1127 Multiple-factor adoption of GM Cotton in China: Influence of conventional technology development and rural change in Jiangsu Province

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Multiple-factor adoption of GM Cotton in China: Influence of conventional technology development and rural change in Jiangsu Province Abstract The large diffusion of Genetically Modified Cotton (GMC) in China, namely Bt-Cotton, has been well evidenced but recent report on its reduced profitability raises the issue of long term adoption. This paper targets to point out that the adoption of Bt-Cotton in China has not depended only on its specific advantages in controlling pests. It focuses on the specific case of Jiangsu Province, along the Yangtze River Valley, for which the use of GMC is little reported in publications accessible to most scientists of the international community. The paper synthesizes the recent analyses published in Chinese from people involved either in research or in extension activities and it exploits the results of a survey implemented in 2005 as well as the data of the network of multi-location experiments of cotton varieties in the Yangtze River Valley. It comes out that in Jiangsu Province, the diffusion of GMC has benefited a lot from the modernization of the seed sector which has integrated Bt trait into hybrid cultivars which are perfectly adapted and profitable to the transplanting technique. In spite of a rather limited reduction in the cost of pest control, farmers should not abandon using Bt-Cotton, because the evolution of Chinese farming does not push cotton growers to be so much vigilant in optimizing their production costs, unless seed prices keeps on tremendously increasing. The continuation of a profitable use of GMC should require some move to better regulate the seed sector.

Keywords: Bt-Cotton, China, farming, hybrid, seed market, transplanting Multiple-factor adoption of GM Cotton in China: Influence of conventional technology development and rural change in Jiangsu

Province 1. Introduction In China, the commercialization of Genetically Modified Cotton (GMC) started in 1997, with varieties integrating a Bt gene to control the attack from some cotton pests (Bt-cotton). Many research papers, mainly from the team, contributed to popularize the idea of successful adoption of Bt-cotton in China, in terms of profitability gain and reduction in pesticide use (Huang, Hu, et al., 2004; Huang, Hu, et al., 2002a; Huang, Hu, et al., 2002b; 2003; Huang, Pray, et al., 2003; Pray, Huang, et al., 2002). With reference to the large extent of GMC coverage, estimated at about 60% of the total cotton area in China, the success of the GMC diffusion must indeed be acknowledged.

The picture of this adoption is nevertheless more complex as cotton growing conditions are very diverse in China. While the results published in foreign language pertained mainly to the Yellow River Valley where the insecticide resistance of the cotton bollworm (Helicaverpa armigera) was the most severe before the GMC introduction, results in the two other cotton regions are little reported. The Xinjiang Province, North West of China, contributes for about one third of the Chinese cotton production. In this semi-arid continental region, the pressure of H. armigera is still very low: there is no use of Bt-cotton and little rationale for it. The Yangtze River valley is the third cotton region where the pressure of H. armigera has always been lower than in the Yellow River Valley. A few articles, published in Chinese, yet underlined a far smaller effect of Bt-cotton in reducing the number of chemical sprays against H. armigera , leading and in profitability gain, if any, of GMC use (Xu, You, et al., 2004; Xu and Ji, 2005; Zhang and Zhou, 2003).

Even in the Yellow River Valley, a recent communication clearly has questioned the continuation of the profitability of the Bt-cotton use because of the need to control more against formerly secondary pests and of the increasing cost of planting seeds (Lang, 2006). The threat of mirids against the sustainability of Bt-cotton success in China is now 2 acknowledged (Anonymous, 2006). The long term effectiveness is no longer be considered as ensured (cricaas, 2006). Several Chinese papers have yet emphasized the increasing damage of another Lepidoptera (Spodoptera litura or Prodenia litura) whose caterpillar, so far leaf eating, is attacking all fruit organs (Guo, Dong, et al., 2003; Li, 2004; Li, Wang, et al., 2004; Qin, Ye, et al., 2000). There seems to be reduction of the Bt-cotton effectiveness, could it lead farmers to move back from using it?

