ADOPTION AND UPTAKE PATHWAY OF GM TECHNOLOGY BY CHINESE SMALLHOLDERS: EVIDENCE FROM BT COTTON PRODUCTION

Dr. Jikun Huang[1] and Dr. Xiaobing Wang[2]
[1]Director and [2]Associate Professor, Center for Chinese Agricultural Policy,
Chinese Academy of Sciences, Beijing, China

HIGHLIGHTS

There has been rapid growth of genetically modified (GM) crop areas since the late 1990s. With an 100-fold increase from 1996 to 2012, the global accumulated GM crop area is now 170 million ha, distributed across 28 countries. Among all of biotech crops, Bt cotton has been proven to be successfully adopted by smallholder farmers in developing countries including China.

Even though existing studies empirically analyzed the key factors that significantly influenced the adoption decision of smallholders on Bt cotton adoption, some information on its uptake process such as the roles of different stakeholders on the technology adoption remain unknown. To fill this gap, this study analyzed the adoption and uptake pathways of Bt cotton among smallholders in China. The specific objectives of the study are as follows:

1. Present the evolution of cotton production in China, with the special attention to the temporal and spatial characteristics of the commercial release of Bt cotton.

2. Explore the factors including demographic and farm characteristics correlated with the adoption of Bt cotton.

3. Assess the impacts of Bt cotton in terms of inputs and yield in production; and direct effects on smallholders' revenue among others.

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

The study employed descriptive statistics using survey and an FGD tool known as Innovation Tree. The sampling strategy for the survey is as follows: first, the four provinces namely Hebei, Henan, Shandong, and Anhui located in Huang-Huai-Hai cotton production zone were chosen according to the area of cotton production and the history of adopting Bt cotton. Secondly, in each province, two counties planting different varieties of Bt cotton and with different cotton farm areas were chosen. Thirdly, two villages in each county and 20

Full report is available at http://www.isaaa.org/

farmers within a village were randomly selected. The final sample came from 439 households (325 Bt-cotton producers and 114 non- cotton producers) from 20 villages located in 8 counties in 4 provinces.

Biosafety Regulatory System in China

China implements strict biosafety regulations covering the research and development (R&D) aspect of biotechnology; its production; and the marketing and trade of GM products. The main policy portfolio includes 'Regulations of Genetically Modified Organisms Safety' enacted by State Council, China on May 23, 2001. China formally institutionalized the National Biosafety Committee in 2004 that consists of government officers from different ministries and scientists in major agencies including agriculture, medicine, and health. The Ministry of Agriculture (MOA) approves the commercial release of biotech crops after the intermediate trial, the environmental release, the pre-production trials and issuing of biosafety certificate.

From 1997 to 2012, MOA accepted 1,525 applications from 192 research institutes. After the appraisal by the National Biosafety Committee, they approved a total of 456 for intermediate trial, 211 for environmental release, and 181 for pre-production trial. Although the world acknowledged China's government issuance of biosafety certificates for Bt cotton, Bt rice, Ring Spot Virus Resistant Transgenic Papaya, and Phytase maize, Bt cotton remains as the only major crop in the field.

The approval of commercial release of Bt cotton in China

Bt cotton were approved to be commercialized step by step by Ministry of Agriculture, China. In 1997, two varieties of Bt cotton were adopted by Chinese smallholders: one variety was patented by Chinese Academy of Agricultural Science (CAAS). It was allowed to be planted in Huang-Huai-Hai cotton production zone which includes Shanxi, Anhui, Shandong and Hubei provinces. The other variety is owned by Monsanto company and was approved for planting in Hebei province. With the characteristics of much less pesticide inputs, less labor input, and the increase in yield, China's government approved the commercialization of Bt cotton in Yangtze river and Xijiang cotton production zones in 1999 and other five provinces in 2003.

The evolution of Bt cotton production in China

With a long history of cultivating cotton in China, the commercial release of Bt cotton is due to its traits which can adapt to the local agronomic and pest pressure. The trend of cotton area shows that cotton production reached the 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% , albeit some fluctuation of the yield in the latter years of 1980s. The institutional reform and the introduction of hybrid varieties contributed significantly to the growth of cotton production. However, with the continuous infestation of pest especially cotton bollworm since 1992, cotton production stagnated. Before the introduction of Bt cotton in 1998, cotton production fell to 3,726 thousand ha, which was around half of the historical record.

Since the latter 1990s, the diffusion of Bt cotton helped re-launch cotton production. At the national level, since Bt cotton was in the market, the area of Bt cotton has increased more than 12 times from 260 thousand ha in 1998 to 3.83 million ha in 2008. The adoption rate indicated that as of 2008, around two third of cotton area in the country was already Bt with the improved traits for the adaptation to local production endowment. The rapid fall of cotton production in recent years is due to smallholder farmers' tendency to save labor inputs 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. Yield reached the summit of more than 1300 kg/ha in 2006.

