Technology integration and seed market organization: The case of GM Cotton diffusion in Jiangsu Province (China)

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Abstract

Several papers contributed to popularize the idea that the specific advantages of Bt-cotton have permitted the successful diffusion of Genetically Modified Cotton in China. The efficiency of Bt-cotton however fluctuates between cotton production regions. In Jiangsu Province, along the Yangtze River Valley, there is not really yield increase, reduction in insecticide control is small and, globally, there is no income gain associated specifically to the use of Bt-cotton.

The use of Bt-cotton is nevertheless almost general there. A more comprehensive approach, beyond focussing on the Bt-cotton specific effects, helps to explain this apparent paradox. In Jiangsu province, the diffusion of Bt-cotton has benefited from its integration into hybrid cultivars which are perfectly adapted to the profitable transplanting technique. This Chinese case indicates that the appraisal of Bt-cotton use in other countries should consider the extent to which this use would be compatible (or not) to existing production technologies.

In China, the commercialisation of Bt-cotton has induced the modernization of the planting seed market. Farmers firstly benefit from this process before suffering now from the resulting high pricing strategy. If Bt-cotton is to give more than it takes from farmers, some regulation of the seed market is desirable.

Keywords: Agriculture, Biotechnologies, Seed industry, varieties, Competition, Seed Marketing

INTRODUCTION

In China, the commercialization of Genetically Modified Cotton (GMC) started in 1997, with varieties integrating a Bt gene (Bt-cotton) to control the attack from some cotton pests, notably H. armigera. It is estimated that Bt-cotton is covering about 60% of the total Chinese cotton area (ISAAA 2005), but the extent of this diffusion is even more important than indicated by this figure. Indeed, among the three regions where cotton is grown (Figure 1), the use of Bt-cotton is little relevant. The Northwest region is a semi-arid continental one (Xinjiang and Gansu Province) accounts for about one third of the Chinese cotton production. In this region, the pressure of H. armigera is still very low and there is little rationale for using Bt-cotton. This use hence is only relevant, and actually generalized, in the two other cotton regions, along the Yellow River Valley in one hand and, in the other hand, along the Yangtze River valley.

(Figure 1, around here)

This large diffusion is supported by the Bt-cotton efficiency as it is reported by many research papers, although based on the results of the same team. These papers targeted at demonstrating the profitability gain and the reduction in pesticide use associated to Bt-cotton varieties, mainly in provinces along the Yellow River Valley (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). They tend to indicate that the GMC diffusion is based upon the specific advantages this cotton has brought, in the vein of the general tendency to appraise GMC from its specific impacts. In terms of methodology, this tendency transpires in the partial budget approach many scientists have used to assess the profitability of GMC (Elena 2001; Gianessi, Silvers, et al. 2002).

This approach in focussing on the specific impacts of GMC could be misguiding in appraising its adoption or non-adoption. Even in China, this approach is not sufficient to explain some observations. In some provinces along the Yangtze River Valley (where the pressure of H. armigera has always been lower than in the Yellow River Valley), a few articles, published in China, yet underlined a smaller effect of Bt-cotton use in reducing the number of chemical sprays against H. armigera , leading to a less profitability, if any (Xu, You, et al. 2004; Xu and Ji 2005; Zhang and Zhou 2003) although the use of Bt-cotton is very frequent among farmers.

This paper targets to check whether such an apparent paradoxical situation actually exists and to explain it. It concerns Jiangsu Province, one of the main cotton provinces along the Yangtze River Valley. It makes extensive reference of scientific communications in Chinese which are of little access to most foreign scientists and it is mainly based on the exploitation of two sets of data.

Firstly, data from a survey conducted in 2005 and covering 176 farmers scattered in four districts (LianYunGang, NanTong, YanCheng, TaiZhou). The second set of data corresponds to the results of the network of multi-location experiments of cotton varieties in the Yangtze River Valley. Regarding the comparative profitability of various types of cotton cultivars, our contribution nevertheless provides only provisory results because of the difficulty to find contrasted situations in the use of cotton varieties, owing to the large and rapid adoption of Bt-cotton in China. Besides, not all farmers responded to the questions to capture production costs and those who responded did not answer to all questions. Consequently, statistical analysis is limited and the information related to production costs must be considered only for indicative value before confirmation by additional research works.

