The Potential Benefits of Agricultural Biotechnology and the Problems of European Attitudes to Biotechnology for the Economies of Small Island Developing States

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Abstract

Agricultural products from many Small Island States such as sugar, banana, cocoa, coffee and tobacco are often destined for the European market at preferential prices. In the face of globalization and the loss of preferential prices many Small Island States seek to diversify or enhance agricultural competitiveness through the use of technologies. Biotechnology offers a potentially powerful tool to increase competitiveness and many developing countries are already growing crops developed using this technology. Evidence of the benefits for small producers of adoption of genetically modified (GM) crops is presented from research carried out by the authors in South Africa and India. The research shows that smallholder farmers in both countries have benefited from the adoption of GM crops such as Bt cotton, with higher profit margins, lower labour requirements and health benefits from reduced pesticide usage. However, given some negative attitudes of European consumers towards agricultural biotechnology products, Small Island States face the dilemma of adopting this potentially beneficial biotechnology for agricultural products destined for the European market. The paper explores consumer attitudes towards genetically modified crops and discusses the implications for the uptake of GM crops mainly agricultural export crops in Small Island States, including international trade considerations.

Introduction

Agricultural products from many Small Island States (SIS) such as sugar, banana, cocoa, coffee and tobacco are often destined for the European market at preferential prices. In the face of globalization and the loss of preferential prices many Small Island States seek to diversify or enhance agricultural competitiveness through the use of technologies. Biotechnology offers a potentially powerful tool to increase competitiveness. The application of biotechnology techniques, particularly genetic engineering or genetic modification technologies, in the agricultural sector can potentially enhance competitiveness and food security by raising crop tolerance to adverse weather and soil conditions; by improving the adaptability of crops to different climates; by enhancing yields, controlling pests and improving nutritional value of crops and using inputs efficiently. Since the introduction of the first genetically modified (GM) Flavr Savr tomato in 1994, today seven GM crops (cotton, canola, maize, papaya, potato, soybean and squash) are grown on more than 67 million hectares in 18 countries and this amount is increasing by more than 10% annually (James, 2003). Two agronomic traits-resistant to herbicides and resistance to insect pest- account for virtually all planted hectares. Nearly a third of all GM crop hectares are now grow in developing countries.

Despite the rapid adoption of GM crops in many countries, there is still an increasingly intense debate about the potential benefits and costs of genetically-modified (GM) agricultural technology for developing countries. Two recent examples are the Action aid document '*GM crops – going against the grain*' (Orton, 2003) which takes a critical stance and that presented by the Nuffield Council on Bioethics (2003) in its discussion paper '*The use of genetically modified crops in developing countries*'. Such rancorous debate about this new technology has influenced consumer attitudes towards GM crops and their products ranging from complete acceptance to acceptance of some GM crops or products to outright rejection. Negative consumer attitudes towards GM technologies, particularly in Europe, create a dilemma for SIS willing to use GM technologies to enhance agricultural productivity and competitiveness, especially in agricultural products destined to EU consumers. Nonetheless, given their potential benefits, the use of GM technologies should not be ignored by SIS.

This paper presents some evidence of the benefits for small producers of adoption of genetically modified (GM) crops from research carried out by the authors in South Africa and India. It also explores consumer attitudes mainly in the European Union (EU) towards genetically modified crops and their products and discusses the implications for the uptake of GM crops mainly agricultural export crops in SIS.

GM cotton in India

India ranks third in global cotton production after USA and China, and with 8-9 million hectares grown each year, accounts for approximately 25% of the world's total cotton area and 16% of global cotton production. Yet the yield of cotton in India is low at 300 kg/ha compared with a world average of 580 kg/ha. Cotton is a very important cash crop for Indian farmers and contributes around 30% to the gross domestic product of Indian agriculture, but a major limiting factor to cotton output is damage due to insect pests, especially bollworms (Lepidoptera). In March 2002 the Indian Government permitted commercial cultivation of genetically-modified Bt (*Bacillus thuringiensis*) cotton. The Bt gene produces a protein that is toxic to bollworms. Bt cotton has now been produced in India for two seasons 2002 and 2003. In 2002 some 38,000 hectares were planted with Bt cotton, with over 12,000 hectares of this being in the state of Maharashtra grown by over 17,000 farmers. Given the scale of the cotton industry in India and the current global debates over advantages/disadvantages of GM technology it is of no surprise that there has been considerable and vigorous debate regarding the agronomic and economic performance of Bt cotton in India with various reports claiming both successes and failures.

