ADOPTION OF Bt COTTON BY SMALL-SCALE FARMERS IN SOUTH AFRICA

Peter Gregory[1] from Novigen Sciences, Inc., Rob Stewart from DRA Development, and Stavros Stavrou from the School of Development Studies, University of Natal, discuss the benefits and risks of the use of *Bacillus thuringiensis* (Bt) cotton by small-scale black farmers in the Makhathini Flats of KwaZulu-Natal, South Africa, together with a consideration of international implications

Introduction

Insect-protected *Bacillus thuringiensis* (Bt) cotton produces Bt protein Cry1Ac that kills larvae of several major lepidopteran pests and decreases the need for conventional insecticides. Globally, the commercial potential of Bt cotton is several times greater than the current size of the entire market for crop protection chemicals (Burges, in press). Local trials underway since 1997 in the Makhathini Flats (population: 900,000) of KwaZulu-Natal, South Africa are among the first in the world to demonstrate that Bt cotton might provide substantial benefits to small-scale farmers in developing countries. Delta and Pineland's Bt cotton varieties with the Bollgard, gene were commercialised in South Africa in 1998. Farmers of the Makhathini Flats were early adopters in a region where chemical control of the pest infestations has proved inadequate and where the cotton industry has been in steep decline. The product provides effective control of the main lepidopteran pests in the region, such as the American Bollworm, (*Helicoverpa armigera*), the Spiny Bollworm (*Earias* spp.) and the Red Bollworm (*Diparopsis castanea*) (Bennett *et al.*, submitted) and has increased cotton yields.

Bt cotton could have a strong, long-term, beneficial impact on the people in this region. The majority of the farming households are categorised as poor to ultra-poor by the South African government and cotton (fibre) is the only cash crop currently with export potential. Cottonseed is also economically important as a by-product that is used for oil extraction and animal feed uses.

The insect-active proteins produced by Bt are harmless to people, wildlife, and most beneficial insects (Betz *et al.*, 2000). Thus, genes encoding Bt proteins that have been incorporated into, and expressed by, cotton and other crop plants, provide environmentally safe control of insect pests. Theoretically, however, widespread adoption of Bt crops could increase the chances that pests might evolve resistance to Bt (Gould, 1998). A critical and widely held assumption of strategies for delaying pest resistance is that genes conferring resistance are rare (Gould, 1998). Although most previous estimates for lepidopteran pests targeted by Bt crops seemed to meet this assumption, recent data (Tabashnik *et al.*, 2000) suggests that the assumptions and predictions of resistance management models should be re-examined.

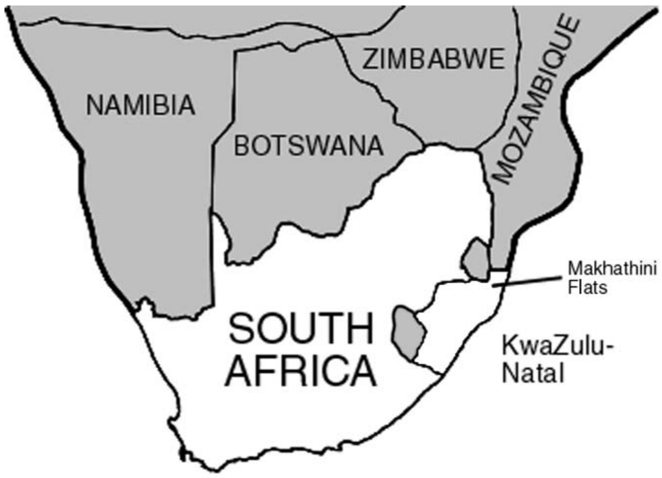

Figure 1. **Location of Makhathini Flats in South Africa**

Meanwhile, to ensure maximum safety in the cultivation of Bt cotton and other Bt crops, efforts are underway worldwide to introduce training and technical support services to ensure adequate management and stewardship. Innovative approaches will be needed to sustain these initiatives in the Makhathini Flats where, as in many other regions of the developing world, agricultural extension activities are often limited.

Cotton production in the Makhathini Flats

The main crops in the region are cotton, maize (the main subsistence crop), sugarcane, and vegetables. Cotton is usually grown on 3–10 Ha plots. There are an estimated 5000 Ha planted to dry-land cotton production. Only 100 Ha are planted to irrigated cotton and expansion of irrigation systems in the region is unlikely for the foreseeable future. The cultural cycle for cotton ranges from 120–200 growing days from seedling emergence to maturity. About 50–60 days after planting, flower buds called squares appear on the cotton plant. The buds form blossoms that wither and are replaced by cotton bolls where cottonseed and fibre are formed. Unless measures are taken to control the bollworm it can cause damage by feeding on the squares and the cotton bolls. Damaged bolls either abort or cannot mature to produce either fibre or seed.

