Bt Cotton and Maize: Associated Benefits and Problems in the Developing World

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Abstract

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Insect resistant genetically modified (Gm) crops containing genes from *Bacillus thuringiensis* (Bt) have been grown commercially for 15 years. Bt cotton and maize are the two Gm crops most widely grown in developing countries. Bt technology was developed by multinational seed companies for the benefit of large-scale commercial farming, where it has provided effective control of certain Lepidopteran insect pests and decreased insecticide use. The benefits of adoption are more controversial for smallholders and a mixed picture emerges. South Africa has grown Bt crops since 1994 but until 2008, no Gm crops were grown in the rest of Africa. In 2008 Burkina Faso introduced Bt cotton and Egypt introduced Bt Maize. Several other African countries have enacted the necessary biosafety legislation and plan to introduce Gm crops over the next few years. This paper examines the evidence for the success or failure of Bt cotton and maize in developing economies and reflects on the lessons for their wider adoption.

Keywords: GMOs, Bt crops, GM crops

Introduction

The first Gm crop varieties were developed by multinational seed companies during the 1980s. Commercial seed sales began around 1994 and the first commercial plantings of Gm crops began in 1996, mainly in the USA. Adoption of Gm crops expanded rapidly, so that by 2008, more than 25 countries were growing at least one Gm crop. The total area of Gm crops planted in 2008 has reached 125 million ha (12). The main Gm crops grown around the World are soybean, maize, cotton and canola (oilseed rape) (Table 1). Among the developing nations, Argentina, Brazil, China, India and South Africa were the first to grow large areas of Gm crops, followed by a number of other Latin American countries. More recently, they have been joined by the Philippines in Asia and Burkina Faso and Egypt, on the African continent.

Table 1. Top biotech crops by area in 2008

Crop	Global area (million ha)
Soybean	66 (53%)
Maize	38 (30%)
Cotton	16 (12%)
Canola	6 (5%)

Source: James (12).

After soybean, the largest area of Gm crops worldwide, is planted to maize and cotton. Ten countries grow Gm cotton and 17 grow Gm maize (Table 2). The most prevalent Gm trait is herbicide tolerance which accounts for 63% of global Gm crops. Insect resistance accounts for 15% of the area and the remainder (22%) is planted to ‘stacked’ or combined traits in crops containing genes for both herbicide tolerance and insect resistance (12).

China and India are the two countries where large numbers of smallholders (at least 5 million in India and 8 million in China) grow Gm crops. In the other countries with significant areas under Gm crops, adoption has been mainly in the large-scale sector. Such lessons as can be drawn from the experiences of smallholders therefore have to come from India and China. On the African continent, it is only South Africa, Burkina Faso and Egypt that already grow Gm crops but in South Africa, the vast majority are grown on large scale farms. Egypt began growing Bt maize and Burkina Faso to grow Bt cotton on a significant scale only in 2008. Although the cotton crop In Burkina is grown mainly by smallholders, it is too soon to draw any lessons. Kenya has been developing Gm sweet potato and Bt maize for a number of years but to date, no commercial releases have been made.

Table 2. Countries growing Gm cotton and maize in 2008

Crop	Countries
Cotton	Argentina, Australia, Brazil, Burkina Faso, China, Colombia, Mexico, India, South Africa, USA
Maize	Argentina, Brazil, Canada, Chile, Czech Republic, Egypt, Germany, Honduras, Romania, Philippines, Poland, Portugal, Slovakia, South Africa, Spain, Uruguay, USA

Source: James (12).

There is an extensive literature in peer reviewed journals and on the internet, covering Gm crops, especially Bt cotton in China and India. However, much of it is supported by lobby groups or others with a vested interest, either for or against Gm. Many of the more scientific studies that have compared the benefits to Gm and non-Gm growers, are biased by the socio-economic differences between Gm adopters and non-adopters, such as educational status, size of holding and access to capital.

Technology acquisition

Cotton - The intellectual property rights (IPRs) for Bt cotton technology are held by a limited number of multinational seed companies, such as Monsanto (Bollguard) and Dow Agro-Sciences (Widestrike). Their varieties may be grown directly, as in South Africa, or permission may be granted to introgress the Bt genes from one of the seed company varieties, into a locally adapted variety. This second approach was used for example, in India to develop the MECH varieties. In either case a 'technolgy fee' is due to the company holding the IPR s and this is reflected in the cost of seed purchased by the grower. The Chinese Academy of Agricultural Sciences has developed its own Bt varieties which are widely grown. India is also working on its own insect resistance technology.

