotton calculated by Bt cotton area to total cotton area. However, in Henan province, even though the percentage of Bt cotton adopter who also attended the program was 13 percent more than those who did not adopt Bt cotton, it was clear that some family heads did not adopt Bt cotton after attending the training program. Based on these evidences, we recommend that the training program should be improved to meet the farmers' demand of a new technology. Furthermore, in order to convince the farmers to adopt new technology, the training program should be combined with technology extension portfolios such as visiting the demo field and experience sharing with fellow farmers.

Cadre

The records from FGDs indicated that village cadres play important roles in the diffusion of Bt cotton. For example, without the coordination and help from the village cadres, it is hard for technicians or seed companies to organize the training program or the visit to demo fields. Furthermore, to breed the seed for seed companies, village cadre also convinced the farmers to consolidate plots from farmers. Our descriptive statistics was consistent with these evidences that the head who was a cadre was more likely to adopt Bt cotton. Our results indicate that on average, there were more than half of the village cadres, as leading farmers adopted Bt cotton across four provinces.

Employment

China's rural economy showed signs of transformation beginning in the 1980s and 1990s. During this period, rural laborers have more opportunities to fully or partially work off the farm. To identify the diversity of time allocation in income-generating activities, we ask whether the head spend more than 50% of working time on farm. If the answer is yes, the head was classified as mainly working on the farm. The results indicated that around 90% of the heads were mainly working on the farm. It was consistent across provinces. There is no statistical difference of time allocation by the head between Bt cotton adopter and the counterpart.

Family Size

The family size ranged from 1 to 7, with an average of 4. However, our results showed that on average, the family size in Anhui and Henan provinces was a bit larger than those in Hebei and Shandong provinces. According to the official statistics (CNBS, 2000), the average rural family size decreased from 5.37 persons in 1984 to 4.25 persons in 1999. This also suggests that compared with the typical farming households in China, the cotton farmers have almost same family size even though cotton is a labor-intensive crop.

Farm size

All farmers in Huang-Huai-Hai region were smallholders with average cultivated land area of 0.66 ha, which is 0.06 ha larger than the average farm size in China in 2012. The average farm size varied significantly across provinces. In Shandong and Henan provinces, the farm size was consistent with those at the national level. However, the average farm size in Hebei doubled that in Anhui province.

The land/capita ratio, calculated by the farm size divided by family size explicitly presents the heterogeneous land endowment across provinces. Farmers in Hebei province have more land resource than the counterpart in the rest of the three provinces. In the aspect of specialization of cotton production, the share of cotton area to total farm size in Henan and Anhui province was larger than those in Hebei and Shandong provinces. This suggests that cotton farmers in Hebei and Shandong province also diversified their production.

Adopting Bt cotton

Our results are consistent with the results obtained from national statistics in 4.1. Table 3.2 presents the trend of cotton production and the adoption of Bt cotton measured by the share of Bt cotton area to cotton area from 1997 to 2012.

We found that the diffusion and adoption of Bt cotton has the following characteristics: first, there is regional difference on the growth rate of adopting of Bt cotton across provinces and within a province. Bt cotton was commercialized at the same year of 1997 in Hebei, Shandong, and Anhui. However, the impressive adoption only appeared in Hebei province whereas it is surprising that in Anhui, none of the adoption occurred in both of the counties. Meanwhile, in one of the counties in Shandong, Bt cotton was cultivated in around one third of the cotton area; but the adoption rate was zero in the other counties. Furthermore, rate of adoption was greater right after the initial commercial release in Hebei province with almost 100% of farmer adoption. It also increased rapidly in other provinces but the growth rate of adoption is much lower. In two counties (one in Anhui and the other in Henan provinces), until 2004, the adoption rate reached above 90%. In Taikang county, Henan, the adoption rate varied between 80% and 95% in the early 2000s. The recent reduction of cotton production in China was due to the increased opportunity cost of labor in cotton, even though Bt cotton is still labor-intensive compared to maize.

Secondly, the diffusion of Bt cotton helped re-launch cotton production in five of the sampled counties. The multiple growth of cotton area in Shenzhou, Hebei is mainly driven by the availability of Bt cotton in the market. Cotton area increased more than 10% in four counties after the adoption of Bt cotton. In one of the counties located in Henan after the commercialization of Bt cotton, the percentage of cotton area to total sown area also increased at around 10%. In contrary, in the two other counties, the cotton area is stable over time despite the growth of Bt cotton area. Thirdly, the variation of diffusion is correlated with the national commercial release portfolio at spatial and temporal dimensions. For those in the first region, the adoption rate with more than 50% in Hebei was higher than those in Shandong and Anhui provinces. The rapid expansion of Bt cotton in Henan was from 1999 with more than half of cotton area planted to Bt cotton.

Finally, Monsanto company is very successful in diffusing its varieties in Hebei province with its better marketing strategy. As documented in the biosafety regulatory report, Monsanto's variety was only allowed to be sold in Hebei province until 1999. In two of the counties representing other cotton areas in Hebei province, 100% of cotton areas were planted to Bt cotton in 1999. This conclusion is consistent with the study by Fox and Xu (2011) who analyzed the endogenous relationship between the adoption of Bt cotton and the development of variety market.

Table 3.2 Trend of cotton production area and Bt cotton adoption by county, 1997-2012

			Year															
Province	**County**	**Percentage (%)**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Hebei	Xinji	Cotton[a]	29	29	38	38	37	38	39	39	34	35	47	40	35	30	25	20
		Bt cotton[b]	54	96	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	Shenzhou	Cotton	8	17	25	45	47	47	47	69	32	32	28	24	16	8	7	5
		Bt cotton	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Shandong	Xiajin	Cotton	50	54	57	63	66	64	62	75	69	75	87	86	83	64	64	51
		Bt cotton	0	53	93	100	100	100	100	100	100	100	100	100	100	100	100	100
	Liangshan	Cotton	35	44	53	52	53	54	53	54	54	54	33	28	23	19	18	24
		Bt cotton	37	77	80	87	92	100	100	100	100	100	100	100	100	100	100	100
Henan	Fugou	Cotton	49	50	50	49	50	47	46	46	46	36	33	31	28	24	21	16
		Bt cotton	0	12	58	93	91	80	81	85	93	92	91	91	100	100	100	100
	Taikang	Cotton	50	50	36	42	46	44	37	29	23	22	9.6	3.3	1.3	1.3	1.4	1.6
		Bt cotton	0	4	51	65	76	81	88	93	97	96	90	90	100	100	100	100
Anhui	Dongzhi	Cotton	31	31	37	40	45	44	46	42	42	40	56	51	53	49	48	49
		Bt cotton	0	38	52	94	98	99	100	100	100	100	100	100	100	100	100	100
	Wangjiang	Cotton	38	38	38	38	37	37	37	37	42	43	35	35	35	35	35	35
		Bt cotton	0	0	1	6	71	70	83	95	98	97	100	100	100	100	100	100

Source: Authors' own surveys.

Notes: [a] here is the percentage of cotton area to total sown area at village level;
[b.] here is the percentage of Bt cotton area to cotton area at village level.

Revenue and cost analysis: Bt cotton and Non-Bt cotton

To conduct the revenue and cost analysis, we use the plot-level data on Bt cotton production when the adoption rate of Bt cotton was above 85% across all of the sampled counties in 2004 (Table 3.3). The unit of this analysis is US$/ha.

Our results indicate that farmers benefit from Bt cotton production under the revenue and cost analysis. On average, the net revenue for Bt cotton in a unit of land is US$667/ha. There is also regional difference of net revenue. Farmers in Anhui province earn more than US$380/ha than counterpart in Shandong province. Total cost of Bt cotton was US$1300.90/ha. We tracked the composition of the cost based on the expense on seed, pesticide, labor cost, chemical fertilizer, manure and other expenses. It was well-known that the price of Bt cotton seed was higher than that of hybrid cotton because of its proved Bt trait. During the FGD, the farmers told us that seed cost of Bt cotton was around four times higher than that of non-Bt cotton. However, greater expense on Bt cotton seed was compensated by less expense on other physical inputs. Labor cost was one of the major components in Bt cotton production. The average cost of chemical fertilizer is around US$215/ha. The expense of chemical fertilizer and pesticide outweighs the cost of seed. It should be noted that there is no statistical difference of marketing between Bt cotton and non-Bt cotton. Our results show that price of Bt-cotton and non-Bt cotton has been the same locally since the availability of Bt cotton in market. Farmers have never met any barrier in selling Bt cotton to the dealers.

Table 3.3 Revenue and cost (US$/Ha) in Bt cotton production by plot across provinces, 2004

	Total	Shandong	Hebei	Henan	Anhui
Net revenue	667.3	474.8	634.0	657.4	860.3
Total Cost	1300.9	1038.0	1230.0	1313.2	2009.6
- Seed	50.2	49.6	42.6	46.3	87.0
- Pesticide	78.3	45.5	106.0	75.4	94.4
- Labor cost	752.7	615.7	582.5	822.1	1189.6
- Chemical fertilizer	214.8	174.7	229.7	181.6	407.0
- Manure	16.3	6.0	22.3	20.1	8.2
- Others	188.6	146.5	246.9	167.7	223.4
No. of Plots	590	111	125	211	143

Yield, pesticide usage and other inputs: Bt cotton and Non-Bt cotton

To better understand Bt cotton traits, we conducted the cross comparison of the inputs and output between Bt cotton and non-Bt cotton production. Obviously, it is only possible to find non-Bt cotton plots to conduct the analysis before the complete adoption of Bt cotton. Table 3.4 presents the distribution of Bt cotton and non-Bt cotton plots by province during the early stage of the commercial release of Bt cotton (1999-2001). After the initial commercial release of Bt cotton in Hebei in 1997, all cotton producers adopted Bt cotton on all of their plots. This has been duplicated in Shandong province from 2000 onwards. Until 2001, in Henan and Anhui provinces non-Bt cotton was planted on around one third of plots.

Table 3.5 presents the yield and physical inputs including chemical fertilizer and labor in cotton production. Overall, the yield of Bt cotton is around 330 kg/ha more than that of non-Bt cotton. There is no exception in Henan and Anhui provinces where there exist Bt-cotton and non-Bt cotton production. However, the yield of Bt cotton also varies significantly across provinces. The average yield in Shandong province was 3842 kg/ha and 2811 kg/ha in Henan province. Similarly, the average yield of non-Bt cotton differed significantly between Henan and Anhui provinces.