This paper is organized as follows. In section 2, we confirm the reality of the almost generalization of Bt-cotton use in Jiangsu Province. In Section 3, we provide indicators of the low specific profitability generated by the Bt-cotton feature. In Section 4, we explain the apparent paradox of large adoption of Bt-Cotton by its successful integration into pre-existing technologies and by the evolution of the seed market organization which favoured this integration.

COTTON PRODUCTION AND FARMING IN JIANGSU PROVINCE

Cotton production and processing in Jiangsu Province

In Jiangsu Province, cotton production has a history of about 700 years. This province has become an important place both for cotton production and processing. In the 1981-2002 period, this province ranks fifth with 10% of the total cotton area in China. The average lint yield was 868 kg/ha, above the national mean. With regard to cotton processing in textile industry, Jiangsu Province substantially has increased 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 joined 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 seedcotton[1] have discouraged farmers who can shift to more profitable alternative crops, notably to cereals after the Chinese government has applied an area-based direct-payment to promote cereal production in 2004 (Yu, Zhu, et al. 2004).

(Table 1, around here)

Consequently, productions decreased but not at the same extent than area reduction because of a remarkable yield gain (Table 1). This yield gain took place prior to the Bt-cotton introduction, thanks to various intensification techniques at farmers' level. Cotton producers make use of various chemical inputs. In addition to the high level of fertilizing based upon mineral fertilizers and of chemical control of cotton pest, farmers systematically apply growth regulators and frequently install cotton plants on plastic mulch. In their yield maximisation approach, farmers also invest strongly in labour: they often eliminate vegetative branches during the fruiting stage and top cotton plants to enhance the boll growth. This brief description demonstrates the amount of technologies carried out and passed to farmers; this particular situation has seldom been mentioned in papers dealing with GMC diffusion in China.

Cotton Farming and variety use

In Jiangsu Province, according to our survey, farms are managed by people born after the establishment of New China, with an average age of 48. Peasants cultivate on small farms of 6.4 mu (0.42 ha), devoting 3.6 mu (0.24 ha) to cotton in 2005, more than half of their 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. They all install cotton plots through the transplanting method in spite of its labour intensity (see infra).

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.

The large range of varieties being used nevertheless is somehow misguiding since the farmers' preferences are concentrated on a limited number of varieties (Table 2). The most preferred variety could be adopted by 25-37% of all farmers. About 75% of the farmers are using a sub-

[1] Per 50 kg of cotton lint, the purchase prices were 617, 390, 540, 340, 480 and 820 Yuan respectively for the the years 1998, 1999, 2000, 2001, 2002 and 2003.

group of five varieties. This phenomenon of concentration is confirmed by the interviews with some seed distributors and it is actually prevailing in all cotton provinces.

(Table 2, around here)

In the surveyed area, GMC cultivars very much prevailed among the varieties used by farmers. The same apply to hybrid cultivars. Only 4 non-hybrid cultivars were encountered for the two campaigns (Table 3). Indeed, 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.

(Table 3, around here)

There are great price differentials among seeds of various types of cultivars (Table 3). There is a gap of about US$ 80/ha between hybrid and non-hybrid cultivars. According to Table 3, the gap between GMC and non-GMC cultivars is close to US$ 50/ha, this figure nevertheless is far much over-estimating the real price differential derived from the GMC feature because it is biased by the large share of hybrid and GMC cultivars among the varieties used by farmers. In our sample, under the reservation of the small number of farmers not using hybrid or GMC varieties, the GMC feature specifically induced a price differential of US$ 5/ha and 7/ha respectively for hybrid and non-hybrid cultivars. Clearly, in the opposite of what is observed in other countries (with likely the exception of India where hybrid cultivars are disseminated too), the GMC characteristic is not responsible of the high increase of the seed cost in China. The diffusion of hybrid cultivars is. The approach of diffusing hybrid cultivars is leading Chinese cotton growers of Jiangsu Province to pay GMC seeds at a level close to what is encountered in other countries, notably the developed ones. This convergence was not observed in Hebei Province (Yellow River Valley) a couple of years ago when mainly open-pollinated cultivars were disseminated (Fok, Liang, et al. 2005). According to discussions with a few seed distributing companies, the seed cost tends to be around US$ 120/ha now.