Our study in India presents an analysis of data collected from a large sample of farmers growing both conventional and Bt cotton under real commercial field conditions over two seasons since Bt cotton has been licensed for commercial use in India, and is the first such study of its kind. It presents a much-needed and timely assessment of the performance of Bt cotton under typical farmer-managed conditions in India (FAO, Rome, 2004). Unlike previous Indian studies (Naik 2001, M. Qaim, D. Zilberman 2003), it analyses commercial field data rather than trial plot data. In this, it meets the FAO's call for more 'market based studies' that will accurately reflect he agronomic and economic environments faced by growers of Bt cotton. The analysis concentrates on addressing the question as to whether Indian farmers have experienced economic gains from growing Bt hybrids released by a company affiliated to Monsanto (Mahyco-Monsanto) compared to a complex of non-Bt hybrids and cultivars.

The analyses presented here relate to two random samples of Bt cotton growers in the state of Maharashtra over the two seasons (2002 and 2003). Maharashtra has an area of 307,690 sq. km, a population of near 79 million and contributes some 23% of the nation's industrial output. It is among the most industrialized states in India, but even so about 70% of the state's population depends on agriculture. In the first season of the study a sample size of 2,709 farmers was obtained, whilst in the second season a sample size of 787 farmers was obtained. The samples covered 16 districts (out of the 31 in the state) and 1,275 villages in three cotton-growing sub-regions of the state (Khandesh, Marathwada, Vidarbha).

There are two species of cotton grown in Maharashtra: *G. hirsutum* and *G. arboreum*. Most of the cotton grown (73% of cotton area) is an intra-*hirsutum* hybrid, with the remainder being covered with improved (non-hybrid) *hirsutum* and *arboreum* cultivars. There are three Mahyco-Monsanto Bt cotton hybrids grown in the sub-regions, MECH-162 Bt, MECH-184 Bt and MECH-12 Bt. Popular non-Bt varieties are Bunny, Tulsi, NHH-44 and JK-666.

Respondents were randomly selected within the three sub-regions. A questionnaire was designed and taken onto farms by trained and experienced agricultural extension workers. Farmers were personally interviewed and data on cotton production (seed quantity/costs, number and cost of sprays, yields, cotton prices obtained etc.) were collected. In nearly all cases farmers grew both Bt and conventional cotton varieties on the same farm, providing useful plot data for comparing the performance of Bt and non-Bt varieties for the same producer. This provides some 'control' for a number of producer-related factors that might influence performance of the technology (such as entrepreneurial ability, age, experience and expertise in growing the crop, access to other inputs such as credit and irrigation). The data provide comparison across some 7,751 plots in 2002 and 1,580 plots in 2003.