The objective of this paper is to address the above question by providing some comprehensive vision about the features of the diffusion of Bt-cotton in China. We contend that the diffusion of GMC in China benefited from pre-existing technologies and reversely, within a dramatic modernisation of the seed marketing. There was hence a phenomenon of technology integration favouring the use of Bt-cotton which cannot be totally questioned by a reduction in efficiency of this latter. Besides, this integration was also implemented within a dramatic change in the commitment in farming activities. Agriculture appears to be kind of secondary activity (Fok, Liang, et al., 2005) for which less attention might be given to its optimisation. Consequently, farmers could keep on using Bt-cotton more than justified, unless GM seeds become excessively expensive.

This paper exploits the recent analyses published in Chinese from people involved either in research or in extension activities. Specific attention is paid to the case of the Yangtze River Valley, by making use of a survey implemented in Jiangsu Province in 2005 and of the results of multi-location experiments of cotton varieties in the Yangtze River Valley. This paper is organized as follows. In section 2, the relative place of cotton production in Jiangsu Province is reminded and it will be elaborated the development of the major technologies which favoured the use of Bt-Cotton. In section 3, the main features of the cotton growing practices in Jiangsu Province will be pointed out and the impact of the GMC trait on productivity and profitability will be appraised. In Section 4, the influences of various factors sustaining the use of Bt cotton will be presented and discussed.

2. Cotton Production and adoption of new technologies in Jiangsu Province

2.1. Cotton production and processing in Jiangsu Province In Jiangsu Province, cotton production has a long history of about 700 years but upland cotton was introduced only in 1904. Since then, Jiangsu Province has become an important place both for cotton production and processing. In the 1981-2002 period, this province accounted for 35% of the cotton area along the Yangtze River Valley. At the national level, this province ranks fifth with 10% of the total cotton area. The average lint yield was 868 kg/ha, above the national mean. With regard to cotton processing in textile industry, Jiangsu Province has increased substantially its mill use of 800,000 metric tons by the end of the 1980s to 1,300,000 metric tons in 2004. This figure is about three times of the local production and it is representing about 1/5 of the total mill use in China.

The farmers' commitment in cotton production nevertheless is declining, since 1995, after a drastic change in the support policy to cotton before China entered WTO. The cotton area has decreased by about 50% as compared to the first half of the 1980s (Table 1). The in-depth analysis of this decline goes beyond the scope of this paper, it suffices here to underline that the great fluctuations of the purchase price of seedcotton1 discouraged farmers who can shift to more profitable alternative crops (Yu, Zhu, et al., 2004), in particular to cereals after the Chinese government applied area-based direct-payment to promote cereal production in 2004. Consequently, productions decreased but not at the same extent than area reduction because of a remarkable yield gain (Xu and Ji, 2005). This yield gain took place prior to the Bt-cotton introduction, thanks to various technology breakthroughs which are little known out of China. Indeed, nowadays, cotton producers make use of various chemical inputs. In addition to high level of fertilizing and of chemical control of cotton pest, farmers systematically apply growth regulators and frequently install cotton plants on plastic mulch. Farmers often eliminate 1 Per 50 kg of cotton lint, the purchase prices were 617, 390, 540, 340, 480 and 820 Yuan respectively for the years 1998, 1999, 2000, 2001, 2002 and 2003. 4 vegetative branches during the fruiting stage and top cotton plants to enhance boll growth. This brief description indicates the amount of technologies and knowledge passed to farmers. Hereafter, we only insist on the two major technologies which have favoured the diffusion of GMC, namely cotton transplanting and cotton hybrids.

2.2. Genesis, development and adoption of the transplanting technique In China, the research on cotton transplanting originated in Jiangsu Province in view of ensuring double-cropping. The contemplated solution was to implement production of cotton seedlings in nurseries and to transplant immediately after the harvest of cereal. The research works started in 1954 and first demonstration at farmers' level was conducted by 1955. The collectivist system could be part of the reasons why no real adoption followed. The technique itself was not perfectly mastered, notably at the nursery stage. The research works were resumed substantially in the late 1970s, after the liberalization of the agricultural economy. The adoption of cotton transplanting really has occurred during the 1980s in Jiangsu Province. It was noted that more than 90% of cotton producers implemented cotton transplanting in 2000 (Li, Ji, et al., 2000) and now one can hardly find a single cotton producer not implementing this technique in this Province. This technique is also extensively adopted in other provinces along the Yangtze River valley.