It comes out clearly that cotton farmers all transplant and almost all use exclusively varieties which are both GMC and hybrid cultivars. This situation seems to prevail for several years yet. It implies that it could be erroneous of talking about the impact of GMC use irrespective to the effects of hybrids and transplanting.

GMC under high level of chemical use

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 in general apply growth regulator three times for a total cost of about US$ 8/ha, with products manufactured locally at price far much lower than in developed countries.

In terms of fertilizing, farmers combine diversely nine types of 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 used by farmers.

Farmers mainly use insecticides to control cotton pests. In our survey, farmers demonstrate a quite good knowledge of the cotton pests. Farmers mention seven pests that must be controlled to prevent economic damages. As indicated in Table 4, 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 (Guo, Dong, et al. 2003; Li 2004; Qin, Ye, et al. 2000). The reduction of bollworm pressure was expected from the use of Bt-cotton and was confirmed by the first impact assessments of this use. However, the increasing threat of pests formerly considered as secondary ones was somehow overlooked.

(Table 4, around here)

LOW SPECIFIC PROFITABILITY OF BT-COTTON

Limited reduction in insecticide use

Our survey tried to capture the number of chemical controls farmers applied for each pest for which they used distinct active ingredients (Table 4). 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 to the total number of controls implemented. These average numbers nevertheless are quite informative. 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 needs one control. Non-lepidoptera pests, like sucking pests, are requiring as many chemical controls 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 used (Table 5). 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. Users of Bt-cotton spent US$ 92/ha, while users of non Bt-cotton spent US$ 142/ha, or US$ 50 more. In this total cost, the control of Lepidoptera pest account for slightly less than half.

(Table 5, around here)

GMC adoption with limited yield and profitability gain

There is not yet systematic use of hybrid cultivars or Bt-cotton cultivars. Our survey confirms 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 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 5 have only indicative value and must be confirmed by further research work for statistical value.

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 on the specific Bt profitability among hybrid cultivars. To our knowledge, there is no previous research works focussing specifically on this aspect.

Substantial profitability of hybrid varieties

Nevertheless, the advantage derived from hybrid cultivars appears to be very substantial in spite of the high seed cost which is largely compensated by far higher yield. 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 other sources of available data.

Technology integration and GMC seed market

For more than fifty years, varietal experiments have been 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 22 sites scattered in eight provinces. The results of the last five years have been computerized and can be processed according to their GMC or hybrid trait.

As it can be seen in Table 6, for the whole 5-year period, there was no yield difference between GMC and non-GMC cultivars, although slight difference could be observed for three years thanks to the great number of results obtained. Hence, GMC did not provide systematically yield gain even under the perfect growing conditions in experiments.

(Table 6, around here)

The yield advantage of hybrid cultivars is confirmed but at a level far less than indicated by our survey. This discrepancy can be explained by the fact that cultivation practices were better implemented in the varietal experiments, notably with regard to plant density. In other words, hybrid cultivars can even show greater yield advantage under the farmers' conditions of less optimal density installation.

These observations are confirmed when the geographic locations of the varietal experiments are taken into account. Owing to the distinct natural conditions for cotton growing, the analysis of the yield difference within the same provinces makes better sense since results are quite different between provinces. In this case, it comes out that GMC cultivar is only significantly superior in one province (Table 7) during the last 5-year period (Zhejiang) while it was significantly inferior in another province (Jiangxi). With regard to hybrid cultivars, their yield superiority has been encountered in three provinces and at a larger extent than when geographic locations are not considered.

(Table 7, around here)

FACTORS OF GMC ADOPTION

The adoption of GMC in Jiangsu Province is not only influenced by the specific efficiency of GMC cultivars. This is opposite to what is implicitly considered in most assessment studies of GMC use in the world. Along the Yangtze River Valley, and notably in Jiangsu Province, this specific efficiency is of limited extent. Other factors contribute in the adoption of GMC, namely the compatibility of pre-existing and high performing technologies in one hand and, in the other hand, the evolution of the planting seed market which favours the integration of GMC into pre-existing technologies.