Evidences obtained from this study are consistent with the findings at the national level. The multiple growth of cotton area in Shenzhou, Hebei is mainly driven by the availability of Bt cotton in the market. Cotton area increased for more than 10% in four counties after the adoption of Bt cotton. In one of the counties located in Henan, the percentage of cotton area to total sown area also increased by around 10% after the commercialization of Bt cotton. However, in other two counties, the cotton area remained stable over time. Thirdly, the variation of diffusion is correlated with the national commercial release portfolio at spatial and temporal dimensions. For those in the first legion, 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 started from 1999 with more than half of cotton area planted to Bt cotton.

Decomposing the adoption rate at the provincial level also presents three important characteristics. 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. Even though Bt cotton was also commercialized in Xinjiang way back 1999, the adoption rate there was still low at 13% due to less pest pressure in 2008. The adoption of Bt cotton mainly happened in Huang-Huai-Hai and Yangtze river cotton production.

Secondly, the heterogeneity of regional adoption rate could only be partially explained by the rate of commercial release. Thirdly, combined with infestation level data at county-level, there appeared the inverse correlation of adoption and the infestation level of cotton bollworm after the commercial release of Bt cotton in China.

Socio-demographic profile correlated with the adoption of Bt cotton

Age

The age of household head ranged from 22 to 68 years old in 1999. The mean of 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 head was distributed heterogeneously in three age ranges (30 and below, 31-40 and 50 and above) across four provinces. For example, more than one third of heads belong to 31-40 age range in Hebei while less than a quarter of their counterparts was noted in Anhui province. The percentage of heads with age of over 50 years old in Anhui is twice more than those in Hebei province. This suggests that the heads were younger in Hebei province than those in Anhui province. Consistent with the existing studies (Torres et al., 2012), our results indicated that the younger heads were more likely to adopt Bt cotton.

Gender

Even though the latest study suggests the feminization in Chinese agricultural production, the households who produce cotton including Bt cotton were dominated by a male head. Almost all of the household heads surveyed (both Bt cotton and non-Bt cotton farmers) were male. This trend is true in all of the four provinces.

Education attainment

On average, the period of schooling of the head is between 6 or 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 head in Hebei was two years more than that in Anhui province. Furthermore, majority of heads in Shandong, Henan, and Anhui provinces did not finish secondary schooling. Within a province, there was not any statistical difference between the Bt cotton adopters and their counterparts.

Attending training program on Bt cotton

The percentage of heads who attended training program on Bt cotton varied significantly across provinces. The results also suggest that those who attended the training program have higher probability of adopting Bt cotton. 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 sharing experiences among fellow farmers.

Cadre

The descriptive statistics shows that the head who was a cadre was more likely to adopt Bt cotton. It further indicates that on average, there were more than half of the village cadres as leading farmers who adopted Bt cotton across the four provinces.

Family Size

The family size ranged from 1 to 7, with the average of 4. However, on average, the family size in Anhui and Henan provinces was a bit larger than those in Hebei and Shandong provinces. Compared with the typical farming households in China, the cotton farmers have almost same family size even though cotton is a relatively more labor-intensive crop.

Farm size

The average farm size obtained from the sample was 0.66ha/household, which is 0.06 ha larger than the average farm size in China in 2012. The average farm size varied significantly across provinces. The land/capita ratio, calculated by the farm size divided by family size explicitly presents the heterogeneous land endowment across provinces. However, there is no statistical significant difference between Bt cotton farm and non-Bt cotton farm.

Revenue, yield, pesticide usage and other inputs: Bt cotton and Non-Bt cotton

Farmers' benefits from Bt cotton production primarily falls under the net income derived from its cultivation. On average, the net revenue for Bt cotton in a unit of land is RMB 5,522

(US$667 /ha) [1]. There are also regional differences in net revenue. Farmers in Anhui province earn more than RMB 3,146 (US$380/ha) than counterpart in Shandong province. Total cost of Bt cotton was RMB 2,491 (US$300.90/ha).

Overall, the yield of Bt cotton is higher than non-Bt cotton by approximately 330 kg/ha. There is no exception in Henan and Anhui provinces where Bt cotton and non Bt cotton production co-exist. However, the yield of Bt cotton also varies significantly across provinces. The average yield in Shandong province was 3,842 kg/ha while that in Henan province was only 2,811 kg/ha. Similarly, the average yield of non-Bt cotton differed significantly between Henan and Anhui provinces.

The inputs including labor and chemical fertilizer between Bt cotton and non-Bt cotton production were also compared. After adopting 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. Overall, the difference of chemical fertilizer use was not statistically significant between Bt-cotton and non-Bt cotton production.