We also compared the inputs including labor and chemical fertilizer between Bt cotton and non-Bt cotton production. After adopting

Table 3.4 The distribution of Bt cotton and Non-Bt cotton plots by provinces, 1999-2001

Year	Province	Total plots	Bt cotton plots	Non-Bt cotton plots
1999	Total	310	279	31
	Hebei	124	124	0
	Shandong	186	155	31
2000	Total	486	382	104
	Hebei	120	120	0
	Shandong	180	180	0
	Henan	186	82	104
2001	Total	526	435	91
	Hebei	91	91	0
	Shandong	114	114	0
	Henan	158	116	42
	Anhui	163	114	49

Table 3.5 Yield and other inputs between Bt cotton and non-Bt cotton production across provinces

	Total		Hebei	Shandong	Henan		Anhui	
	Bt	Non-Bt	Bt	Bt	Bt	Non-Bt	Bt	Non-Bt
Yield (kg/ha)	3376	3003	3510	3842	2811	2634	3380	3150
Labor (day/ha)	504	618	440	410	445	477	653	674
Labor on spraying pesticide (day/ha)	41	79	28	33	21	43	74	93
Chemical fertilizer (kg/ha)	1163	1301	1565	684	770	668	1650	1554

Bt cotton, labor input was reduced significantly with the evidence that the average labor input in Bt cotton production was 100 days/ha less than that in non-Bt cotton production. The reduction of labor inputs is marginally driven by the reduction of labor input in spraying pesticide. Initially, with the reduced frequency of spraying pesticide (more details in Table 3.5), the labor input was reduced accordingly. The average labor input among Hebei, Shandong and Henan provinces were 410-450 days/ha, however, smallholders in Anhui spent much more time in both Bt cotton and non-Bt cotton production.

Overall, the difference of chemical fertilizer use was not statistically significant between Bt cotton and non-Bt cotton production. However, the use of chemical fertilizer presents the regional variation.

Compared to non-Bt cotton, one of the main traits of Bt cotton is to reduce the pesticide use in production. Pesticide input is measured in the quantity of pesticide input (kg/ha) and the frequency of spraying pesticide (number) in cotton production. The results by counties between Bt cotton and Non-Bt cotton plots are presented in Table 3.6.

On average, the pesticide usage on Bt cotton plot is much less than those used on non-Bt cotton. The difference of pesticide usage between Bt and non-Bt cotton is statistically significant across counties. The frequency of spraying pesticide on non-Bt cotton is three times more than that on Bt cotton plot. Even though the frequency of spraying pesticide slightly increased from 1999 to 2001, the farmers who adopted Bt cotton sprayed less pesticide than those who did not adopt. However, it deserves further analysis as to why the pesticide usage on Bt-cotton plots increased.

Table 3.6 The usage of pesticide and the frequency of spraying pesticide between Bt-cotton and non-Bt cotton production by province, 1999-2001

		The quantity of pesticide input (kg/ha)			The frequency of spraying pesticide (no.)		
		1999	2000	2001	1999	2000	2001
Bt-cotton plots							
Total		11.5	20.8	24.1	6.8	10.3	12.6
Hebei	Xinji	5.7	21.5	16.7	4.6	11.2	11.6
	Shenzhou	5.6	5.7	-	3.9	4.6	-
Shandong	Xiajin	17.2	33.4	-	8.6	14.5	-
	Liangshan	15.4	20.9	19.0	8.9	10.3	10.7
Henan	Fugou	9.5	11.7	13.8	6.0	6.9	9.9
	Taikang	18.1	24.0	13.3	8.5	11.5	10.2
Anhui	Dontgzhi	-	-	46.5	-	-	16.9
	Wangjiang	-	-	45.0	-	-	19.2
Non-Bt cotton plots							
Total		77.5	47.3	64.1	25.9	21.3	21.2
Hebei	Xinji	-	-	-	-	-	-
	Shenzhou	-	-	-	-	-	-
Shandong	Xiajin	77.5	-	-	25.9	-	-
	Liangshan	-	-	-	-	-	-
Henan	Fugou	56.5	52.7	35.2	23.7	23.6	15.3
	Taikang	54.5	44.7	37.7	24.0	20.1	17.0
Anhui	Dontgzhi	-	-	93.7	-	-	24.0
	Wangjiang	-	-	82.6	-	-	26.8

Uptake pathways of Bt cotton: Evidences from China National Cotton survey

Source of Bt cotton information

To explore the source of Bt cotton information, we categorized sources as fellow farmers, technicians, seed suppliers and others including media and village committee (Table 3.7). The results show that farmers obtained Bt cotton information from different sources across provinces. In Hebei and Shandong province, majority of farmers learn about Bt cotton from media or village committee. During the initial commercial release of Bt cotton

in Hebei and Shandong, some of the village committees were convinced by seed companies to start demo field of Bt cotton or breed Bt cotton seed within this village. The adoption of

Bt cotton in Henan and Anhui lagged behind Hebei and Shandong provinces. Around 40% of farmers in Henan and Anhui province learned about Bt cotton from technicians. Furthermore, Bt cotton information was shared among farmers.

Organizations that conducted the training program

Our results indicated that the attendance rate of training program ranged between 12% in Anhui and 46% in Hebei (Table 3.1). The evidences from our field work suggest that farmers benefit from attending the training program or seminar. To extend Bt cotton, the organizations including technology extension bureau, seed companies and village committee conducted the training program to farmers (Table 3.8). In general, a village committee is composed of 5-6 village cadres including village leader and accountant. It is consistent across provinces that majority of farmers attend the training program organized by village

committee. Here, we should clarify that even though the training program was coordinated under the help of the village committee, the lecturers were facilitated with technology extension bureau or seed companies. We also asked the farmers why they did not attend the training program organized by seed companies in Henan and Anhui provinces. Based on the experience of buying hybrid cotton seed, farmers did not believe the good quality of seed advertised by seed companies unless they had visited the demo field or were informed by fellow farmers.

Table 3.7 Source of Bt cotton information (%)

Source	Hebei (n=99)	Shandong (n=183)	Henan (n=80)	Anhui (n=121)
Fellow farmers	5.05	21.11	21.05	51.40
Technicians	1.01	2.78	40.35	38.32
Seed suppliers	12.11	20.00	3.51	0
Others including media and village committee, etc	81.82	56.11	35.09	10.28
Total	**100.0**	**100.0**	**100.0**	**100.0**

Table 3.8 Organizations that conducted training programs on Bt cotton

Organization	Hebei (n=46)	Shandong (n=55)	Henan (n=19)	Anhui (n=14)
Technology extension bureau	13.04	21.82	0	28.57
Seed company	36.96	40.00	10.53	0
Village committee	50.0	38.18	89.47	71.43
Total	**100.0**	**100.0**	**100.0**	**100.0**

From whom farmers who did not attend the training workshop learn how to plant Bt cotton

To keep the demographic characteristics constant, the information and knowledge of biotechnology are of importance in farmer adoption. At the early stage of commercial release of Bt cotton (1999) only three households did not adopt Bt cotton; the rest of the farmers completely or partially adopted Bt cotton in Hebei and Shandong provinces (Table 3.1). However, less than half of farmers (46% in Hebei and 30% in Shandong) attended the training program. How did the rest of farmers who did not attend the training program learn about Bt cotton production?

Even though the traits of Bt cotton differ significantly with those of non-Bt cotton, one third of farmers in Shandong, Henan, and Anhui provinces planted Bt cotton based on their own experiences (Table 3.9). In Hebei province, a quarter of farmers also learnt by trial. The planting experiences shared by fellow farmers and by the seed supplier were of importance for farmers in Hebei and Shandong provinces. In Henan and Anhui, technicians instructed farmers planting Bt cotton in the field. For example, farmers consulted the technicians when they should spray pesticide after the broadcast of potential infestation and how much pesticide should be used.

Table 3.9 From whom farmers who did not attend the training workshop learn how to plant Bt cotton (%)

	Hebei (n=53)	**Shandong** (n=125)	**Henan** (n=59)	**Anhui** (n=40)
Self-learning	20.75	32.80	33.9	32.5
Fellow farmers	16.98	15.20	20.33	30.0
Technicians	11.32	6.40	38.98	25
Seed supplier	20.75	20.80	-	-
Other including village committee	30.19	24.80	6.77	12.5
Total	**100.0**	**100.0**	**100.0**	**100.0**

Source of Bt cotton seed

The adoption of Bt cotton is highly correlated with the availability of Bt cotton seed. Here, the sources of Bt cotton seed were categorized into only reserved seed, cotton processing company, seed company, seed trader and others including village committee (Table 3.10). Unlike the regulation in US, self-reservation of seed is allowed in China. In Shandong, more than a quarter of farmers reserved seed in production. This is not surprising as some farmers in Shandong and Hebei in the FGDs told us that even though they would like to plant Bt cotton, they cannot obtain Bt cotton seed. Seed companies are definitely the most important source of Bt cotton seed to farmers at its initial stage of commercialization. Currently, all farmers are able to access Bt cotton seed from the market without any constraints. The transportation cost of buying seed is also low because there are shops that sell seed and other physical inputs including chemical fertilizer and pesticide, within a village or at the township seat.

Table 3.10 Source of Bt cotton seed

	Hebei (n=99)	Shandong (n=180)	Henan (n=80)	Anhui (n=121)
Only reserved seed	3.03	27.78	0	0
Cotton processing company	17.17	0.56	19.83	0
Seed company	37.37	32.22	59.48	51.54
Trader	1.01	0.56	0	
Other including village committee	41.41	38.89	20.69	48.46
Total	**100**	**100**	**100**	**100**

Benefits from adopting Bt cotton

We used two kinds of answers to explore the benefits from adopting Bt cotton. Given the proved trait of reducing pesticide input, we asked quantitative questions about the frequency of spraying pesticide during the first year of adopting Bt cotton and one year before the adoption of Bt cotton. Furthermore, we also asked several questions on labor input, yield, good quality and cost. These are multiple responses.

Our results in Table 3.11 suggest that farmers benefit significantly from adopting Bt cotton in the following dimensions. Consistent with the existing studies (Huang et al., 2002), the frequency of spraying pesticide has been reduced dramatically. The trend was true in all the four provinces. In Hebei, farmers only sprayed pesticide 4 times while they sprayed pesticide more than 25 times when planting hybrid cotton. Majority of farmers reported that planting Bt cotton uses less labor input, and had higher yield with good quality cotton. One of the important characteristics is the cost reduction in planting Bt cotton, compared to the conventional cotton. Similarly like conventional seed, once the combination of new farming practices and biotechnology has been proven to lower cost and increase yield, the adoption rate is likely to be far quicker.