The transplanting technique now is perfectly commanded and its diffusion is due to its effectiveness and to various advantages it brought. In practice, the implementation of the transplanting technique encompasses five stages: soil preparation, making of nutritious blocks, sowing in nursery, transplanting and appropriate water management and fertilizing afterwards. Machines (pedal block press) have been carried out to manufacture the "nutritious blocks" on which seeds are deposited. Sowing is implemented in nursery which is covered by plastic film. The transplanting is implemented when the soil temperature is above 19° C. Cotton seedlings of 3-4 leaves stage are optimal. Seedlings are moved into pits previously dug and fertilized. Densities vary according to locations but are anyway lower than in direct sowing because of 5 the plant stronger vigour. Water management, and furthermore fertilizing of the cotton plots, must be adjusted to the higher yield expectancy resulting from greater growth and development observed with transplanted cotton plants (Table 2).

The technique nevertheless is very labour demanding. The soil preparation and the making of nutritious blocks also require arduous work. The labour investment is proportional to the plant density. As far as no mechanized solution is available, lower the density can be, lower is the labour requirement and better appreciated the technique will be. The supply of hybrid varieties, with more vigorous plants, eventually has helped meet this implicit demand.

2.3. Genesis, development and adoption of cotton hybrids

In China, the first hybridization was implemented in the 1940s (Xing, 2004). The first generation of cotton hybrid plants being obtained were strong and vigorous, showing important growth, great fructification, but their late fruiting after occurrence of frost led to low yields. Research on hybrids was resumed in the late 1970s. The resulting hybrid varieties were released in the early 1990 and combined high productivity, fibre quality and resistance to diseases. They did not diffuse so much because the prevailing cultivation techniques did not enable them to express their superiority (Liu, Han, et al., 2005). It was the adoption of transplanting which made hybrids more attractive.

When pest resistance to insecticides out broke, in the early 1990s, the genetic resistance to pest became the additional criterion to integrate into hybrids, by introgression of Bt gene. This integration eventually has led to the real development of hybrid use by farmers. At national level, the cotton area under hybrid varieties increased from 130,000 ha in 1998 to 530,000 ha in 2004 (Li and Liu, 2005), which represented about 10% of the total area. In some locations in Henan Province (Yellow River Valley), hybrids are representing 65% of the total cotton area (Ma and Zhang, 2005; Zhang, Wang, et al., 2005). Globally speaking, it is estimated that Bt-cotton hybrids correspond to about 80% of all hybrid cotton area (Xing, 2004). The use of Bt-cotton hybrids firstly started in the YanCheng District of Jiangsu Province, before 6 spreading to Hubei, Hunan, Jiangxi and Anhui Provinces along the Yangtze River Valley and before shifting northward to some provinces of the Yellow River Valley, like in Henan and Shandong Provinces (Li and Liu, 2005).

The real diffusion of hybrids did not derive only from the yield gain they brought, estimated at 15-25% on average (Xing, 2004). It also has benefited from the additional trait of pestresistance when most if not all hybrid cultivars have been made incorporating Bt-gene. Overall, the diffusion of hybrid cultivars has resulted from the modernization and development of the cotton seed industry after the introduction of GMC in China.

The large scale of commercialisation of Bt-cotton, firstly through American origin varieties, involved Delta & Pineland Company, and it corresponded to a real modernization of the seed market. The supply of cotton planting seeds was somehow revolutionized through the distribution of delinted seeds in attractive packaging, adjusted to the tiny size of the farmers' cotton plots, and through the guaranty on seed germination rate. The combination of the hybrid and GMC traits shortly became the general marketing strategy of seed distributors, in Jiangsu Province and other provinces. This strategy has permitted seed distributors to safeguard the seed market size and proceed to high seed pricing (Fok and Xu, 2007).

In a nutshell, the large extent of GMC use in provinces like Jiangsu does not depend only on its sole advantage of pest resistance. The command of the transplanting technique ensured the success of doubling-cropping, the use of vigorous hybrid plants enabled to decrease the associated labour requirement. The integration of Bt-gene further enhances the advantages of using hybrids. The prospects of a promising seed market push breeders to implement this integration. The analysis of how farmers are growing cotton provides more evidence about this phenomenon.