Favourable situation of pre-existing technologies

The introduction of Bt-cotton benefited from a favourable economic and technical context for its adoption. In a nutshell, the shift towards individual farming made the implementation of the high yielding technique of transplanting far more attractive than before 1980, in spite of its labour requirement. This labour requirement is proportional to plant density. The highest vigour of hybrid plants permits to reduce plant density, making hybrid cultivars particularly adapted to the transplanting technique yet familiar to cotton growers. The introduction of the pest resistance trait of Bt-cotton offered the opportunity to further enhance the interest of hybrid cultivars.

In China, the research on cotton transplanting originated in Jiangsu Province. The Chinese government was concerned by meeting the needs in cereal and cotton lint of an increasing population (20% of the world population enjoying only 7% of the world arable land). Double-cropping was the keyword, but the constraint was the possible occurrence of early frost. The technical challenge was to install cotton crop right after the harvest of wheat or barley and to ensure that cotton bolls would open before frost. 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 but adoption did not follow (Zhu, Ni, et al. 1991). The collectivist system could be part of the reasons because there was no reward to compensate harsh work. The technique itself was not perfectly mastered, germination rate was insufficient at nursery and transplanted seedlings were weak.

The adoption of cotton transplanting really occurred during the 1980s. 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 Jiangsu Province. This technique is also extensively adopted in other provinces along the Yangtze River valley as well as in some northern provinces along the Yellow River valley (Zhu, Ni, et al. 1991).

The transplanting technique now is perfectly commanded and provides various advantages to farmers. 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) for which recommendations are clearly carried out[2].

Advantages from transplanting are manifold. Briefly speaking, the shortening of the main root during the transplanting process is favourable to the development of primary branch roots and their assimilation capacity. As compared to direct sowing, transplanted cotton plants show larger leaf area, earlier development, earlier boll forming, and greater number of early and middle bolls. More bolls which weighed more (Table 8) led to a yield increase of about 35% (in experiments of 1980-81).

(Table 8, around here)

The technique nevertheless is very labour demanding. The soil preparation and the making of nutritious blocks require also arduous work, even for men. The labour investment is proportionate 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, will eventually meet this implicit demand.

China very early paid attention to the creation of cotton hybrids, firstly through inter-specific crossings: the first national conference for the creation of cotton hybrids was organized in 1956. Attention shifted later to the creation of intra-specific hybrids. A research group dedicated to this topic was formed in the late 1970s. The first marketing of hybrids of intra-specific hybrids started in the early 1990. These cotton hybrids were developed according to the criteria of productivity, fibre quality and resistance to diseases. They did not diffuse so much because the prevailing cultivation technique did not enable them to express their superiority. The farmers' practices in term of planting densities, and the late period of sowing (after the harvest of wheat or barley) appeared not to be compatible with the hybrid growth and development features (Liu, Han, et al. 2005). This situation changed when the promotion of hybrid cultivars specifically targeted at provinces where cotton is transplanted.

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[2] The preparation of the soil to be used in nursery is particular. It is recommended to reach organic matter content over 2% and minimum contents of available nitrogen, phosphorous and potassium. Sowing in nursery is operated on blocks of soil which are called "nutritious blocks" made from the soil previously prepared. Machines have been carried out to manufacture the "nutritious blocks". Blocks are cylinders of 6-7 cm in diameter and 7 cm high. A small dip of 1.5 cm deep is formed at the upper surface of each block where seed is sown. Sowing in nursery can be implemented through two possible ways. One is to install the sown blocks into a plastic-covered frame. Another way is to plastic-mulch the sown blocks directly. The transplanting is implemented according to well-determined conditions. It is recommended to transplant after 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 the plant stronger vigour.