Table 1 shows a summary of the results comparing the costs and returns of growing Bt cotton and non-Bt cotton varieties for the two seasons. It can be seen that in both seasons the non-Bt plots were larger than the Bt plots and yield (quintal/acre) of Bt cotton was significantly higher than the yields for the non-Bt plots (by an average of 45% in the first season and 63% in the second season). This is despite both soil type and irrigation being much the same for the different types (at least in the 2002 season for which data on these are available). Expenditure on seed for Bt plots was over three times that for non-Bt plots and this reflects the relatively high cost of Bt cotton seed. The use of sucking pest (such as aphids and jassids) sprays was slightly lower for the Bt plots in 2002 and slightly higher but not significantly different in 2003. It may be that in the first season some farmers did not fully understand the nature of the new technology and reduced sucking pest spray input believing that the Bt variety needed less of such sprays. There was also a low level of use of bollworm sprays on Bt plots in 2002, although it is clear that the use of bollworm sprays was much lower for Bt than for non-Bt plots. It should be noted that while Bt confers resistance to bollworm some spraying may be necessary as the resistance diminishes with plant age. By the second season, very little bollworm sprays were applied to the Bt sample plots compared to more than three sprays for the non-bollworm plots (saving around 1,000 rupees per acre on average in that season). There is a slight difference in the price per unit of cotton sold by producers for Bt (lower) compared to non-Bt in the first season but not in the second season. It may be that in the first season there was some perceived uncertainty as to the acceptance of the Bt variety in some areas, which was reflected in a slightly lower price. The revenue from cotton sold is significantly higher for the Bt plots than for the non-Bt plots in both seasons with this difference being due to the greater yields generally obtained on Bt plots. The final row of Table 1 shows differences in gross margin (revenue less costs of seed and costs of sprays per acre) across the two seasons. It can be seen that gross margins are significantly higher for the Bt cotton varieties than for the non-Bt ones, with increases of 50% or more. This is entirely due to the higher yields of the Bt plots since any savings in bollworm pesticide costs are negated by the more costly Bt seed.

While the results are not presented here, analysis by area (district) shows considerable and statistically significant spatial variation in yields for both Bt and non-Bt plots. Yields per acre range from 3.39 to 8.24 quintals in some districts for non-Bt plots in 2002 and 4.13 to 14.15 quintals for Bt plots. Similarly, in 2003, yields per acre ranged from 3.91 to 7.44 quintals in some districts for non-Bt plots and 5.54 to 13.14 quintals for Bt plots. All Bt plots in all districts had significantly higher average yields associated with them in 2003 but in 2002, three out of 16 districts showed little difference between the average yields from Bt and non-Bt plots.

GM cotton in South Africa

The Genetic Modification Organism Act (1997), allowing Bt cotton to be grown in South Africa, was implemented in 1998. This was the first commercial release of a GM crop variety in Sub-Saharan Africa. By 2002, some 30 thousand hectares had been planted to Bt cotton in

South Africa (James, 2002). Of this, around 5.7 thousand hectares were grown in the Makhathini Flats area of KwaZulu Natal province of South Africa, where the research described here was undertaken. The Bt cotton variety (NuCOTN 37-B with Bollgard^{TM}) contains a set of genes controlling the production of a natural insecticide (toxins produced by *Bacillus thuringiensis* – Bt), which acts specifically on Lepidoptera, such as the cotton bollworm (*Helicoverpa zea*), and some Coleoptera.

Agriculture is the most important source of income in Makhathini and rural households cultivate small plots of land (typically of 1-3 ha) allocated to them by tribal chiefs. The major crops grown are beans, maize and cotton. Cotton is a very useful cash crop and usually occupies most of the farm area. There are nearly 5,000 smallholder farmers in the area of which around 1,400 grow cotton in any one year, and around 60% of these are women as a result of men migrating to urban areas for work. By 2002, an estimated 92% of the smallholder cotton growers in Makhathini had adopted the Bt variety.

Individual farmer records held by Vunisa Cotton, a private commercial company in Makhathini supplying all cotton inputs (including seed, pesticide and credit) and buying cotton output, were used to collate data on input use (seed, pesticide, labour and credit), farm size, age and sex of farmers, yields and other information. Some 1283 clean records representing 89% all cotton growers in the Makhathini area were analysed for the 1998/99 season (first season of commercial scale release), 441 (32%) in the 1999/2000 season and 499 (33%) in the 2000/2001 season. The 1999/2000 growing season was particularly wet, and yields were reduced as a result.

In addition, personal interviews were undertaken with a random sample of 100 smallholder farmers. This included visits to farm holdings and fields where cotton was grown to check information given by farmers (‘ground truthing’). Information on inputs, growing practices and yields was collected for the 1998/99 and 1999/2000 growing seasons. During the 2000/2001 season, some 32 in-depth case-study interviews were undertaken with smallholders on their farms concerning their use of pesticides.