The reduction of labor inputs is marginally driven by the reduction of labor input in spraying pesticide. Compared to the non-Bt cotton, one of the main advantages of Bt cotton is the reduction of pesticide use. Pesticide input is measured by the quantity of pesticide input (kg/ha) and the frequency of spraying pesticide (number) in cotton production. 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 more than three times than that on Bt cotton plot.

Source of Bt cotton information

The results show that farmers obtained the Bt cotton information from different sources across provinces. In Hebei and Shandong provinces, 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 village committees were convinced by seed companies to start demonstration field of Bt cotton or breed Bt cotton seed within these villages. The adoption of Bt cotton in Henan and Anhui lagged behind Hebei and Shandong province. Around 40% of farmers in Henan and Anhui province learned about Bt cotton information from seed technicians. Furthermore, Bt cotton information was shared among farmers.

Organizations that conduct training programs

To extend Bt cotton, organizations like technology extension bureaus, seed companies, and village committees conducted training programs for farmers. It is consistent across provinces as majority of farmers attend the training program organized by the village committee. However, it should be clarified that even though the training program was coordinated under the help of the village committee, the lecturers were facilitated with technology extension bureaus or seed companies. Farmers were also asked why they did not attend the training

[1] 1US$= RMB 8.28

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 seed advertised by seed companies unless they had visited the demo field or they were informed by fellow farmers.

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's seed were categorized into reserved seed, cotton processing company, seed company, seed trader, and others including village committee. Unlike the regulation in the US, self-reservation of seed is allowed in China. Seed companies are definitely the most important source of Bt cotton seed to farmers at its initial stage of commercialization. Currently, all the farmers access Bt cotton seed from the market without any constraint. 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 center.

The uptake pathway of Bt cotton: Evidences from FGDs

Findings from the FGDs explicitly shows that the trait of Bt cotton and, its improved adaptation to local agronomic and other benefits make the adoption and rapid diffusion of Bt cotton true 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 observe the production of these plots. They would go to the plots of leading smallholders every planting season as well as the season for pruning, blossom, and harvest.

At the initial release of biotechnology, demo fields and training workshops proved to be effective for smallholders to obtain information and better understanding of the performance of this new technology. In general, both institutes and Multinational Companies (MNCs) cooperated with seed companies at county level to breed on a large areas of land in villages to extend Bt cotton. Smallholders who contracted one or more land plots on the trial field within villages will sign a contract with seed companies to breed for them.

Technicians in the township or sellers of seed and other inputs play important roles in diffusing Bt cotton information. For example, technicians were invited to visit the trial field or demo field during each of the planting or harvest seasons and trained during the workshops. The shops sold the Bt cotton seed to smallholders and also told them some planting information to smallholders. Given the close contact between technician and smallholders, and since they are being trusted by smallholders, trained technicians also extend the knowledge of biotechnology to them.

The variety initially commercialized in Hebei was patented by the company Monsanto company. Even though this study were not able to control other factors, the researchers'our observation in the field still suggest that the MNCs extended GM technology through its better market chain.

However, the gap of adaption rate of GM technology was also correlated with the attitudes of village cadres to Bt cotton, which is diversified across the villages. In some villages, village cadres who also have plots on the trial fields will produce Bt cotton and other smallholders followed them. They visited trial fields or demo fields together with other smallholders and then they help to extend Bt cotton in the village. In other villages, village cadres are neutral and did not help coordinate the extension of Bt cotton. However, smallholders within the village are free to adopt Bt cotton or not.

From the aspect of impact of adopting Bt cotton on production and welfare, all of the smallholders revealed that compared to non Bt-cotton, the use of pesticide, specially those that targeted bollworm was reduced significantly and the yield increased. The incidence of poisoning was also reduced. Farmers benefit significantly from adopting Bt cotton in the following dimensions: Majority of farmers reported that planting Bt cotton use less labor input, and attained higher yield with good quality cotton. One of the important differences 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 entail lower cost and result in higher yield, the adoption rate is likely to be far quicker.

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

Policy Recommendation

It should be noted that when Bt cotton was just released in the field, there were some barriers in its diffusion. With the limited knowledge about biotechnology, some smallholders have delayed the adoption due to peer anecdotes. To diffuse GM crops to smallholders, there is a need to provide technology extension portfolio that will disseminate information and knowledge to farmers to further help them reduce their pesticide input before and even after the adoption of GM crops. The identification of the traits of GM crops is to a larger extent dependent on the knowledge of biotechnology rather than only adopting it in the production stage. Further extension of either biotechnology or conventional technology should be provided through training services to smallholders to improve their knowledge on technology in parallel with the spread of GM crops.