Development and adjustment of the cotton seed market

Hybrid cultivars existed for a long time but the market of hybrid seeds did not develop before 1998, just after the marketing of GMC which has induced a dramatic change in the cotton seed market. Before 1998, hybrid seeds which used to be marketed were mainly F2 ones, because it was considered that the production cost of F1 seeds were too high for farmers to afford them. Indeed, the productivity in F1 hybrid seed production was very low, at about 0.3 kg of seeds per worker-day. Nevertheless, the strategy of marketing F2 seeds encompassed its own shortcoming in the sense that hybrid F2 seeds did not show obvious superiority towards open-pollinated seeds (Li and Liu 2005). Consequently, farmers seldom demanded these seeds.

The hybrid seed market has finally developed thanks to the reduction of the relative price of hybrid seeds, as a result of technical progress in seed production and particularly of the introgression of Bt gene to make hybrid cultivars more appealing.

In the late 1970s, hybridization was implemented on selected flowers of selected plants. Since the late 1980s, hybridization was implemented on plant basis, on every flower of the plants, productivity increased to 0.8 kg of seeds per worker-day. This still is the dominant mode of hybrid seed production today, requiring about 2000 (wo)man-day per hectare, for a production of about 1000 kg of seeds, meaning that 45-60 persons are required to timely emasculate one hectare (Li and Liu 2005). Production through male sterility has now started. It resulted from the discovery of a naturally male sterile plant in Sichuan province in 1972. Today there are 16 varieties of this kind being recorded (Xing 2004). The production by two-line method (male sterility line and it's restorer line) reduces production labour cost from US$3.62/kg (Yuan 30/kg) to US$2.41/kg (Yuan 20/kg), while it is expected that three-line method (male sterility line, maintenance line, and restorer line) will help to further decrease production cost at Yuan 10/kg. The production by male sterility is not yet widespread because the distinction of male and female lines requires more space, a seriously scarce factor in China. Besides, the issue of fertility restoration line limits the number of parents to integrate into hybrids.

The addition of a new benefit accounted more in the expansion of the use of hybrid cultivars. When pest resistance to insecticides out broke, firstly in 1992-93 in the Yellow River Valley, then in 1998 in the Yangtze River Valley, the genetic resistance to pest became the additional criterion to integrate. It was the second generation of intra-specific hybrids integrating pest resistance, through the introgression of Bt gene, which eventually led to the real development of hybrid use by farmers.

Technology integration and GMC seed market

Hybrids are now commonly used. 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 like in Henan Province (Yellow River Valley), hybrids are representing 65% of the total cotton area (Ma and Zhang 2005; Zhang, Wang, et al. 2005).

Making hybrid cultivars pest resistant impacted a lot on their diffusion. 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 spreading to Hubei, Hunan, Jiangxi and Anhui Provinces along the Yangtze River Valley and before shifting northward to some provinces where cotton transplanting is implemented too, like in Henan and Shandong Provinces (Li and Liu 2005); but penetration is still uncertain: in Shandong, cotton hybrid still account for less than 15% of the seed market (Li, Zhao, et al. 2005).

The real diffusion of hybrids did not derive only from the yield gain they brought (Xing 2004), estimated on average at 15-25% (Huang 1998) under transplanting technique. This advantage of hybrids is relatively enhanced by the additional trait of pest-resistance, which has reduced somehow insecticide use and has made pest control more convenient.

A drastic change in the strategy of seed marketing certainly accounted the most in the development of the cotton seed market. The large scale of commercialisation of Bt-cotton, firstly through U.S. origin varieties, involved the well acknowledged seed company, Delta & Pineland Company, 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 guaranty on seed germination rate.

The combination of the hybrid and GMC traits seems to be the general marketing strategy of seed distributors. This is an approach which has protected them against the farmers' temptation to hold back seeds from one season to another and hence to safeguard the seed market size. Indeed, the share of the seeds farmers hold back from one season to another was reduced from 30.4% to 16.1% at the same period of 2001-4 (Lu, Tian, et al. 2006). This marketing orientation is not specific in Jiangsu Province or in China. The same trend is being observed in other provinces in China, even where hybrid cultivars do not necessarily induce the same level of yield gain. This strategy is clearly retained in India with the exclusive marketing of hybrid Bt-cotton (Bennett, Ismaël, et al. 2005) since 2002.