Table 3.11 Benefits from adopting Bt cotton

	Hebei (n=99)	Shandong (n=180)	Henan (n=80)	Anhui (n=51)
Frequency of spraying pesticide (no)				
- In the year of planting Bt cotton	4.7	7.48	9.4	16.59
- One year before planting Bt cotton	25.78	29.56	21.75	29.35
Less labor input[a] (%)	97.98	97.22	46.25	16.25
Higher yield[a] (%)	90.91	61.67	36.25	39.22
Good quality[a] (%)	-	-	48.75	19.61
Lower cost[a] (%)	87.88	82.22	80.00	83.82

Note: [a] Multiple responses

Uptake pathways of Bt cotton: Evidences from focus group discussion

Introduction of the Innovation Tree

The Innovation Tree is a method that helps visualize and analyze the way in which an innovation like biotechnology is spread over time among community members (Van Mele and Zakaria, 2002; Torres et al., 2012). A FGD organized with a village facilitated us to draw an Innovation Tree to identify the uptake pathway of Bt cotton by Chinese smallholders. Furthermore, the discussions during the FGD provide the evidences on the roles of different stakeholders including village cadres, seed dealers, and the technicians in the diffusion of biotechnology. The perspectives as a biotech smallholder shared by the smallholders in FGD are of important policy implication in promoting the diffusion of biotechnology.

The coordination of *National Cotton Survey* 2012 makes it possible for the same survey subgroup to organize FGDs. To collect the survey data, we visited smallholders twice: the first time was in June and the second in November to record the detailed information on each combination of pesticide targeted to different pests including bollworm, cotton mirids and cotton aphid. We organized one FGD within a county for a total of eight FGDs. Furthermore, the practice of FGDs organized by the same survey sub-group also guaranteed the quality of FGDs.

Following Torres et al. (2012) who studied uptake pathways of biotechnology in the Philippines, the results of the FGDs are explained by using Innovation Tree through flowcharts. Arrows used in the figures were coded as follows:

- Thick black arrows represent the flow of information between and among smallholders in the FGD
- Thin black arrows represent the flow of information from FGD participants to other smallholders not present in the practices but whom the participants convinced to adopt Bt cotton

Actors or players in the innovation tree were also color-coded:

- Black for FGD smallholder-participants
- Red for technicians from company and local technology extension stations
- Blue for the dealers of seeds or other inputs
- Green for the smallholders who did not participate in the FGD but who influenced the smallholder participants to adopt Bt cotton
- Gray for the smallholders who did not participate in the FGD but are influenced by those who adopted Bt cotton
- Dashed square indicate that the smallholders participate in the demo trial within the village

The distribution of the participants in FGDs is presented in Table 4.1. Participants in the FGDs include the smallholders, the village cadres, technicians at village level or from township technology extension stations and seed or input dealers (if any) within a village. If the village is located close to county seat or township, farmers will buy seed there. The study by Huang et al. (2012) suggests that there are no constraints for farmers to access seed in the market. However, even though we witness the expansion of seed markets at all levels, administrative authorities have been facing a storm of criticism on the seed without the traits that have been advertised. Furthermore, in some villages, if the smallholders have questions about production, they have to seek the help of technicians outside the home village as there is no local technician. On average, there are seven participants in FGDs, with about five to 11 participants.

Before presenting the findings from FGDs, we would like to clarify some information in the Innovation Tree. Here, the name of the participants are presented with the surname plus abbreviation of name because all of the participants in the survey and FGDs were informed that all of the information obtained from them is confidential and only for research purpose.

Table 4.1 Distribution of participants in focus group discussions (FGDs) by village, 2012

Province	County	Village	Total (no)	Smallholders (no)	Village cadres (no)	Technicians (no)		Seed or inputs dealers (no)
						Village	Township	
Hebei	Xinji	Daxisi	8	7	0	0	0	1
Hebei	Shenzhou	Dongmuzuo	11	9	1	0	0	1
Shandong	Xiajin	Qianhuo	9	4	4	0	0	1
Shandong	Liangshan	Liuxianzhuang	5	4	0	1	0	0
Henan	Fugou	Gonghe	6	5	0	1	0	0
Henan	Taikang	Qianhe	7	5	1	0	1	0
Anhui	Dongzhi	Longtan	5	4	1	0	0	0
Anhui	Wangjiang	Jiguan	7	4	1	1	0	1
Total			**58**	**42**	**8**	**3**	**1**	**4**

Findings from the Innovation Tree exercises

As supplement to the descriptive statistics, evidences from FGDs to a larger extent explain the variation of adoption and diffusion process of Bt cotton across provinces. To present our findings from FGDs, we categorized the FGDs into two groups: one group is composed of smallholders in a FGD who started to adopt biotechnology within three years after initial commercialization in a province; the rest are the other groups. Thus there are five FGDs in group one and the other three in group two.

Dalisi village, Hebei province

The Innovation Tree exercise is consistent with the adoption rate at village level and obtained from national statistics. Both of the two FGDs in Hebei provinces (Figures 5.1 and 5.2) explicitly show the rapid diffusion of Bt cotton (NC33B) in the villages. All of the smallholders started to cultivate Bt cotton one or two years after Bt cotton was offered in the market.

In 1996, some technicians from a local cotton and fiber factory paid a visit to smallholders and showed them demo fields in other townships. They were instructed on different production aspects many times in a demo field - right after transplanting the cotton crop from the sowing seeds in nutrient blocks in a nursery to the harvest season in November. The participants of the training program were convinced by the better performance of Bt cotton in the field compared to the conventional cotton. Smallholders and village cadres also paid special concern to the impact of Bt cotton on other cereal crops because in Hebei, cotton is rotated with winter wheat and in the same cultivating season of maize.

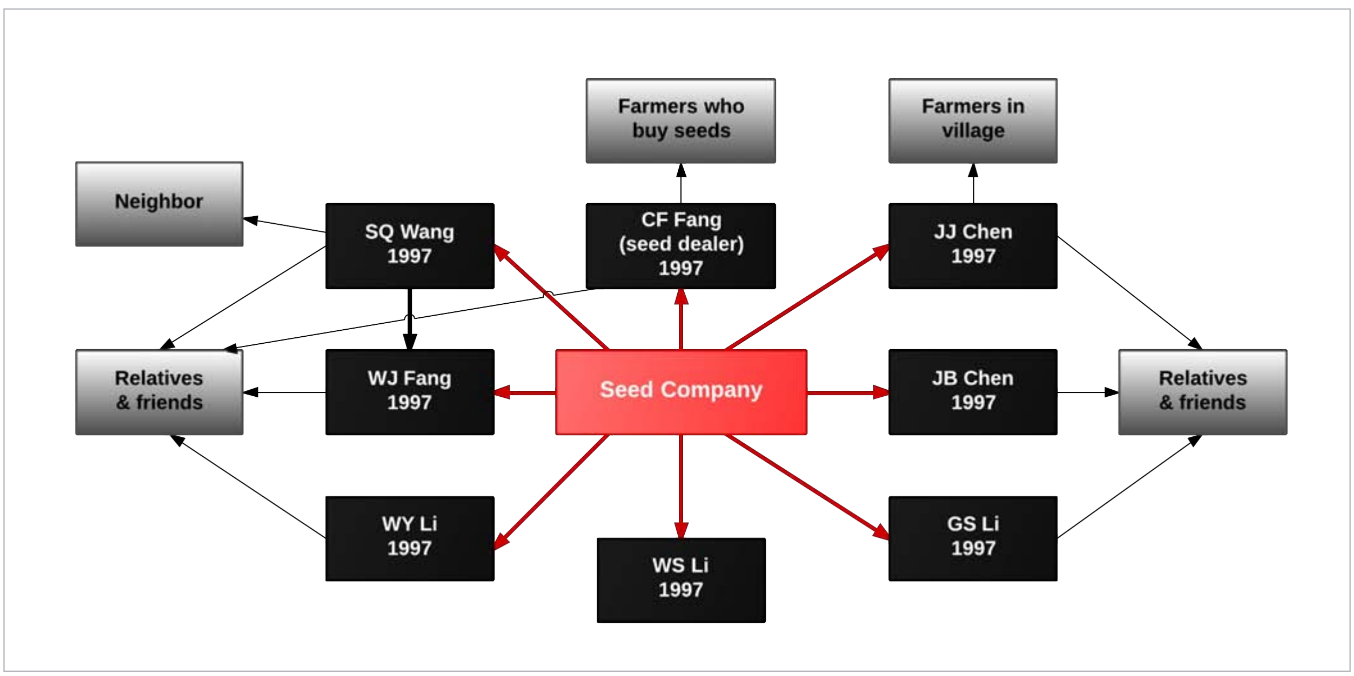


Figure 5.1 Uptake pathway of Bt cotton in Dalisi village, Hebei province

They were also promised that Bt cotton with better adaptation to local agronomic is to suppress the bollworm population and will not influence the production of winter wheat.

The contribution by local cotton and fiber industry to diffuse Bt cotton is more than its role in guiding smallholders in demo fields. In 1997, the industry signed a contract with the village cadres to collect all of the cotton after harvest. Because there exists the risks like early frost and bollworm infestation that reduce yield, industry will compensate for the crop loss.[3] The local industry was responsible for supplying Bt cotton seeds to smallholders and guide them during the production including spraying pesticide. All of the harvested cotton is sold to this industry and smallholders were not allow to save seeds for next year.

CF Fang, as the only seed seller, played an important role to diffuse Bt cotton later in this village. In 1997, he cultivated Bt cotton together with his father WJ Fang. Having seen his family benefiting from Bt cotton, he started to sell Bt cotton seed supplied by local market chain of Monsanto company in the village one year later. Meanwhile, he also sold conventional cotton seeds. He started to learn more about the trait of Bt cotton and the knowledge of Bt cotton production including the quantity of pesticide usage targeted to cotton aphid and mirids. He, acting as part-time technician, always shared his knowledge about Bt cotton to the smallholders who stop by his shop and help them choose other inputs like pesticide and chemical fertilizer.