Maize – Several multinational seed companies have commercialised Bt maize, among them, Monsanto, Syngenta and DowAgroScienes. The 'Insect Resistant Maize' (IRM) project in Kenya is being developed with 'Public Good' collaboration involving the International Maize Improvement Centre (CIMMYT), for Bt technology for which the IPRs are held by the University of Ottowa (15).

The lessons from adoption of Bt cotton by smallholders

Ten countries now grow Gm cotton, the USA having the largest area, followed by Argentina and Brazil, then China and India (Table 3). The last two countries having the largest number of farmers growing Gm cotton.

Table 3. Countries growing Gm cotton in 2007/08

Country	Area (Million ha)
Argentina	19.1
Australia	0.1
Brazil	15.0
Burkina Faso (seed production from June 2008)	-
China	3.8
Colombia	0.1
India	6.2
Mexico	0.1
South Africa	1.8
USA	57.7

Source: James (11), except BF (see 10)

Republic of South Africa (RSA)

In South Africa in 2001, 95% of the cotton crop was produced by 300 large-scale farmers and the rest by more than 3000 smallholders. Bt cotton has been grown in South Africa since 1997/98 and by 2000, it was estimated that 75% of smallholders were growing the Bt variety (6). At first, most of the peer-reviewed reports about Bt cotton adoption by smallholders in Makhathini were favourable and have been used to promote the technology in the rest of Africa. When cotton smallholders there began to experience economic losses, it was explained that this was due to a combination of consecutive seasons of drought affecting Kwazulu-Natal and a change in the marketing arrangements. When Bt cotton was first introduced, the Makhathini, smallholders were served by a single ginnery and this monopoly position gave the ginning company the confidence to invest in a credit scheme which allowed farmers to cover the input costs and technology fee for the Bt variety. When a second ginnery was licensed to operate in the same area, competition for seed cotton became the priority and the number of loan defaulters rose dramatically, leading to the collapse of the input credit system (5). Without access to credit the technology fee for the Bt variety became unaffordable for many cotton farmers at Makhathini. By 2002/03 the number of cotton smallholders had fallen to 400, although promotion of irrigation by the new ginning company has seen numbers rise again (5). The conclusion drawn by one study was that the introduction of Bt cotton for smallholders in RSA had been a 'technical triumph but an institutional failure' (7).

Two lessons can be learned from the experience in RSA. Firstly, in seasons when weather conditions are unfavourable for cotton production and in the absence of irrigation, smallholder profits from cotton are unlikely to be sufficient to cover the input costs and technology fee. Secondly, the role of the ginnery is crucial in providing input credit and ideally, technical support services.

China

Bt cotton varieties were released commercially in China in 1997 and were rapidly adopted. By 2007, 3.8 million ha of Gm cotton were being grown by 7 million households, representing more than two thirds of national production (11). Average cotton holdings are small in China at only 0.59 ha per household. This is similar to individual holdings in many SSA countries but in some Provinces of China, such as Xinjiang, a number of farmers may grow their cotton in a block.

Most of the adoption studies of Bt cotton in China concluded that *Helicoverpa* was well controlled, at least in the early part of the season, resulting in a decreased requirement for insecticide and cost savings (e.g. 9). The main risk identified has been an increase in secondary pests such as, thrips, aphid, whitefly, spider mites, lygus bugs and leaf hoppers, which have occasionally replaced bollworm as the primary pest (18). In some parts of China, this risk appears to have become a reality. During the first three years of planting Bt cotton, pesticide use was cut by more than 70% and profits were higher than was obtained by farmers growing conventional cotton varieties. However, by 2004, due to continued increase in populations of some sucking pests on Bt cottons, spray frequency had returned to the levels used previously on conventional cotton, resulting in lower profits for the Bt cotton farmers (4, 17). These problems have arisen because Bt cotton is not being deployed as an IPM component technology and adoption has not been accompanied by adequate technical support services. A study conducted in Northern China for instance, found that farmers were still spraying more than was necessary to control sucking pests and they had a poor understanding of pest identification and management (19). Where Bt cotton has been deployed within an IPM framework, less pesticide is used and higher profits obtained and the key to success has been access by cotton farmers, to IPM education (20)