3. Features of GM Cotton use in Jiangsu Province

3.1. Diversity and changing picture of the cotton varieties used In the survey we conducted in 2005, covering 176 farmers scattered in four districts (LianYunGang, NanTong, YanCheng, TaiZhou), farmers are using a large range of cotton varieties. During the 2004 and 2005 campaigns covered by our survey, 33 distinct varieties were encountered. Farmers are showing a great versatility in the varieties they use: while 14 were maintained from 2004 to 2005, 7 were abandoned after 2004 and 12 were newly used in 2005. This result reflects the real situation of excessive varietal choices in China. In 2001, there were 120 varieties officially registered for commercial release. This figure was increased to 266 and 300 respectively in 2004 and 2005 (Lu, Tian, et al., 2006). This is an indication of how harsh the competition between cotton varieties now is.

The large range of varieties being used nevertheless is somehow misguiding since the farmers' preferences are concentrated on a limited number of varieties (Table 3). The most preferred variety could be adopted by 25-37% of all farmers. About 75% of the farmers are using a subgroup of five varieties. The implication is the reduction of the lifespan of the proposed varieties. This lifespan was 10-15 years during the 1980-85 period, 5-6 years in the 1995-2000 period and no more than 3-4 years in the 2001-2005 period (Lu, Tian, et al., 2006). This situation implies that only high seed pricing could help expect reaching reasonable profitability. In the surveyed area, hybrid cultivars prevailed among the varieties farmers used. Only 4 nonhybrid cultivars were encountered for the two campaigns. The same apply to the GMC cultivars (Table 4). Farmers are mainly adopting hybrid and GM cultivars: 79% are using hybrid cultivars either GMC or not, while more than 90% are using GMC cultivars, either hybrid or not. Actually, there are only 5.9% using cultivars which are neither hybrid nor GMC. There are great price differentials among seeds of various types of cultivars. There is a gap of about US$ 80/ha between hybrid and non-hybrid cultivars (Table 4). The price gap between GMC and non-GMC cultivars cannot be assessed with precision owing to the small number of farmers not using GMC. This price gap is estimated at US$ 5/ha and 7/ha respectively for 8 hybrid and non-hybrid cultivars. Clearly, the GMC characteristic is not responsible for the high increase of the seed cost in China. The diffusion of hybrid cultivars is.

The large adoption of hybrid cultivars looks amazing owing to their high seed cost, it can be understood by the generalization of the cotton transplanting technique in the surveyed villages where all farmers acknowledged the advantage of using hybrid cultivars to decrease the plant density, hence the labour requirement at the transplanting stage.

3.2. Intensive cropping and chemical pest control under evolution

Chemical products commonly involved in cotton production in China are growth regulators, mineral fertilizers and pesticides. The use of growth regulator is somehow systematic. In Jiangsu Province, our survey found that farmers apply in general growth regulator three times for a total cost of about US$ 8/ha, with locally-manufactured products. In terms of fertilizing, farmers combine diversely nine types de fertilizers, several of them are of low nutrient concentration. Consequently, the total amount of commercial products is high, about 1250 kg/ha. Our survey does not reveal difference in fertilizing in relation with the type of varieties farmers are using.

In our survey, farmers demonstrate a quite good knowledge of the cotton pests and beneficials. Farmers mention seven pests that must be controlled to prevent economic damages. As indicated in Table 5, farmers report evolutions of the pressures for various pests. These evolutions can be related to about ten years of Bt-cotton use. Pest pressures for bollworms have decreased, but they have clearly increased for red spider and lygus. The farmers' observation confirmed the increasing threat of Spodoptera litura, a caterpillar known commonly as a leaf eater and which is also damaging various fruiting organs. The reduction of bollworm pressure is consistent with the use of Bt-cotton and was actually expected. Nevertheless, the increasing threat of pests formerly considered as secondary ones was somehow overlooked.