Technology integration and GMC seed market

This strategy seems to be more profitable to seed distributors in China. From 1995 to 2005, the labour cost has increased from US$1.20 to about 2.22/day (or Yuan 10/day to about 18/day). Consequently, the production cost of hybrid seeds had increased from US$2.90 to 3.95 (or Yuan 24/kilo to Yuan 32/kilo) (Xu, Qian, et al. 1999; Yan, Wang, et al. 2006), in the same time the market price of hybrid seeds has increased from US$12.08 to 31.00/kg (or Yuan 100/kilo to Yuan 251.4/kilo) (Anon. 2004).

Within this marketing strategy, GMC appears to be kind of secondary marketing argument, inducing rather limited increase in the seed price (see supra, about US$ 5-7/ha). This is opposite to what is observed in all other countries using GMC.

Questionable effects of the current seed market organisation

The apparent business attractiveness of the cotton seed market is responsible of the current situation of excessive varietal choice which is detrimental to the quality of the Chinese cotton. 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.

At national level, there is also the phenomenon of concentration of farmers' choice on a limited number of varieties (as we observed in the case of our survey), but the diversity of the varieties being used by farmers at the same location is inducing the undesired effect of quality heterogeneity underlined by several recent studies (Lu, Tian, et al. 2006; Man, Xu, et al. 2006; Zhao, Wang, et al. 2005). The high level of technology characteristics embedded in newly bred varieties is not achieved at field level because of the mixture phenomenon occurring at the seed production stage and/or at the marketing of the farmers' seedcotton production. This phenomenon is inducing yield loss for the farmer and quality loss at the spinner level (Man, Xu, et al. 2006).

The situation of excessive varietal choice leads also to high pricing of seeds at the expense of farmers. The process of cotton breeding has become a very dynamic one, as a consequence of the acknowledgement of breeders' right (Yang 2005). 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). Every seed distributing company is expecting to provide one of the happy few cultivars having the farmers' favour. Marketing hence is critical through various means (notably TV ads), implying additional costs. The investment in carrying out and in promoting a new variety has to be paid back in a shorter and shorter period, implying automatically high seed pricing. Yet, for Chinese cotton growers, the cost expense of seeds is quite similar to the one encountered in developed countries (USA, Australia) and it seems that it keeps on increasing at the expense of farmers' income. We actually heard farmers complaining about the high price they pay for seeds.

The farmers' discontent can be exacerbated by the lack of guaranty of paying for quality seeds because of the lack of actual regulation of the seed production. The high price of cotton seeds (hybrid cultivars) attracted many new seed firms to join the market. It is estimated that, at national level, there are around forty hybrid seed suppliers producing seeds on 3,300 ha. Most of these seed firms are small size ones, producing only on tens of hectares. It is estimated that less than ten seed companies produce on more than 67 ha (1000 mu), there are only a couple of large cotton hybrid seed companies[3]. Most companies have a seed production area in the range of 13.3-20.0 ha. In addition, it is common to encounter in the same village farmers producing seeds on behalf of distinct seed companies, of varieties which might be hybrids or not, Hybrid F1 or not (Li, Zhao, et al. 2005). The threat on seed quality is clear.

The current situation of harsh competition is neither ensuring quality nor fair price to farmers. It is acknowledged that there is a positive relationship between the size of the seed company and the quality of their seeds. Only large companies have the needed means to control that the seed producing farmers they contract are doing properly, but these companies will not necessarily survive the current competition as far as 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). The Chinese case illustrates the relevance of some regulation of the cotton seed market that the introduction of GMC has contributed to vitalize. This is a requirement which attracted little attention from scholars assessing the impacts of GMC use.

CONCLUSION

Several papers released continuously in a short period contributed to popularize the idea of the successful diffusion of GMC in China and to emphasize the specific advantages of Bt-cotton (in reducing insecticide use) in this success. This result was obtained in provinces along the Yellow River Valley where the pest resistance to insecticide was most severe. It has been recently

[3] The Shandong Nong Xing Zhong Ye Ltd is among the biggest. It started cotton hybrid production in 1991, and it is now producing on 1000 ha.

debated because of the increase of seed price and of the need to control more against some pests which were secondary ones (cricaas 2006; Lang 2006). Less favourable results were reported in some provinces along the Yangtze River Valley but they were overlooked likely because they were published in Chinese. The research work we recently implemented confirms that, in Jiangsu Province, there is not really yield increase and insecticide control against Helicoverpa armigera is reduced only by 2-3 times. Globally, there is no significant income gain associated specifically to the use of Bt-cotton. The use of Bt-cotton nevertheless does not induce yield losses as it has been reported for India (Anon. 2006; Qayum and Sakkhari 2005). In spite of a rather limited gain specifically brought by Bt-cotton, its use is almost general.