In this village, we were not able to identify the leading farmers because all of the participants started adoption in 1997. Even before the existence of potential risk, all of them cultivated Bt cotton in a small plot of land. They also cultivated conventional

cotton at the same time. Their answers are summarized: even though yield of conventional cotton was very low, they are not very familiar with biotechnology, and thus they would like to reduce production risk through variety portfolio. Furthermore, at the first year, they could compare the performance of Bt cotton with convention cotton under almost the same agronomic condition and the exposure to natural risk such as bollworm infestation, and frost.

The rapid diffusion of Bt cotton in this village happened because all participants were anxious to share biotechnology with others. They shared information to fellow farmers in a village, neighbors, and relatives outside the local community. They said some fellow farmers or relatives came to their fields to observe the production as they themselves did one year before on the demo field. Bt cotton area doubled in 1998 and kept growing to more than two thirds of total sown area in this village until 2006.

Dongmuzuo village, Hebei province

The introduction of Bt cotton is unique in this village. After the introduction of household responsibility system, land use right is vested in households subject to an equalized framework but smallholders were requested to fulfill quota tied with the land (Liu et al., 1998; Brandt et al., 2002; Huang et al., 2011). Quota could be paid

[3] Up to now, there are few agricultural insurance programs implemented in rural China.

only in kind for a long time but later in cash as well (Sicular, 1996). In this village, cotton is one important crop under the quota system. However, due to the serious pest infestation especially bollworm, all the smallholders stopped cultivating cotton even though they have to fulfill quota in cash and have much experience in cotton production. However, at that time, even though smallholders in another village also suffered from bollworm infestation, they still cultivated conventional cotton before Bt cotton in the field.

The source of Bt cotton information was from the local seed company. Guided by the local seed company, one village cadre JL Zhao and farmer M Li were very impressed by the yield of Bt cotton on demo field and also were informed by other smallholders who worked on demo field about major advantages of Bt cotton versus conventional cotton.

Subsequently, the diffusion pathway of Bt cotton was mainly promoted by village cadres under the constraint of land equal distribution system. In 1997, village cadres representing some farmers signed a breeding seed contract with the local seed company. Under the terms of contract, a 10 hectare area was used for the purpose of breeding Bt cotton seed (here for the clarity, it is defined as trial field). The seed company would buy all Bt cotton seed at a certain price. Some of the other terms concerned compensation for risks and farmers' saving seeds. Under the current land distribution system, this trial field has been distributed to some of the farmers in this village. In order to accomplish the breeding contract, village cadres should convince all of the households who own some plots there to agree to this contract because farmers are free to organize their own agricultural production. The leading farmers were those who owned

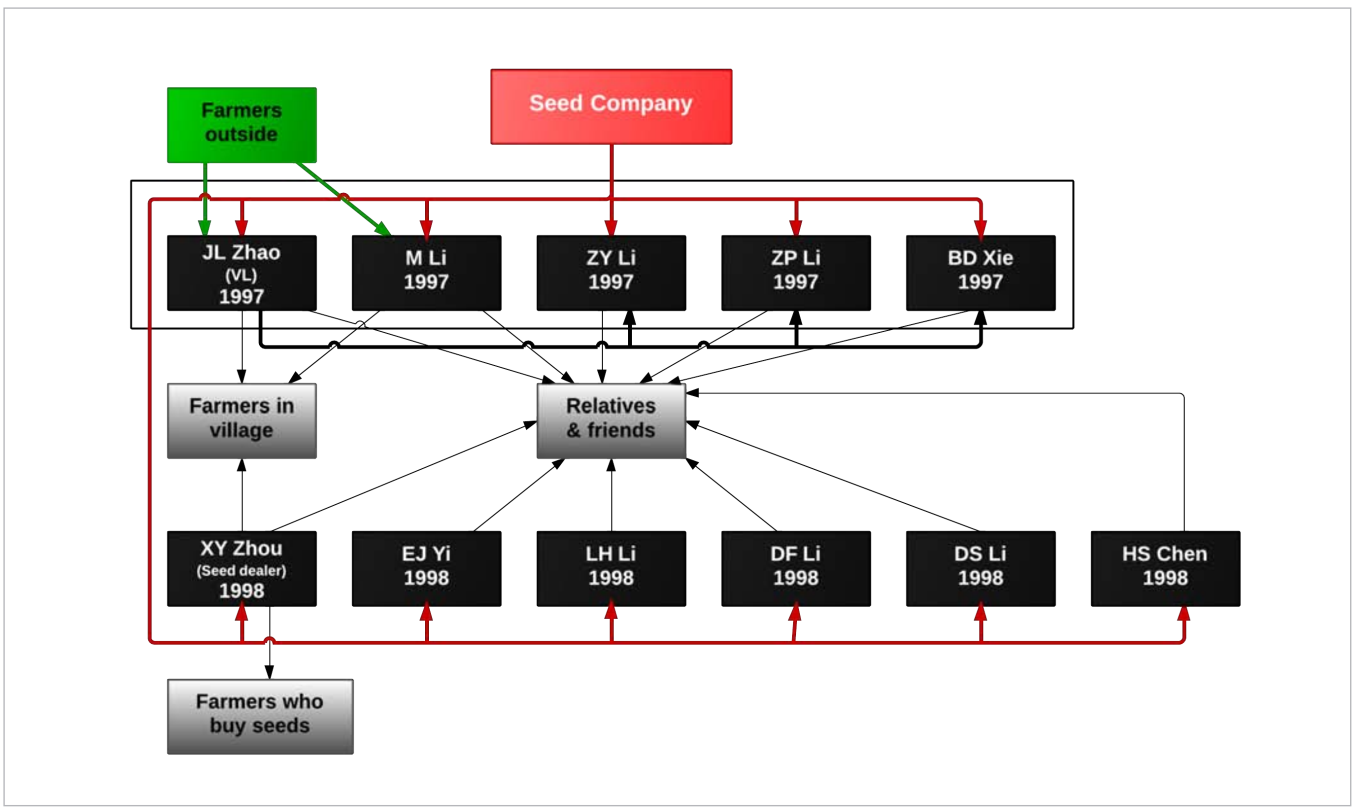


Figure 5.2 Uptake pathway of Bt cotton in Dongmuzuo village, Hebei province

one or some plots of land on this trial field and started to cultivate Bt cotton in 1997 together with the village cadres including JL Zhao.

It took two years for all of the participants in this village to adopt Bt cotton and the appearance of Bt cotton contributed significantly to the recovery of cotton production. Following the leading farmers, other smallholders in FGDs started to cultivate Bt cotton after stopping conventional cotton production in the early 1990s.They were motivated by the good performance of Bt cotton in the trial field and was anxious to adopt Bt cotton after being informed about the benefit and cost of Bt cotton by those leading farmers. We also asked if they also cultivated conventional cotton at the same time. All of them said they will not cultivate cotton if Bt cotton was not offered in the market. They will not take risk of crop loss in case of serious pest infestation. Furthermore, they were also afraid that the bollworm on conventional cotton also makes a negative impact on Bt cotton production, suggesting that smallholders still have limited knowledge about biotechnology. However, at the beginning of the adoption, smallholders only cultivated Bt cotton on small plot of land. That is why the share of cotton area to total sown area was still lower at only 8% in 1997 and 17% in 1998, much less than those in other counties.

Seed seller plays an important role in the diffusion process. He started to cultivate Bt cotton and sell Bt cotton seed in 1998. He also extended this biotechnology to farmers locally and outside through the marketing of seed and other inputs.

Qianhuo village, Shandong province

It took about three years for farmer-respondents to adopt Bt cotton in the two villages located in Shandong province starting from trial field (Figure 5.3 and 5.4). Local seed companies at county levels were the major stakeholders to extend Bt cotton every year. In 1997, with the help of some of village

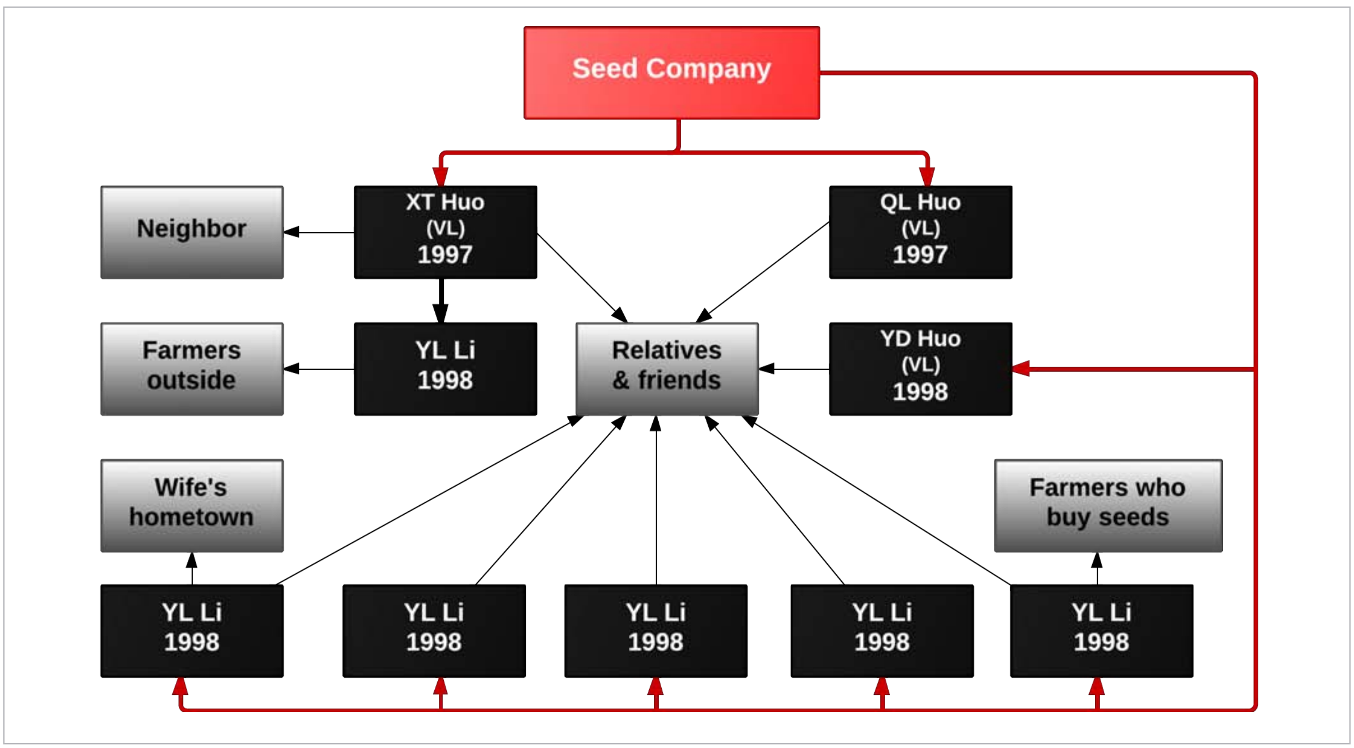


Figure 5.3 Uptake pathway of Bt cotton in Qianhuo village, Shandong province

cadres, the seed company started to breed Bt seed in Qianhou village. However, the supply of Bt cotton seed by local seed company did not meet the demand of smallholders. Some smallholders did not benefit from biotechnology as early as possible because of the unavailability of Bt cotton seed in 1997. In the following two years, the local seed company also extended biotechnology to other smallholders including village cadres and local seed seller.