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Figure 2. **Women harvesting cotton in the Makhathini Flats. Photo courtesy of Rob Stewart.**

To chemically control the bollworm in fields of conventional, non-Bt cotton, farmers usually spray carbamate and pyrethroid insecticides 6–10 times during the growing season. This results in high input costs. Very few farmers can finance themselves, but, depending on their credit worthiness, farmers who do spray have access to finance, *via* the gin, or through various lending institutions including Land Bank, a specialist agricultural bank guided by a government mandate. Farmers use the same source of revenue to purchase their other inputs, including seed of Bt cotton and conventional varieties.

Even for many of those farmers who secure financing, inefficient application and unreliable availability of pesticides have severely limited their productivity. Inadequate scouting for the onset of pest infestation has also been a major threat to production. Eighty percent of the cotton is sprayed using hand sprayers and the rest is applied using tractor sprayers. Many sprayers are old, poorly maintained, and inefficient. Management of the crop can be time and labour intensive. One hundred percent of the cotton is picked by hand and delivered in bales to the local gin. Up to a 5 km walk to collect water may be necessary for preparing pesticide sprays, and it can take up to 20 km of walking to spray one hectare of non-Bt cotton with knapsack sprayers.

Benefits of Bt cotton

Adoption of Bt cotton in the Makhathini Flats has increased yield and reduced the need for chemical pesticides (Thompson, 2000; Thompson, in press). In the 1998/1999 growing season a 20% yield increase in cotton, relative to sprayed conventional cotton, was observed. Results from the 1999/2000 growing season indicated a two-fold yield increase in some areas. The need for chemical insecticides, often including the more toxic organophosphates, was reduced by an average of 5–8 sprays per season with some farmers not having to spray for bollworms at all. This decreased the time, energy and health risks associated with crop management by farmers and their families.

In conventional cotton production, many farmers scout weekly and even daily (during the course of hand weeding or other routine activities) to locate the insects' eggs. They must then spray within a day to minimise bollworm damage to squares and bolls. Other farmers follow a 7–10 day spray programme. If a pest outbreak occurs in Bt cotton, these squares and bolls are protected through a protein produced by the plant that selectively controls the bollworm pests. With Bt cotton, little or no spraying is needed to control such an outbreak. However, Jassids, other *Hemiptera*, and *Dysdercus* can cause problems on Bt cotton and need to be scouted for. One or two sprays with systemic compounds usually provide effective control at a low cost.

By dramatically reducing the need for chemical control of bollworms, the Bt cotton reduces potential health risks caused by exposure to pesticides in the field and avoidance of accidents in the farmers' homes where chemicals are often stored. Also, replacing chemical controls with plant-expressed Bt protein allows natural populations of predators and parasitoids to thrive and, indeed, there has been a resurgence of non-target insects, including predators of the bollworms. There is anecdotal evidence, currently being substantiated by research, that midges, lacewings, pirate bugs, six-spotted thrips, assassin bugs, and various kinds of ladybirds that have not been seen in South African cotton fields for several decades are now reappearing in fields planted to Bt cotton.

An economic survey in the region indicated that small-scale farmers who adopted the Bt cotton in the 1998 and 1999 seasons benefited from the new technology (Ismael *et al.*, in press). The increased yields and reduced chemical application costs outweighed the higher seed costs, even when the labour inputs associated with the bigger harvest were considered.

Adoption of Bt cotton also has potential benefit to the general public and to the environment by reducing the manufacturing, shipment, storage and use of chemical insecticides. It also reduces the number of empty pesticide containers and the amounts of pesticide spray solutions that must be disposed of. Furthermore, there is a potential reduction in mycotoxins produced by fungi that invade the cotton boll upon insect damage.

Figure 3. **Farmer displays more cotton bolls on Bt than non-Bt plants. Photo courtesy of Maurice de Billot.**

Possible risks

There are no substantiated instances to date, in South Africa or globally, in which Bt cotton or any other bioengineered crop has caused harm to human health or to the environment. Under the South African government's GMO Act implemented in 1999, conditions currently in force address the possibility that bollworm populations might build up resistance to the Bt mechanism, and hence describe the need for the implementation and long-term monitoring of an insect resistance management (IRM) system.

Such considerations have led the South African government to require that the refugia comprise 20% of the total Bt cotton growing area if sprayed and the less preferred option of 5%, if untreated. Furthermore, the South African Agricultural Research Council's Plant Protection Research Institute has developed a baseline for determining resistance increases in bollworm populations and a diagnostic dose test that will detect early resistance development.

IRM options

According to a review by the National Research Council of the USA (NRC, 2000), current approaches for IRM of bioengineered pest resistant crops focus on gene deployment and use of refugia and include:

- High dose of a single contained toxin in most plants, with some plants producing no toxin at all and thus serving as refugia, or areas where susceptible insects can breed without selection pressure for resistance to Bt
- Multiple toxins at high (or in some cases moderate) doses in most plants, with some non-toxic plants serving as a refuge
- Insect-protected plants with low doses of a toxin that only slow the growth of the pest, so that the pest population growth decreases and natural enemies can become more effective
- Development of insect-protected plants that produce toxin only when and where it is most critical to protecting the plant

However, none of the above options specifically apply to Bollgard® cultivation in the Makhathini Flats. At this early stage of commercialisation, low sales of Bt cotton ensure that areas of conventional cotton are in place to act as refugia. Conventional cotton could continue to be an important refuge for the long-term if sales of Bt cottonseed were to be strategically limited. Equally important, cotton production areas in the region are often interspersed with vast areas of natural bush that are likely to provide additional refugia.