This result which might sound paradoxical in fact questions the general tendency of appraising the adoption of GMC through the specific advantages it might bring. Certainly, from the perspective of the GMC advocators, this tendency makes sense in presenting it as a miraculous product. Objectively, this approach is debatable as it is disconnecting this technology to existing technologies which may make GMC more or less attractive. A more comprehensive approach in appraising the GMC diffusion should make better sense.

China is providing a very valuable illustrative case. Cotton growing in China has benefited from a series of remarkable and adapted technology achievements carried out well before the GMC introduction. In Jiangsu Province, the assessment of the GMC adoption cannot be disconnected from the large diffusion of the transplanting technique and the offer of hybrid cultivars. The specific efficacy of GMC could be rather small, but the global efficiency of the whole set of technologies integrating GMC could be far more attractive. This experience in Jiangsu Province indicates that the prospective appraisal of GMC use in other countries will gain from an assessment of the extent to which GMC would be compatible (or not) to existing production technologies in these countries.

In Jiangsu province, the diffusion of GMC is 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. It seems that GMC and hybrid technologies helped each other. The introduction of pest resistant cultivars helped to set up a modern seed distribution system and to open business opportunities for hybrid cultivars. In the same time, the pre-existing development of hybrid cultivars and its evidenced adaptation to transplanting helped the diffusion of GMC.

It hence comes out that the commercialisation of GMC has had very important implications on the planting seed market in China. In one side, the positive impact on the modernization of the planting seed sector must be emphasized. In the other side, the combination of GMC and hybrid technologies orients somehow the cotton seed market with debatable outcomes. Farmers firstly benefit from the modernization of the seed market but they seem to mainly suffer from its evolution. The tendency to exclusively distribute hybrid seeds, even in places where the use of hybrids is not so much valuable, is basically a move to preserve technology rent. This seed marketing strategy, along with the harsh competition prevailing in the seed market, implies high pricing which is detrimental to farmers' cotton income. Some regulation of the seed market is desirable to defend farmers' income, to prevent wastage of breeders' efforts through mixture of varieties, and hence to preserve the benefit to the whole cotton sector.