However, breeding seed was not in the trial field in this village because all members in the village management committee (*Cunweihui,* in Chinese) did not make a consensus to organize the trial field.[4] As well documented about Chinese micro-level production, smallholders are able to organize their production free of request by village management committee. If coordinating the trial field, village cadres have to make great effort to convince all of the farmers who own land use right in a certain large piece of land.

Furthermore, village cadres would also face much uncertainty in Bt cotton production. As a result, some smallholders including two village cadres started the adoption of Bt cotton as a promise to breed seed for the local seed company with independently oral agreements between each of the farmers and seed company. Some village cadres were the leading farmers in the adoption of Bt cotton while others lagged behind other farmers. Based on the descriptive statistics at village level, the adoption rate in the third year after the initial commercial was over 90%. Until then, one village cadre started to cultivate Bt cotton.

Once there exists the constraint of accessing Bt cotton seed, farmers will save seed by themselves and to some extent delay the rapid diffusion of Bt cotton. Smallholders YL Li told us that he did not adopt Bt cotton as early as 1997 because of limit supply of Bt cotton. Even though there is also an agreement not to save seeds for commercial or own use in the following year, he requested the village cadre XT Huo to save some for him. In 1998 he also cultivated Bt cotton. Furthermore, the behavior of seed seller SZ Huo also proved the limited supply of Bt cotton in 1997 and 1998. He wanted to sell Bt cotton in his mini shop, but he could not supply the seed either from local or other seed companies. Until 1999, he started to sell Bt cotton seed and diffuse this technology to fellow farmers.

The leading farmers also helped to extend Bt cotton to neighbors, and relatives including the families of farmers' wives in or outside this village.

Liuxianzhuang village, Shandong province

Evidences obtained from this Innovation Tree are consistent with findings in other villages. The commercial release of Bt cotton in 1997 in Shandong province was patented by CAAS. Because seed companies have better marketing chain and professional staff with much marketing experience, the institute heavily depends on the local seed companies to offer Bt cotton seed. Unlike that in the other village in Shandong province, the seed company located at county seat organized demo field under the help of a local technician. In 1997, the seed company first organized a

4 All of the current village cadres in the committee are also those in the 1997 survey

training program to technicians at township and from villages on the traits of Bt cotton and the production practice of Bt cotton. After the training program, this village technician was a volunteer to start the demo field on his own plots and some neighboring farmers gave permission to use their plots. Local seed company provided the significant technology support to this technician concerning free Bt seed and the instruction during the production process. Furthermore, the seed company bought all of the Bt cotton harvest from this technician and other farmers at a price higher than the market price of conventional cotton.

Even though there are only five participants in FGDs consisting of one village technician and four smallholders, the diffusion pathway explicitly show that village technician is the important stakeholder to diffuse Bt cotton. All of the other smallholders who started to adopt Bt cotton in the different years are somehow influenced by the technician. When Bt cotton was completely new to other farmers, two participants cultivated Bt cotton under the guidance of the technician and seed company. Two reasons make the adoption of Bt cotton a reality. The first is because they trust the technician who introduced the technology or gave instructions on production in this village for decades. The second reason is that this area has experienced serious pest infestation in the past years. In fact, Chinese smallholders always try some new varieties in the market because they think new varieties adapt better to local agronomic condition. During the first year of adoption, the technician also invited other farmers to visit his plots to witness the trait of Bt cotton -eventually, Bt cotton was diffused rapidly in the village.

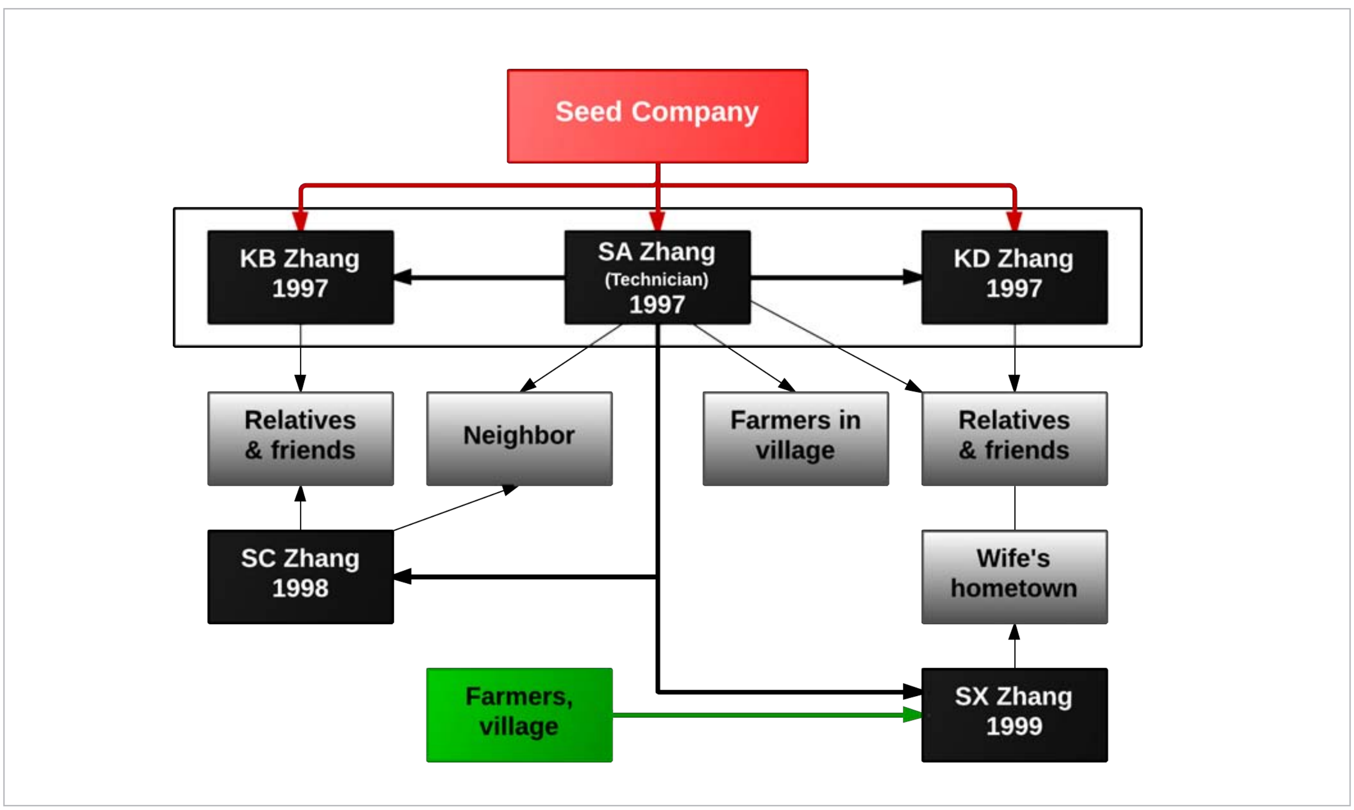


Figure 5.4 Uptake pathway of Bt cotton in Liuxianzhuang village, Shandong province

Gonghe village, Henan province

The initial commercial release of Bt cotton in Henan province started in 1999 but lagged for two years. It is not surprising that some of farmers obtained information on Bt cotton from the farmers in the neighboring provinces or from the newspaper or TV. In this village, one leading farmer who also joined the FGDs started to cultivate Bt cotton earlier than the others (Figure 5.5). Even before the extension from local seed company, village-level data showed that the adoption rate was more than 50% in 1999. This to some extent suggests that the better trait of biotechnology itself makes farmers to adopt it. Furthermore, even though the seed price of Bt cotton is higer than conventional cotton, the farmer decided to cultivate Bt cotton for the following reasons: first, he heard from other adopters in other provinces that farmers found it easy to sell Bt cotton at the same price as that for conventional cotton without any barrier. Secondly, he learned from the newspaper that Bt cotton has the proved traits in reducing pesticide usage and increasing yield; more benefit was promised compared to cultivate conventional cotton. Thirdly, he experienced nausea, headache after spraying pesticide, and thus he expected the variety to be either Bt cotton or some other hybrid cotton which required less pesticide. Finally, in his family, he and his wife were the laborers in agriculture and they are aging, and thus he would like to choose the comparatively labor-saving technology in cotton production. In 1999, he bought Bt cotton seed from a neighboring county. During the process of Bt cotton production, he also shared his experiences of cultivating Bt cotton to neighbors and relatives but none of the participants learned about Bt cotton from him.