Chinese experience provides lessons for Africa. Where regular spraying has previously been carried out, primarily for bollworm control, if farmers adopt Bt varieties and cease to spray, minor or secondary pests may become more of a problem. For example, results from China show that the populations of lygus bug can increase greatly on unsprayed Bt cotton. Lygus bug (*Taylorilygus vosseleri*) is a significant pest on cotton in Uganda but is kept in check by sprays targeted at bollworms. This has also been the case in China with leafhoppers, similar to the cotton jassid bug which is potentially a major pest of cotton in eastern and southern Africa.

India

Bt cotton was introduced in India only in 2002 but by 2007, Bt varieties were being grown by 3.8 million smallholders, covering 6.2 million ha (11). The average cotton holding is larger than in China at 1.63 ha per household.

As in China, most of the independent reports on Bt adoption across India, have been favourable. For instance Morse *et al*. (14) reported that gross margins among farmers who adopted Bt cotton, were 2.5 times higher than among non-adopters but they acknowledge that results may be influenced as much by differences between adopters and non-adopters, as by the technology. A nationwide survey conducted in 2003 concluded that yield increase associated with Bt adoption was 29%, with a 60% decrease in insecticide use and a 78% increase in net profit (1).

A large number of Indian seed companies have produced or are developing their own Bt cotton varieties, in addition to the Monsanto varieties. There is therefore a wide range of quality and performance. Wide publicity was given to cases where adoption of Bt cotton failed to provide an economic benefit (e.g. 16) but it seems that in most cases, these failures were explained by one or a combination of poor seed quality, drought and poorly performing genetic background used for the transformation (1, 2).

The main lesson from India is that the adoption of Bt cotton can have large economic benefits where there is a high pest pressure from *Helicoverpa* bollworm and spray frequency has escalated in response to insecticide resistance. The qualifier is that seed quality and agronomic performance of the adopted Bt variety must be at least as good as the non-Bt variety it replaces. Nowhere in SSA is there such a combination of high bollworm pressure and pesticide resistance as was the case in several Indian States before the introduction of Bt cotton. Expectations in Africa, of economic benefits from the adoption of Bt cotton, should be adjusted accordingly.

The lessons from adoption of Bt maize

Bt maize is grown mainly for the management of Lepidopteran stalk and cob borers but in some situations, certain Bt toxins also show some efficacy against nematodes. Decreased damage from cob borers has the indirect benefit of decreasing cob rotting by a number of fungi which produce mycotoxins associated with human and animal disorders (3). Bt maize provides good control of *Sesamia* spp., *Helicoverpa armigera*, *Ostrinia nubilalis*, *Chilo* spp. and *Eldana sacharina*. *Busseola fusca*, an important stalk borer in Upland maize in Africa, is poorly controlled by the current endotoxins and they have no efficacy against *Agrostis* spp.

Republic of South Africa (RSA)

Sixty-two percent of white maize grown in RSA is now Gm (*Cry 1Ab*) and has been adopted almost exclusively by the large-scale farming sector. The target pest is maize stalk borer (*Chilo partellus*). Adopting farmers have seen increased profits due to decreased insecticide use. Wider adoption has been limited due to the limited incentives for smallholders, who rarely use insecticide for stalk borer control and the poor control of *B. fusca.* Gouse *et al*. (8) conducted an economic assessment of Bt maize adoption among smaller farms. They concluded that there were economic benefits in seasons with high pest pressure. Research results suggest that smallholders could benefit economically from Bt maize in some areas of RSA, provided they were well supported by extension services (13).

Philippines

11% of maize grown in the Philippines is Gm, targeted at management of the Asian maize borer (*Ostrinia* sp.) which is a major pest. Bt maize gives higher income, due mainly to decreased insecticide use but it is recognised that income comparisons between adopters and non-adopters, may be biased because the adopters were better educated, wealthier and had larger farms than non-adopters (21). High seed cost limits adoption by smallholders although James (11) reports that 125,000 smallholders are growing Gm maize.