Our survey tried to capture the number of chemical controls farmers applied for each pest for 9 which they might use distinct active ingredient. On average, for those farmers who answered, farmers implemented in total 14.4 controls in 2005, which must correspond to a smaller number of sprays as several controls can be combined into the same spray. Not all farmers applied insecticides against all cotton pests. In fact, if all farmers fight against the most common pests like bollworms, aphids and red spiders, this is not the case for pests like Spodoptera litura or lygus. The sum of the average control numbers for each individual pest consequently is different of the total number of controls implemented. These average numbers nevertheless remain interesting. They indicate that H. armigera and pink bollworm still need respectively about four and three chemical controls. It comes out that Spodoptera litura, a Lepidoptera generally overlooked, at least need one control. Non-lepidoptera pests, like sucking pests, are requiring as many chemical control as Lepidoptera ones, if not more. There seems to be a more relative importance of non-lepidoptera pests to be controlled and which go beyond the power of Bt-cotton varieties.

In terms of costs, the chemical control is representing around US$ 100/ha with some variation according to the types of varieties farmers are using (Table 6). The few farmers who did not grow Bt-cotton tend to implement 2-3 controls more, and which are targeted at H. armigera. Because the number of these farmers was too small, the differentials in the insecticide cost we observed are only indicative ones. Users of Bt-cotton spent US$ 92/ha, while users of non Btcotton spent US$ 142/ha, or US$ 50 more. In this total cost, the control of Lepidoptera pest accounts for slightly less than half.

3.3. GMC adoption with limited yield and profitability gain

There is not yet systematic use of hybrid cultivars or Bt-cotton cultivars. Our survey confirm that farmers are still using the four possible types of cultivars (Hybrid and Bt-cotton, Hybrid and non-Bt-cotton, Non-hybrid and Bt-cotton, Non-Hybrid and non-Bt-cotton) but their distribution is very unbalanced with predominance of hybrid and Bt-cotton users. As not all farmers responded to the questions related to their production costs, we miss information on 10 farmers who use hybrid but non-Bt-cotton cultivars. Besides, the number of farmers who use cultivars which are not hybrid or GMC cultivars was very small. The figures of the Table 6 have only indicative value and must be confirmed by further research work.

Under the reservation above mentioned, it seems that there is no productivity and profitability advantage from Bt-cotton when non-hybrid cultivars are considered. This observation is consistent with some previous research works (Xu, You, et al., 2004). The partial results we obtained from our survey do not enable us to pronounce in the case of hybrid cultivars and which were not specifically considered in previous research works.

Nevertheless, the advantage derived from hybrid cultivars appears to be very substantial in spite of the high seed cost. This observation confirms the rationale of the farmers' adoption of hybrid cultivars, at least in Jiangsu Province where transplanting is implemented.

We tried to complement our findings through the exploitation of available data. For more than fifty years, varietal experiments are implemented before the varieties are authorized for commercial release. These experiments are coordinated within regionalized networks in China. Jiangsu Province is integrated into the network of the Yangtze River Valley which encompassed 23 sites scattered in eight provinces. The results of the last five years (from 2001 to 2005) have been computerized and can be processed to assess the impacts of GMC or hybrid cultivars.

It is clear that, at the level of multi-location experiment before the commercial release of varieties, hybrid and GM varieties far dominate. It is also clear that the GM feature brought no yield advantage (Table 7), in the opposite of the hybrid feature whose positive effect on yield has to be statistically tested. Taking the seedcotton yield as a dependent variable, it can be assumed to be under the influence of various factors, notably the years, the provinces, the hybrid and the GM features of the varieties. All the predicting factors we retain are significant except for the GM feature of the varieties (Table 7). This outcome confirms that, at least along the Yangtze River Valley, there was no yield advantage resulting from the GM feature (in fact 11 the Bt feature) of the varieties but the positive effect of the hybrid feature is significant. In other words, it seems hard to dissociate the diffusion of GM varieties from the adoption of hybrid varieties.

4. Factors of the GMC future

The adoption of GMC in Jiangsu Province is not only influenced by the specific efficiency of GMC cultivars as it is implicitly considered in most assessment studies of GMC use. Along the Yangtze River Valley, and notably in Jiangsu Province, this specific efficiency is of limited extent and furthermore seems to be on reduction. Other factors have contributed to the GMC adoption and will influence the future of this adoption, namely the relatively low specific cost of GMC seeds, the marketing strategy of cotton planting seeds and the evolution of the Chinese farming.