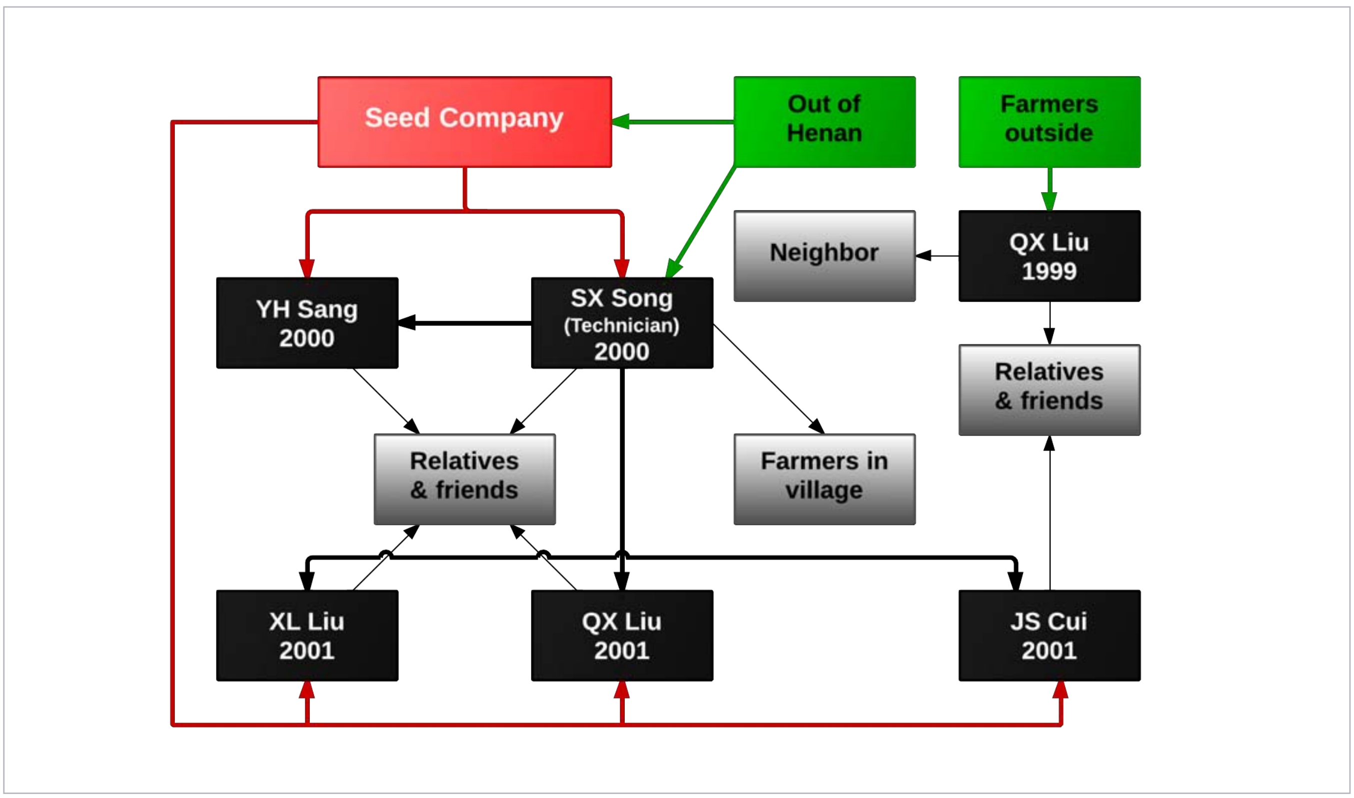


Figure 5.5 Uptake pathway of Bt cotton in Gonghe village, Henan province

In the second year of official commercial release of Bt cotton in Henan province, the local technician obtained the information on Bt cotton from two sources: one from local seed industry, the other from farmers in neighboring provinces. From then on, Bt cotton expanded in the village rapidly to more than 50% with effort made by technician and the staff from local seed industry. Their effort in the diffusion of Bt cotton paid off as the adoption rate at this village increased to more than 90%. All of the participants in FGDs indicated that the technician was willing to answer all of their questions concerning production. Furthermore, this technician also helped them to choose Bt cotton variety with the improved adaptation to local environment because until the end of 2002, there were five varieties in the market: DP99B from Monsanto company and the others including GK-12 from CAAS.

In the following parts, we present findings from group two that took a longer time for them to adopt Bt cotton.

Qianhe village, Henan province

In this village, there are two diffusion pathways: one is through the technology extension system and the other is through the market chain of seed sellers. The technician from township plays the important role in the diffusion in this village.[5] CAAS has production trial in Taikang county for decades not only for its GM varieties but also for conventional cotton. Technician (TZ Yao) at township level established the cooperation with technicians working on production trials since the early 1980s. He started to work on the production trial in 1995 before its official commercial release and learned about the production practice of Bt cotton from CAAS for three years. Even before the commercial release, he shared his experience on Bt cotton production to fellow farmers in his home village. Furthermore, he also introduced another farmer Yao B from home village to work on production trial. Due to the strict biosafety regulatory system, the technician did not save seeds for cultivating on his own plots even though he is sure that Bt cotton has many better traits than conventional cotton. This technician also shared with us that in the mid 2000s, after the rapid expansion of Bt cotton, agricultural bureau at county level announced the production instruction and forecasted pest infestation, the variation of temperature and wind on TV. The production instruction includes the proper timing when the farmers should spray pesticide; and the quantity and quality of fertilizer and pesticide; and the price of cotton seed and cotton. All of these are more than welcomed by smallholders.

Those farmers without direct instructions by the technician obtained Bt cotton information from seed sellers. Furthermore, fellow farmers trusted each other and liked to follow the leading farmers. Here, the roles of village cadres were neutral in diffusing Bt cotton and responded the same as other smallholders. For example, village cadre cultivated Bt cotton in 2000 when two thirds of cotton area in this village was Bt cotton. The start of cultivating Bt cotton was because Bt cotton was contracted to supply cotton to Cotton and Fiber company at county level that expanded its production in 2000.

---

[5] This village is also the home village of the technician at township level

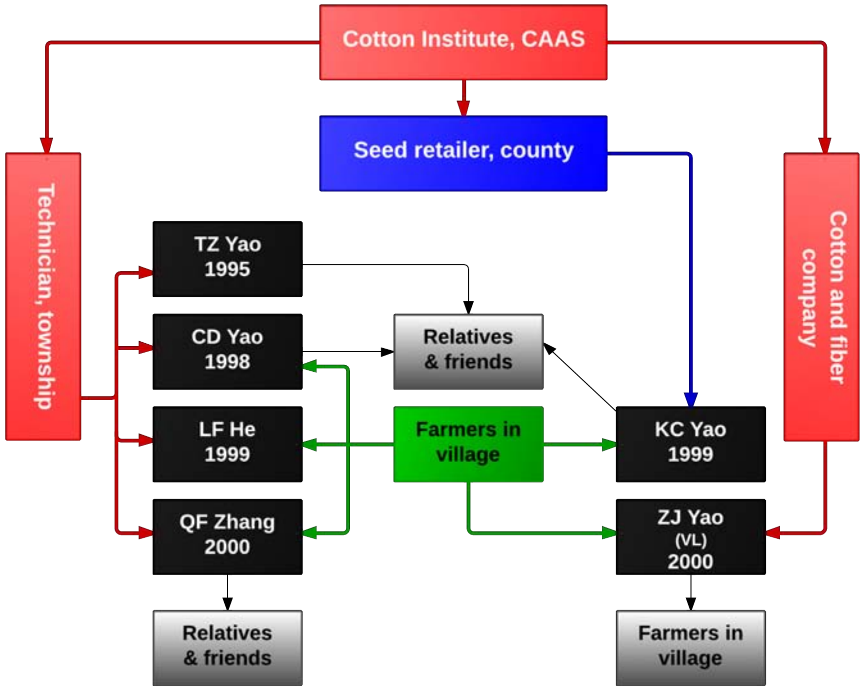


Figure 5.6 Uptake pathway of Bt cotton in Qianhe village, Henan province

Due to the pest infestation during 1997 and 1998, the share of cotton area to total sown area was reduced to more than 10% from 50% in 1998 to around 36% in 1999. At that time, Bt cotton was offered in the market. The diffusion pathway explicitly shows that fellow farmers share their experiences and information about Bt cotton within the village. For all the participants in the FGDs, the source of Bt cotton is diversified from technician at township and other farmers within this village as well. This mechanism of diffusion functioned well to convince the smallholders to adopt Bt cotton. The cotton area, mainly driven by the growth of Bt cotton adoption increased to 6% from 1999 to 2000.

Longtan village, Anhui province

The commercialization of Bt cotton in Anhui province dated back to 1997. However, unlike Hebei and Shandong provinces, none of the farmers in two villages adopted Bt cotton in the first year due to two reasons (Table 3.1, Figure 5.7 and 5.8). First, farmers were not able to obtain Bt cotton seed due to the limited supply of Bt cotton seed in the market. Bt cotton seed was only supplied by institutes but not yet made available in the market. Secondly, without confirming about the promised traits of Bt cotton, farmers would not take risk to cultivate Bt cotton as bollworm infestation is as serious as those in Hebei and Shandong provinces. After the collapse of technology extension system at township, farmers have never been guided to the demo field. Furthermore, at that time, the market strategy of seed companies in these two counties was too limited to offer farmers to the demo field.[6]

[6] In the latter 1990s and early 2000s, the size of seed company is very small with only few staff to sell seeds locally