Egypt

Egypt is the first Arab country to deploy a Gm crop commercially and the first on the African continent, other than RSA. Bt maize was commercialised in Egypt in 2008, when around 700 ha were planted. There are no adoption studies and it is too soon to evaluate.

Kenya

Bt maize is not yet commercially available in Kenya, mainly because of poor control of *B. fusca* which is the most important stalk borer in the highland areas, where much of the countries maize is produced. The IRM project in Kenya illustrates some of the problems in developing Gm crops for a smallholders (smallholders should be the main target for this technology in Kenya, as it has been developed with Public funds). The research was not sufficiently demand-led and therefore, not targeted at the most important constraints for smallholder households which are drought, witchweed, low soil fertility and stalk and cob damage by *B. fusca*.

Note on drought-tolerant maize

Drought tolerant transgenic maize, is the most advanced of the drought tolerant crops under development, and is expected to be launched commercially in the USA in 2012, or earlier. Notably, a Private/Public sector partnership hopes to release the first biotech drought tolerant maize by 2017 in sub-Saharan Africa, where the need for drought tolerance is greatest (12).

Requirements for successful adoption of Gm technology in SSA

- For Gm crop development targeted at smallholders, R & D needs to be demand led through participatory needs assessment and supported by thorough baseline data.
- A well implemented public information campaign, so that the potential benefits of Bt crops are understood and farmers come to appreciate that making a profit will depend even more than it did with conventional varieties, on the implementation of best practice ICM.
- Smallholders need to have access to credit for input purchase and are well supported with technical advice.
- Well before commercial release of Gm varieties, plans need to be in place for seed multiplication and seed separation. Not all farmers will have the technical competence to benefit from Bt technology and non-Bt varieties therefore have to remain available to them. However, this will create a problem of how to keep separate the Bt and non-Bt varieties. There is a similar issue between organically and conventionally grown crops.
- Ensure that the period of validation of Bt technology – confined field trials and open field trials, is overseen by organisations without a vested interest in the adoption of Gm technology.
- Promote Bt crops, especially Bt cotton as an IPM component technology, not primarily as a yield enhancing one and carefully monitor changes in the pest complex.
- If Bt genes are to be transferred to locally adapted varieties, these must be at least as good agronomically and consumer acceptance, as the non-Bt varieties they are to replace.

الملخص

هيلوكس، روري. 2009. القطن والذرة الصفراء/الشامية المحورين بالبكتيريا *Bacillus thuringiensis*: المنافع والمشكلات المرافقة في العالم النامي. مجلة وقاية النبات العربية، 27: 221–225.

تم تنمية المحاصيل المقاومة للحشرات المحورة وراثياً، المحتوية على مورثات من البكتيريا *Bacillus thuringiensis* على نحو تجاري لأكثر من عقد ونصف. يعد القطن والذرة الصفراء/الشامية المحورين بالبكتيريا *Bacillus thuringiensis* المحصولين المحورين الأكثر انتشاراً في البلدان النامية. وقد تم تطوير تقنية التحوير بالبكتيريا *Bacillus thuringiensis* من قبل شركات بذور متعددة الجنسيات لصالح الزراعة التجارية واسعة المدى، حيث أتاحت مكافحة فاعلة إزاء آفات معينة من حرشفيات الأجنحة، وخفضت من استخدام مبيدات الآفات. على أن منافع التبني هي أكثر جدلاً لمالكي الحيازات الصغيرة حيث تظهر صورة مختلطة. وتم في جنوب أفريقيا زراعة المحاصيل المحورة وراثياً بالبكتيريا منذ 1994 على أنه لم تتم زراعة محاصيل محورة في باقي أفريقيا حتى 2008. وقامت بوركينا فاسو، في 2008، بإدخال القطن المحور كما أدخلت جمهورية مصر العربية الذرة الصفراء/الشامية المحورة. كما أقرت دول أفريقية عديدة تشريعات الأمان الحيوي الضرورية وتخطط لإدخال المحاصيل المحورة وراثياً في السنوات القليلة القادمة. وتعالج المقالة بيانات النجاح أو الإخفاق لمحصولي القطن والذرة الصفراء/الشامية المحورة وراثياً بالبكتيريا في اقتصاد البلدان النامية وتعكس الدروس المستقاة من تبنيهم الأوسع في أفريقيا.

كلمات مفتاحية: محاصيل محورة وراثياً.

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