Current research shows that, in the Makhathini Flats, natural vegetation and not crops provide the refugia. Annual crop plantings are on relatively small areas and their flowering and fruiting cycles do not coincide with the extended flowering and fruiting cycle of a perennial plant like cotton. Also, there are extremely low numbers of cotton farmers practicing intercropping. If they do it is with maize and, in this case, the maize is only attractive to *H. armigera* for a very short time during the silking stage. Both *D. castanea* and *Earias* spp. are not attracted to maize.

Implementing management and stewardship measures

Training programs that address the management and stewardship of Bollgard® are already underway in the Makhathini Flats. All of the chairmen of the cotton farmer associations and their members have received a first round of training on financial management, agronomics of cotton production, transgenic crops, refugia and other IRM practices including effective scouting. This is an ongoing process and demonstration sites have been planted to accelerate the training. The initiative involves governmental extension officers, Vunisa cotton gin, Land Bank, and Monsanto Company.

Sustaining such training and educational programs for the long-term involves substantial logistical and financial challenges. The Governmental extension services are limited in the region and strengthening them appears to be a low priority. There are few paved roads and transportation can be very challenging, especially under the wet, cyclonic, conditions that can be so destructive to the region.

A strategy is needed to promote sustainability of the Bt cotton production system while reducing the long-term burden on the private sector. Such an approach might involve participatory social sciences methodologies, including community action planning or selective participatory rural appraisals (see Narayan *et al.* (1999), for further reading on participatory approaches).

Activities and outcomes might include:

- Interaction with cotton farmers, their wives and their children to:
  - highlight the need for improved management and stewardship of Bt cotton and the risks associated with not addressing the issue (including the possibility that the technology might have to be withdrawn from the area unless stewardship is improved)
  - determine whether the farmers would embrace the idea
  - ascertain whether they would be willing to try to use proper stewardship strategies through participation, training, *etc*. This would allow the farmers to select their community leaders (those known for their integrity and openness to share information) who would be the pioneers in demonstrating stewardship measures to the community as a whole
- Selected leaders would agree to give time and labour to the initiative and to provide leadership in training the trainers
- The resource people and selected leaders and farmers would walk or drive through farming areas and make various stops. They would identify constraints and locally available resources and discuss how strategic issues would be tackled
- The demonstration plots of the selected farmer leaders would provide focal points for training of other farmers. The trainers could initially forego payment and instead benefit from free, early access to technology. The selected farmers would be well trained and convinced about the management and stewardship package in order to convince other farmers about the commercial benefits that would come with effective practice

- Each farmer would then be given a minimum target group to train. Those who were trained would also become trainers
- The outstanding performers within the first group would be made *de facto* extension workers to inspect and police the stewardship practices; constant reinforcement of the good practices agreed upon by the community would be needed, because once farmers are left on their own they tend to develop their own practices
- The trainers of trainers would need some higher office reference point (*e.g.*, a government official(s) or company extension operator) to discuss their experiences as well as remedial actions that may be needed

The quality and cost-effectiveness of such an initiative could be enhanced by co-operation between private companies and a range of public and other non-profit organisations such as community organisations and any available governmental extension service operators, universities, government institutions, non-governmental organisations, and regional networking organisations. Funding from development agencies or private foundations could be requested based on the local benefits that would accrue and the lessons that could be learned, adapted and applied in other regions of the world.

Concluding remarks

Adoption of Bt cotton is already bringing significant economic benefits to the small-scale farmers in the Makhathini Flats and is also likely to result in significant health and environmental benefits. Much of the biological and social sciences information on the production system generated to date has been qualitative, semi-quantitative, or anecdotal. Rigorous research is already underway to provide a firmer basis for the development of effective management and stewardship strategies for Bt cotton and for accurately predicting the long-term benefits and risks that might accrue. The conditions facing cotton farmers in the Makhathini Flats have much in common with circumstances facing poor, small-scale farmers in other regions of Africa and the developing world. Thus, the research conducted in this region is likely to have implications for policy makers and other stakeholders in agricultural biotechnology around the globe.

Ultimately, whether or not farmer adoption of Bt cotton will continue to increase in the Makhathini Flats and elsewhere will depend to a great extent on consumer perception. Should farmers struggle to sell their cotton as a result of consumer resistance, they will be forced to return to conventional varieties, or even abandon cotton production, whether or not the benefits of Bt cotton outweigh the risks. Consequently, industry must learn to inform the public about advantages and perceived risks in a clear, palatable and attractive way (Burges, in press). This should be linked to rigorous impact case studies that generate reliable and credible data on which the public awareness campaigns could be based (Gregory, *et al*., 2001).

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Further reading

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