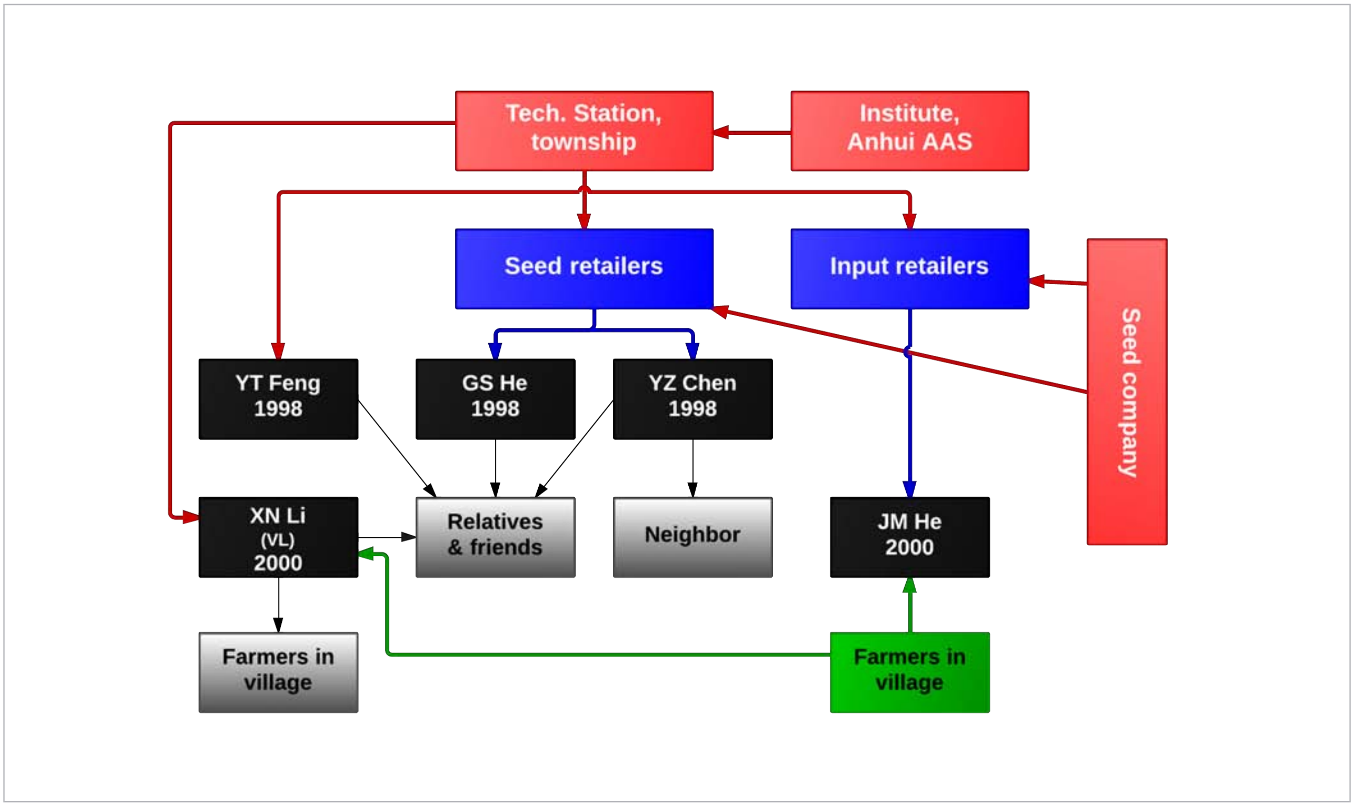


Figure 5.7 Uptake pathway of Bt cotton in Longtan village, Anhui province

Again the availability of Bt cotton seed made the adoption of Bt cotton possible. The source of Bt cotton seed to the seed or inputs sellers at village were from extension station at township or seed company at county seat. In 1998, the leading farmers who were willing to cultivate Bt cotton bought the seed from seed sellers within a village after they were informed of the traits by the sellers. Under village cadres in Hebei province, village cadres in the village were neutral to the diffusion of Bt cotton. They were not against the adoption of leading farmers on their plots of land in 1998; meanwhile they themselves would not act as the leading farmers. The village cadre in the FGDs only followed the leading farmers and responded similarly as those fellow farmers to adopt Bt cotton in 2000 when the adaptation rate increased to 50%.

Jiguan village, Anhui province

The diffusion pathway obtained from this village indicated that it takes a decade for all of the participants to adopt Bt cotton since the initial commercial release in 1997. The following four reasons could explain the slow adoption: first, in fact, technology extension station only organized one workshop to introduce Bt cotton in this village in 1997; however without the help of village cadres, few farmers joined the workshop and did not understand the advantage of Bt cotton

over conventional cotton. Secondly, Bt cotton seed can only be supplied through the chain of technology extension station and the supply of Bt cotton seed hardly met demand in this county. Until 2001, after three varieties developed by Monsanto company became available in the market, the short supply of Bt cotton seeds has been addressed. Thirdly, the incentive of adopting Bt cotton was dampened by anecdotes. When news about Bt cotton was announced, farmers misunderstood that when a gene is modified, the seed becomes poisonous. This anecdote expanded rapidly among smallholders with some cases fabricated. Furthermore, the local Cotton and Fiber industry refused to collect Bt cotton. Finally, the price of Bt cotton seed was much higher than that of conventional cotton. Without the calculation on cost and benefit of Bt cotton and conventional cotton, farmers were not willing to cultivate Bt cotton.

Furthermore, there is not any diffusion pathway among the participants even though both village cadre and village technician were involved in the Innovation Tree exercise. Smallholder WZ Xiao who cultivated earlier than other participants was informed about Bt cotton from farmers in the neighboring villages and from the workshop organized by technology extension station in other villages. One year later, village cadre CS Tang and farmer KB Wang also learned from this similar workshop and started to cultivate Bt cotton. After 2000, the offering of varieties was

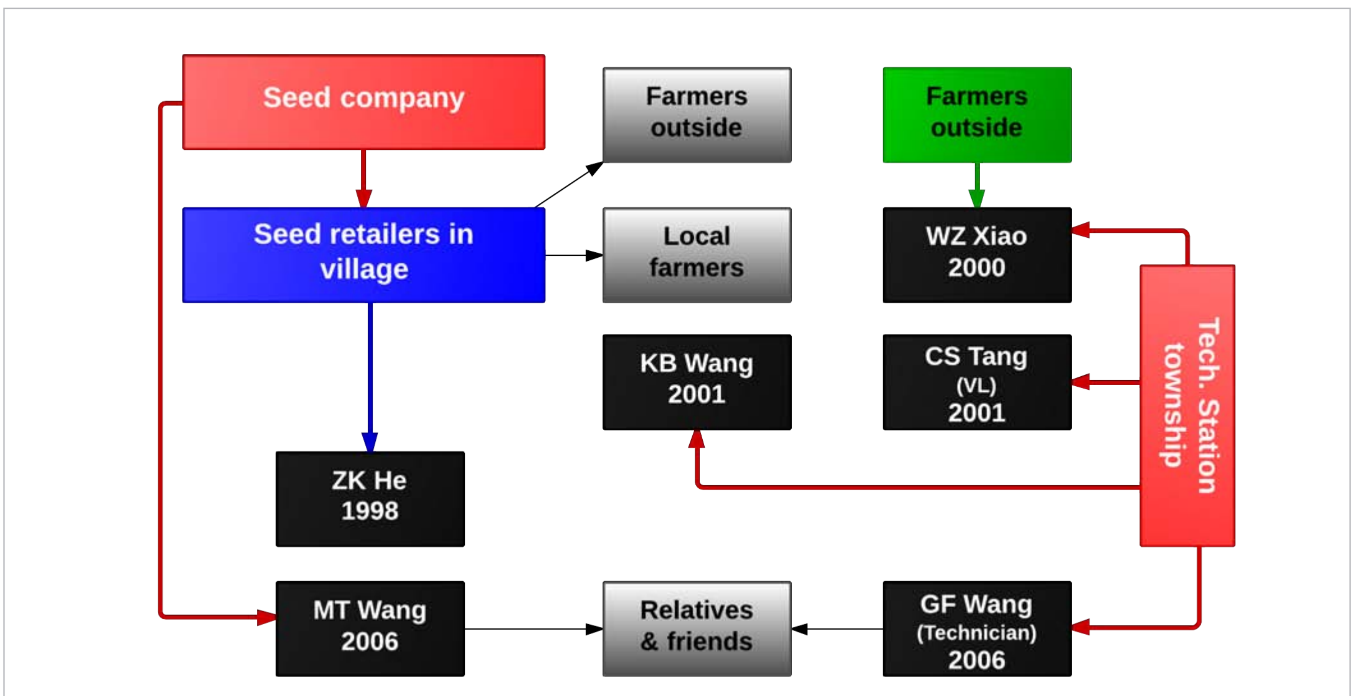


Figure 5.8 Uptake pathway of Bt cotton in Jiguan village, Anhui province

accelerated and seed sellers in a village were able to be supplied Bt cotton seed from a seed company at county level. After a decade of almost 100% adoption rate of Bt cotton, the technician at village level started to cultivate Bt cotton (Table 3.1). If a technician does not understand biotechnology despite being trained well, his role in diffusing biotechnology within a community is very limited.

During the group discussion, farmers told us that their decision on whether to adopt Bt cotton or not is influenced by the attitude of village cadres and technician. The attitude of village cadres to Bt cotton was regarded as being neutral because they did not help technology extension station to organize the training workshop within this village. However they did not say no either. After they attended the workshop, they themselves did not cultivate Bt cotton. Even until 2001, the village cadre started to cultivate Bt cotton, but he did not share his experiences with others. The attitudes of village cadres and technician makes the farmers doubt about the information on Bt cotton from other sources. Without the training workshops every year, the diffusion of Bt cotton would take longer.

Summary from FGDs

Findings from the FGDs explicitly shows that the trait of Bt cotton, the improved adaptation to local agronomic conditions and other benefits result in the rapid diffusion of Bt cotton in China. Without the good performance of Bt cotton, smallholders will not adopt Bt cotton after stopping cultivating cotton for some years given the risk of serious pest infestation. Smallholders will not buy a specific seed without the promised benefit after the careful cost and benefit calculation. If the plots cultivated by leading farmers are regarded as demo plots, smallholders followed leading farmers by observing the production on these plots. Smallholders went to the plots of leading

smallholders during each of the planting seasons like the season for pruning, blossom, and harvest.

In the first stage of Bt cotton diffusion, both seed companies and the technology developers (e.g. research institutes or biotech companies) that conducted Bt cotton field trials and demonstration in cotton production regions played important roles in farmers' use of Bt cotton. Leading domestic seed companies worked with technology developers sold Bt cotton seeds to some of initial adopters. Meantime, local public agricultural extension technology extension staff (or technicians) and leading farmers were invited to visit Bt cotton trial fields or demonstration fields of technology developers to facilitate initial adoption of Bt cotton by farmers. In some villages, training workshops on Bt cotton or visits to Bt cotton field trials and coordinated by village leaders were provided to farmers who became the first adopters of Bt cotton. Some village leaders also coordinated the Bt cotton seed generation and set up the seed purchasing contract with seed company, which helped their villagers become the first adopters and facilitators of expansion of Bt cotton in the villages.

With the outstanding performance of Bt cotton by its the first adopters, the other farmers in the same village followed up rapidly. Generally, farmers visited the Bt cotton fields of the first adopters and learned the advantages of the technology. The followers also learned and adopted Bt cotton from their neighbors, other farmers inside or outside their villages or the hometown of the farmers' wives.

However, it is worth noting that when Bt cotton was first released, there were serious constraints in its adoption. Many farmers would like to plant Bt cotton but the supply of Bt cotton seed did not meet their demand. With the limited knowledge about biotechnology, some farmers also delayed their adoption. This study has several policy implications. To facilitate GM technology diffusion to farmers, seed companies, technology developers, local village leaders, and the first adopters of technologies can play important roles. Local technology extension service and training are also critical in disseminating appropriate information and knowledge to farmers so that they can fully benefit from the new technology.

About the perspective of GM technology, some smallholders mentioned they know all the agricultural practices in planting Bt cotton. Others are eager to understand when and how much to use pesticide and fertilizer.

Conclusion

China is one of the first countries that have commercialized GM crops. Bt cotton was commercially released in 1997 and has been rapidly adopted by farmers thereafter. Our survey shows that adoption rate of Bt cotton reached nearly 100% by the early 2000s in Huang-Huai-Hai region, a major cotton production region in China. Bt cotton is well reported as a successful case of biotechnology adoption in China.