4.1. Limited specific advantage of the low cost GMC trait

In opposite to what is observed in many countries, the use of GMC cultivars does not lead to significant increase in yield in China. Where this has been reported, like in provinces along the Yellow River Valley, the increase was slight while such increase was seldom confirmed in provinces along the Yangtze River Valley. The absence of yield effect in this Valley is confirmed by the provisional results of our survey and by the exploitation of the results from the network of multi-location varietal experiments.

The use of Bt-cotton actually induces a reduction of 2-3 in the number of chemical control against bollworms, far less than what has been reported in provinces along the Yellow River Valley. This reduction implies some saving in insecticide use which is not translated into a better net income. This is partly due to the increase of seed cost and to the higher cost in controlling the pests against which Bt-cotton is not effective. This observation is consistent to what is now acknowledged in China. For all that, the use of GMC is not generating income loss, or not yet, because the specific cost of the GMC trait is small. It is normal that farmers keep on using GMC in Jiangsu Province in spite of the limited efficiency it specifically brings.

4.2. Seed cost and marketing

Farmers in China have less reason to turn their back to GMC seeds because the specific cost of the GMC trait is low (US$ 5-7/ha in our survey). An even lower cost was found on average in Hebei Province in 2002 and 2003 where farmers held back seeds from one season to another (Fok, Liang, et al., 2005). This range of additional cost in using GMC, in absolute terms, is very low. In relative terms, the additional cost comes out to be furthermore small. Cotton cropping is very intensive in China and requires cash expenses for chemical use around US$ 350/ha against which the additional cost of the GMC trait represent less than 2%. This additional cost of the GMC trait may not even been perceived by farmers because it is confused with the hybrid trait which is well adapted to the transplanting technique.

The combination of the hybrid and GMC traits is becoming the general marketing strategy of seed distributors. The marketing approach of hybrid-GMC cultivars creates economic rents which can lead to excessive seed price. High pricing also results from the functioning of unregulated seed market (Fok and Xu, 2007).

There has been a very dynamic release of new varieties resulting from the acknowledgement of breeders' right (Yang, 2005). The implication is harsh competition and reduction of the lifespan of the proposed varieties. Marketing, notably through TV and magazine ads, hence is critical to survive competition, but it implies additional costs which further sustain high seed pricing. Nowadays, Chinese cotton growers are paying seed at prices similar to their counterparts in developed countries (USA, Australia) and prices keep on increasing at the expense of farmers' income.

The current situation of harsh competition is neither ensuring quality seeds to farmers. There is numerous seed production and distribution companies, most of small sizes, but the control and regulation system has not been updated to prevent some companies from competing through the release of fake hybrid seeds (Li and Liu, 2005). It is still common to encounter in the same village farmers producing seeds on behalf of distinct seed companies, of varieties which might 13 be hybrids or not, Hybrid F1 or not (Li, Zhao, et al., 2005). The threat on seed quality is clear. At the level of cotton growers, the diversity of the varieties they used at the same location, with seeds whose purity is not guaranteed, is inducing the undesired effect of quality heterogeneity (Lu, Tian, et al., 2006; Man, Xu, et al., 2006; Zhao, Wang, et al., 2005) or yield losses (Man, Xu, et al., 2006).

The Chinese case illustrates the relevance of some regulation (Liu, 2006) of the cotton seed market that the introduction of GMC has contributed to vitalize. The absence of actions to correct the current trend of increasing seed price in one hand, and in the other hand to ensure seed quality, could modify the adoption rate of GMC.

We actually have heard farmers complaining about the high price they pay for seeds and regretting the variety mixture phenomenon. This nevertheless might remain passive complain owing to the evolution of the farming in Jiangsu Province, like in many other provinces in China.

4.3. Farming and rural changes: factors of passivity?

The global income of farming families is increasing although its gap with urban families is increasing too (Figure 1). This is due to their involvement in off-farm activities which bring back regular wage income whose share is steadily increasing. The involvement in off-farm activities provides cash to afford rather high price seeds but it also tends to transform agriculture into a secondary activity for which the optimization target cannot be considered only through the mere reduction of production cost. The survey we conducted provides some evidence to this phenomenon.