Figure 1. Cotton regions and provinces in China

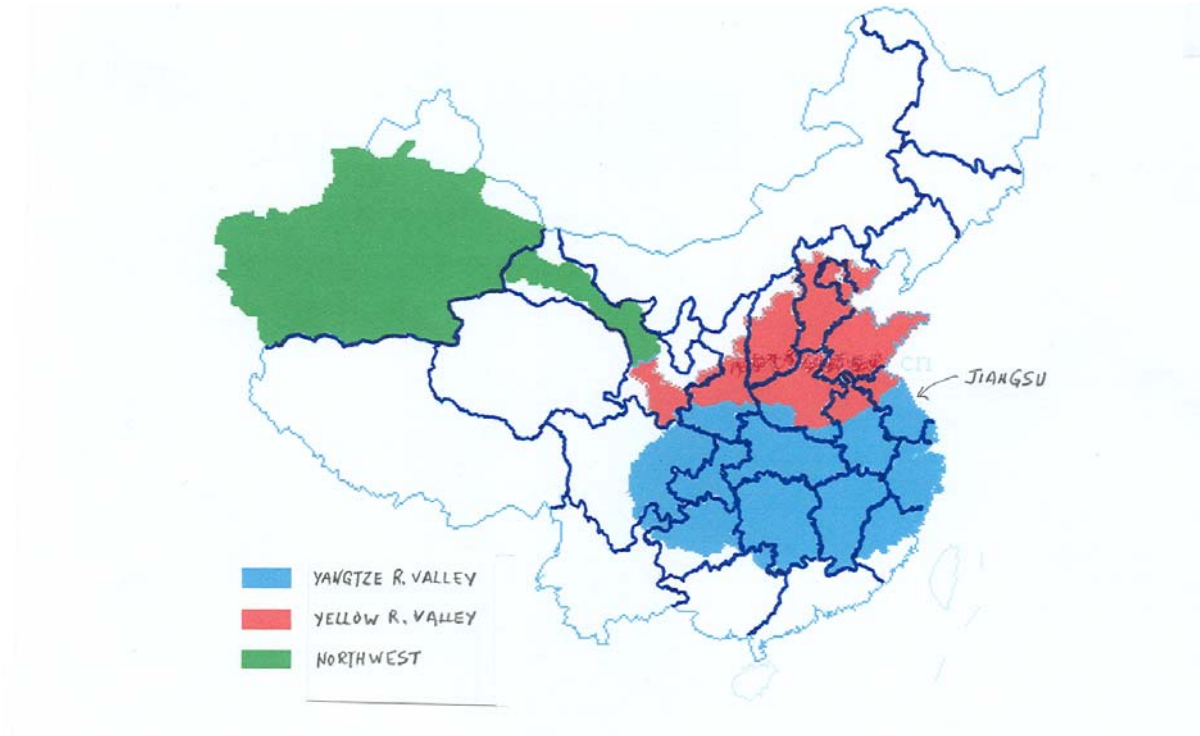

Table 1. Evolution of cotton production in Jiangsu Province, China

	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.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 3.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 4.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 5.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 6.Yield effect of cultivar types according to production years

		Hybrid varieties		GM varieties	
		Yes	No	Yes	No
2001	Number results	132	56	132	56
	Mean value	3750**	3405	3825*	3555
	std. Deviation	675	690	675	690
2002	Number results	79	47	79	47
	Mean value	3615	3525	3660	3540
	std. Deviation	675	615	675	630
2003	Number results	219	44	202	61
	Mean value	3045	2970	3015	3120
	std. Deviation	735	675	720	765
2004	Number results	219	86	261	44
	Mean value	3540**	3165	3465*	3270
	std. Deviation	555	555	555	645
2005	Number results	446	43	386	103
	Mean value	3255*	2985	3150**	3045
	std. Deviation	690	750	660	795
5 years	Number results	1099	280	958	421
	Mean value	3360**	3225	3330	3330
	std. Deviation	705	675	690	750

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

Table 7. Yield effect of cultivar types according to production provinces

		Hybrid varieties		GM varieties		all varieties
Provinces		Yes	No	Yes	No	
Anhui	Number results	108	27	92	43	135
	Mean value	3 720	3 540	3 690	3 675	3 690
	std. Deviation	540	450	540	525	525
Henan	Number results	52	13	44	21	66
	Mean value	2 775	3 015	2 775	2 925	2 835
	std. Deviation	450	465	420	525	465
Hubei	Number results	282	72	248	106	354
	Mean value	3 525**	3 195	3 465	3 450	3 450
	std. Deviation	660	750	675	735	690
Hunan	Number results	188	48	165	70	236
	Mean value	3 690*	3 450	3 630	3 675	3 645
	std. Deviation	630	735	555	870	660
Jiangsu	Number results	193	49	169	73	242
	Mean value	2 850	2 805	2 835	2 880	2 850
	std. Deviation	690	645	675	705	675
Jiangxi	Number results	76	19	62	33	95
	Mean value	3 270	3 360	3 135	3 540**	3 300
	std. Deviation	600	585	540	555	600
Sichuan	Number results	115	29	106	38	144
	Mean value	3 165	3 165	3 195	3 030	3 150
	std. Deviation	660	555	660	585	630
Zhejiang	Number results	57	13	48	22	70
	Mean value	3 600*	3 330	3 645**	3 285	3 540
	std. Deviation	405	390	375	420	420

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

Table 8. Comparative advantages of transplanted cotton

	Plant height cm	Fruit branch No./plant	Fruit position No./plant	Boll No./plant	Boll set %	Boll weight g	Seedcotton yield 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

Source: Huang 1998

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