The introduction of Bt cotton had helped millions of small farmers to recover their cotton production in the late 1990s. Even though China has a long history of cultivating cotton due to breakout of cotton bollworm in the middle 1990s, the cotton area shrank. With the availability of Bt cotton for farmers, in majority of sampled counties, the share of cotton area to total sown area increased parallel with the diffusion of Bt cotton.

Bt cotton technology is neutral technology that benefited all farmers. Farmers in Huang-Huai-Hai region were all smallholders with average cultivated land area of less than one hectare. Field work of both Bt cotton and non-Bt cotton were mainly conducted by women as men engaged in off-farm job more than women. Such reducing pesticide use and saving labor due to Bt cotton adoption benefited women. There were no significant differences in household characteristics between Bt cotton adopters and non-Bt cotton adopters.

However there was spatial pattern of Bt cotton production evolution. It started in Huang-Huai-Hai region and then followed by Yangtze River cotton production region. This spatial evolution was closely correlated with serious local pest problem (e.g., bollworm), the nature of biotech crop, and biosafety regulation.

As all cotton farmers are smallholders, all gained significantly from adoption of Bt cotton. Major benefits of planting Bt cotton include the reduction of insecticide use, mitigating yield loss from bollworm attacks (or increase yield), and saving labor inputs in cotton fields. As the cotton farmers are also relatively poor, Bt cotton also significantly improved their income and livelihood.

Our analyses show that in the first stage of Bt cotton diffusion, both seed companies and the technology developers played important roles in farmers' use of Bt cotton. Seed companies and technology developers (e.g. research institutes or biotech companies) conducted Bt cotton field trials in cotton production villages where farmers often became the first adopters of Bt cotton varieties. Technology developers also arranged Bt cotton field demonstrations in major cotton production regions, which helped the early adopters' understanding and interest in the technology.

Meantime, local public agricultural technology extension staff (or technicians) and leading farmers were also important facilitators in the initial stage of Bt cotton adoption. For example, some local extension technicians invited farmers to visit Bt cotton trial fields or demonstration fields of technology developers. In some villages coordinated by village leaders,

training workshops on Bt cotton or visiting Bt cotton field trials were provided for farmers who became the first adopters of Bt cotton. Some village leaders also coordinated the Bt cotton seed generation and set up the seed purchasing contract with the local seed company, which helped their villagers to become the first adopters and facilitated future expansion of Bt cotton in the villages.

With the outstanding performance of Bt cotton by its first adopters, the other farmers in the same village followed up rapidly. Generally, farmers visited the Bt cotton fields of the first adopters and learned the advantages of the technology. The followers also learned and adopted Bt cotton from their neighbors, other farmers inside or outside their villages or the hometown of the farmers' wives.

However, it is worth noting that when Bt cotton was first released, there were serious constraints in its adoption. Many farmers wanted to plant Bt cotton but the supply of Bt cotton seed did not meet their demand. Because most Bt cotton varieties were conventional (or not hybrid), lack of seed availability was overcome by many farmers by using own saved seeds or getting seeds from other farmers who planted Bt cotton in the previous year. Availability of Bt cotton seed in a new province was also subjected to biosafety regulations because approval of Bt cotton in China is case-by-case and region-by-region. In addition, our study also shows that with the limited knowledge about biotechnology, some farmers delayed their adoption.

The results of this study have several policy implications. To facilitate the rapid diffusion of GM technology to farmers, both public and private sectors can play important roles. First, ability of seed companies to generate seed available in the market after commercial approval of a biotech crop affects the scale of initial adoption or numbers of farmers who can plant the new crop. Second, technology developers from either public research institutions or biotech companies are important facilitators in the initial diffusion of the biotech technology. Through field trials and demonstration, nearby farmers can learn the advantage of the technology and become the initial beneficiary, which will stimulate other farmers to follow them. Third, local technology extension service and training are also critical in disseminating appropriate information and knowledge to farmers so that they can fully benefit from the new technology. Fourth, engagement of local village leaders in arranging the purchases of biotech crop seed helps farmers, particularly smallholders, to access the new technology. Last but not least, similar to other technology diffusion, social network affects the rapid adoption and pathways of Bt cotton diffusion.

References

Ali A. and Abdulai A. 2010. The Adoption of Genetically Modified Cotton and Poverty Reduction in Pakistan. *Journal of Agricultural Economics*, **61**, 175-192.

Alan de Brauw, Jikun Huang, Linxiu Zhang, Scott Rozelle, 2013. "The Feminisation of Agriculture with Chinese Characteristics," The Journal of Development Studies, Taylor and Francis Journals, vol. 49(5), pages 689-704.

Brandt, Loren, Huang, Jikun, Li, Guo and Rozelle, Scott. (2002). Land Rights in Rural China: Facts, Fictions and Issues. *The China Journal*, No. 47, pp.67-97.

Carlson G. A. 1970. Decision-Theoretic Approach to Crop Disease Prediction and Control. *American Journal of Agricultural Economics*, **52**, 216-226.

Feder G. 1979. Pesticides, Information, and Pest Management under Uncertainty. *American Journal of Agricultural Economics*, **61**, 97-103.

Fok, M. & Xu, N. (2011). Variety Market Development: A Bt Cotton Cropping Factor and Constraint in China. *AgBioForum*, *14*(2), 47-60.

Hofs J., Fok M. and Vaissayre M. 2006. Impact of Bt Cotton Adoption on Pesticide Use by Smallholders: A 2-year Survey in Makhatini Flats (South Africa). *Crop Protection*, **25**, 984-988.

Huang J., Hu R., Rozelle S., Qiao F. and Pray C. E. 2002a. Transgenic Varieties and Productivity of Smallholder Cotton Farmer in China. *The Australian Journal of Agricultural and Resource Economics*, **46**, 1-21.

Huang J., Rozelle S., Pray C. and Wang Q. 2002b. Plant Biotechnology in China. *Science*, **295**, 674-677.

Huang J., Hu R., Pray C., Qiao F. and Rozelle. S. 2003. Biotechnology as an Alternative to Chemical Pesticides: a Case Study of Bt Cotton in China. *Agricultural Economics*, **29**, 55-67.

Huang, J. K., Hu, R., Rozelle, S., Pray, C. 2005. Insect-resistant GM Rice in Farmer Fields: Assessing Productivity and Health Effects in China, *Science*, Vol. 308 no. 5722: 688-690.

Huang, J.K., Yang, J., and Rozelle, S. 2010. China's Agriculture: Drivers of Change and Implications for China and the Rest of World, *Agricultural Economics*, Vol. 41: 47-55.

Huang, J. K., Hu, R.,F., Chen, R.J., Mi, J.W., Rozelle, S., Pray, C., 2010. The impact of Biotechnology on economy: One decade of Bt cotton in China. Science Press, China.

Huang, J.K., Zhang, D.L., Yang, J., Rozelle S., Kalaitzandonakes N. 2008. Will the Biosafety Protocol Hinder or Protect the Developing World: Learning from China's Experience, *Food Policy*, 33: 1-12.

James C. Global Status of Commercialized Biotech/GM Crops: 2012. ISAAA Brief, 2012,43: Executive Summary. Ithaca, NY: International Service for the Acquisition of Agri-Biotech Applications (ISAAA). Available at http://www.isaaa.org/resources/publications/briefs/43/executivesummary/pdf/Brief%2043%20-%20Executive%20Summary%20-%20English.pdf

Liu, Shouying; Carter, Michael; Yao, Yang, 1998. Dimension and Diversity of Property Right in Rural China: Dilemmas on the Road to Further Reform. *World Development* 26, 1789-1806.

Marvier M., McCreedy C., Regetz J. and Kareiva P. 2007. A Meta-Analysis of Effects of Bt Cotton and Maize on Nontarget Invertebrates. *Science*, **316**, 1475-1477.

Ministry of Agriculture, 2012. The list of new varieties of GM Crops approved to be commericial release in China. *Ministry of Agriculture*.

Napasintuwong O. and Traxler G. 2009. Ex-ante Impact Assessment of GM Papaya Adoption in Thailand. *AgBioForum*, **12**, 209-217.

Pemsl D., Waibel H. and Gutierrez A. P. 2005. Why Do Some Bt-Cotton Farmers in China Continue to Use High Levels of Pesticides? *International Journal of Agricultural Sustainability*, **3**, 44-56.

Pray, Carl E., Latha Nagarajan, Jikun Huang, Ruifa Hu, Bharat Ramaswami (2011), Chapter 4 The Impact of Bt Cotton and the Potential Impact of Biotechnology on Other Crops in China and India, in Colin A. Carter, Gian Carlo Moschini, Ian Sheldon (ed.) *Genetically Modified Food and Global Welfare (Frontiers of Economics and Globalization, Volume 10)*, Emerald Group Publishing Limited, 83-114.

Qaim M. and Zilberman D. 2003. Yeilds Effect of Genetically Modified Crop in Developing Countries. *Science*, **299**, 900-902.

Thirtle C., Beyers L., Ismael Y. and Piesse J. 2003. Can GM-Technologies Help the Poor? The Impact of Bt Cotton in Makhathini Flats, KwaZulu-Natal. *World Development*, **31**, 717-732.

Group questions for the Innovation Tree activity

The following will be asked after all smallholders have shared the month and year of adoption, who informed him/her first, who convinced him/her, and who he/she convinced:

1. Did you hesitate at first to adopt? If yes, why so? What other factors made you apprehensive about adopting the crop? If no, why so?
2. What compelling statements (e.g., phrases, assurance) did you receive or hear from people convincing you to adopt Bt cotton and those discouraging you?
3. How did the leaders in your village react to the introduction of Bt cotton among the local smallholders? Were they fearful, hopeful or disinterested about it being cultivated in your village? Why so?
4. What did the village cadres do to help the adopters become successful in growing Bt cotton? Please elaborate on the important roles that they play in the adoption of Bt cotton by smallholders and the increase in number of adopters in the village.
5. What were the most crucial chunks of information shared to you by the following that contributed to the success of your Bt cotton production endeavor: fellow smallholders, relatives, traders, seed technicians, MAO technicians, and others? How did the information help you?
6. Among the benefits you have had from growing Bt cotton, what made a considerable impact on your life and your family? Why?
7. What benefits did your village, in general, get from growing Bt cotton?
8. What else do you want to know about Bt cotton? Why?
9. How do you see yourself as a biotech smallholder in the next five years?
10. What role must the government play in promoting Bt cotton?