In Jiangsu Province, according to our survey, farms are managed by people with an average age of 48. They cultivated on small farms of 6.4 mu (0.42 ha) with little prospect to increase their farm size. Cotton area was 3.6 mu (0.24 ha) on average in 2005, more than half of the available land. Farmers seldom have machineries for their agricultural production, our survey only recorded that all farmers had knapsack sprayers; some of them are equipped with a motor. 14 On average, there are three people per farming family of which 1.6 people are engaged permanently in field works. About two third of the farms we interviewed had members engaged in off-farm activities, either permanently or occasionally.

The extent of the engagement in off-farm activities explain why the farmers of our survey responded that agriculture (cropping, husbandry…) is on average representing 52% of their total income. This is an indication of the secondary feature of agricultural activities in terms of income generation. This feature is reinforced by the instability of the agricultural income resulting from product price fluctuations that farming families cannot control.

The engagement in off-farm activities varies between generations and gender (Table 8). Young people and males tend to more migrate out of their province of origin, leaving their own children at home under the care of their parents, a task which adds to the agricultural activities. In return, wage incomes enable families to get equipped with durable consumer goods of modern life to save time, to alleviate hardness, to communicate or for leisure (Table 9).

The people who remain most involved in farming are now shared between more opportunities to have leisure time and more responsibility in taking care of their grand-children, the optimisation of some production costs does not seem to remain the unique target. This optimisation could even be questioned from the economic viewpoint. Efforts of optimisation can be nullified by unfavourable price fluctuations that farmers have been experiencing since the liberalisation of the agricultural economy and which severely hurt cotton production these recent years.

This phenomenon hence could discourage people from making the needed efforts. This seems to be the case. Through our interaction with farmers, we realized that they complain about high prices of production inputs, in particular seeds, as well as about low purchasing price of the seedcotton they produce, but we felt no real intention of individual or collective moves to reverse these trends. Kind of vicious circle seems to be taking place. Farming is becoming secondary activity. This is leading to reduce efforts to optimize production costs, inducing 15 lower and more unstable agricultural income which makes agriculture appear furthermore secondary in generating income.

5. Conclusion

There is a general tendency to appraise the adoption of GMC through the specific advantages it might bring. This approach is debatable as it is disconnecting this technology to pre-existing technologies which may make GMC more or less attractive. China is providing an example to sustain the relevance of more comprehensively looking at the various factors which influence the GMC diffusion. Cotton growing in China has benefited from a series of remarkable and adapted technology achievements carried out well before the GMC introduction, namely transplanting and hybrid breeding. In Jiangsu Province, the specific yield advantage of GMC cultivars is of limited extent. In this province, the diffusion of GMC and its continuation hence are not due only to the GMC specific advantage but rather to its integration into hybrid cultivars which are perfectly adapted and profitable to the transplanting technique.

This more comprehensive approach also enables to predict that a reduction in effectiveness will not necessarily lead farmers to abandon GMC use. Nevertheless, the functioning of the cotton seed market leads to high pricing. If seed price keeps on rising as it is now observed and if seed quality is not ensured by lack of control and certification, farmers could modify their behaviours in buying seeds. Of course, the secondary characteristic of agriculture in farming families is corresponding to some level of inertia against this behaviour change, but the seed price has increased so much these recent years that the acceptable price level might have been approached yet. The Chinese experience points out that the regulation of the seed sector to accompany a smooth and profitable use of GMC is an issue which must be better considered.

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Sources: China Statistical Yearbooks

Table 1. Evolution of cotton production in Jiangsu Province, China

	1981-85	1986-90	1991-95	1996-00	2001-05	Average
Area, 1000 ha	660	430	560	370	350	491
Area, %	11.4	11.0	9.7	8.9	7.7	10.1
Lint Yield, kg/ha	884	692	894	1075	1183	868
Lint production, t	589	378	506	413	411	466
Production, %	13.7	12.0	11.0	9.6	8.0	11.1

Source: Xu, LiHua & Ji, CunMei, 2005

Table 2. Comparative advantages of transplanted cotton (results of early 1980s)

	Plant height	Fruit branch	Fruit position	Boll	Boll set	Boll weight	Seedcotton yield
	cm	No./plant	No./plant	No./plant	%	g	Kg/ha
Transplanting	103.4	17.1	52.2	15.7	30.2	3.59	2726
Direct sowing	93.2	13.5	43.8	11.8	26.9	2.95	2025

Table 3. Diversity and concentration of the cotton varieties being used

	2004	2005
Total number of varieties encountered	21	26
of which		
GM & hybrid varieties	9	17
GM & non-hybrid	8	5
Non-GM & hybrid	0	1
Non-GM & non-hybrid	4	3
% of farmers using		
TOP 1 variety	36.9%	24.6%
TOP 3 varieties	62.5%	57.9%
TOP 5 varieties	77.8%	73.8%

Source: our survey

Table 4. Distribution of the farmers according to the cultivar types

	Hybrid varieties		GM varieties	
	Yes	No	Yes	No
Farmers using, %	79.0%	21.0%	91.4%	8.6%
Planting seed price, US$/ha				
Mean value	92.1	12.4	79.4	32.8
Standard deviation	25.3	9.5	37.1	37.7

Source: our survey

Table 5. Farmers' practices and feeling about pest control

	Average number of chemical control	% farmers feeling that the pest pressure is			
		stable	decreasing	increasing	fluctuating
Helicoverpa armigera	4.1	4%	69%	9%	17%
Pink Bollworm	3.0	4%	53%	1%	15%
Spodoptera litura	1.5	3%	1%	57%	25%
Aphids	2.0	41%	7%	23%	22%
Lygus spp.	3.0	2%	2%	45%	40%
red spider	3.2	35%	2%	35%	24%
Yellow cutworm	1.0	21%	15%	3%	35%
Other	2.4	0%	0%	13%	0%

Source: our survey

Table 6. Cotton production cost and income according to the types of cultivars used

	Non-Hybrid varieties		Hybrid varieties
	GM	non-GM	GM
Planting seed cost, US$/ha	13.7	8.7	92
Growth regulater, US$/ha	7.1	7.1	7.1
Fertilizers Amount, kg/ha	1252	1252	1252
Fertilizers Cost, US$/ha	249.0	249.0	249.0
Number of pest controls	14.0	16.7	14.0
Cost of pest control, US$/ha	96.0	142.0	96.0
Seedcotton yield, kg/ha	3232	3457	4395
Gross income, US$/ha	1569.0	1678.0	2133.0
Income net of input expenses US$/ha	1203.2	1271.2	1688.9

Source: our survey

Table 7. Influencing factors of the seedcotton yields in multi-location varietal experiment

	GMC		Hybrid	
	Yes	No	Yes	No
Number of results	958	421	1099	280
Average yield (kg/ha)	3330	3330	3360	3225
Std error	690	750	705	675
Results of the model explaining the dependent variable of seedcotton yield				
Standardized coefficient, Beta	-.045		-.117	
t	-1.565		-4.329	
Sig. level	.118		.000	

Source: Multi-location varietal experiment Network of Yangtze River Valley

Table 8. Great extent of engagement into off-farm activities

	Types of family members concerned			
	Generation of farms' heads		Children of farms' h	
	Male	Female	Male	Female
% farms with engagement in off-farm activities	55%	24%	80%	86%
of which permanently	24%	2%	58%	54%
occasionally	30%	22%	22%	32%
Distribution of the farms involved in off-farm activities according to the locations of these activitie				
within the district of the farms concerned	71%	95%	40%	53%
Out of the district of the farms concerned				
of which, within the same province	14%	5%	31%	28%
out of the Province	15%	0%	29%	19%

Source: our survey

Table 9. Material welfare in farming families

	% of farmers		
	having	having one	having more than one
Bicycle	95%	44%	51%
motobike	48%	43%	5%
Fixed phone	80%	78%	2%
Mobile phone	53%	39%	14%
TV set	95%	75%	20%
Rice cooker	77%	73%	3%
Microwave_oven	14%	14%	0%
Electric fan	96%	23%	73%
Washing Machine	59%	57%	1%

Source: our survey

Figure 1. Increasing income gap between rural and urban families