Table 2 shows the mean levels of input use by quantity and value, yields and gross margins (margin of value of output less variable inputs such as seed, pesticides and hired labour) over the three growing seasons for both adopters of the Bt cotton and non-adopters. Bt cotton adopters achieved consistently higher yields per hectare than non-adopters over the three years, particularly in the poor wet growing season of 1999/2000 (such conditions favour the bollworm), where adopters achieved yields that were 85% higher on average than those growing the conventional crop. These differences are all statistically significant at the 0.1% level.

In terms of inputs, adopters used less seed per hectare than non-adopters, despite managing to achieve higher yields, such that the yield per kilogramme of seed was substantially higher for the Bt seed variety than for the conventional cotton (from between 89% to 129% higher – not shown in Table 2). Adopters also used less pesticide across the three seasons as might be expected and again this difference is statistically significant at the 0.1% level. When considering labour inputs, there was no significant or consistent difference for weeding labour but for harvesting the Bt adopters used more labour due to the higher yields achieved, and substantially less labour for spraying pesticides (again, these differences are statistically significant at the 0.1% level). The result of these differences between Bt adopters and non-adopters is that adopters achieved substantially higher gross margins per hectare than non-adopters across all three seasons. In financial terms, this advantage amounts to around 387-715 SAR per hectare on average depending on the season. This equates to around US$70-US$130 for a smallholder with just 2 hectares of cotton. This is a relatively substantial sum for a smallholder farmer in Makhathini where there is little opportunity for employment. When employment is available, the average wage rate is around 10-15 SAR (US$0.91-US$1.36) per day.

It should be noted that in the 1999/2000 wet season, those growing conventional cotton actually had a negative gross margin, whilst adopters of the Bt variety fared much better with a reasonable positive gross margin. The negative gross margin for conventional growers resulted in them having difficulty paying back credit that they had borrowed from Vunisa to buy inputs, such as seed and pesticide, to grow cotton. This meant reducing savings or borrowing from relatives to repay their loan, and a number of smallholders who could not repay their loans did not then grow cotton the following year, or grew a smaller area because of their acquired poor credit rating.

In the first (1997/98) growing season following release of the Bt variety only 0.1% of farmers grew it. Release was purposely targeted at a few farmers with relatively large land areas. In the 1998/99 growing season around 10% of smallholders in Makhathini adopted the Bt cotton variety, followed by around 25% by the second season and 50% in the 2000/2001 season. Analysis of the dynamics of adoption show that in 1998/99 it was very much the larger, older, male and wealthier farmers that adopted Bt. However, by the second, and particularly the third season, smaller farmers of various ages and both genders were also adopting and reaping the benefits in terms of higher gross margins.

Analysis of cotton area grown (not shown here) shows that the benefits of growing Bt cotton are apparent regardless of the size of plot available to smallholders. Moreover, during the 1999/2000 wet growing season, the smallest producers growing less than one hectare of conventional cotton fared the worse, with an average negative gross margin per hectare of 569 SAR, compared to a positive gross margin of 174 SAR for those growing the Bt variety. This highlights the vulnerability of small producers under conditions of environmental stress and the apparent ability of the Bt cotton variety to reduce the risk associated with a season of unfavourable weather. Those with such a high negative gross margin are unlikely to have been able to repay the credit that they had borrowed to purchase inputs, again, making it difficult for them to obtain credit to grow the next season's crop. Given the apparent benefits of Bt cotton for small producers, it is not surprising that the rate of adoption increased to over 90% of farmers by 2001/2002.

One of the often cited-criticisms of the adoption of new technology in developing countries – and certainly one levelled at the previous Green Revolution crop varieties – is that the technology mainly benefits the larger farmers. Analysis of the benefits of adoption according to planting area/farm size shows that in fact, for smallholder growers in Makhathini, those with smaller holding sizes appear to benefit as much as larger holdings, if not more, from the uptake of Bt cotton.

On average, those using the Bt variety reduced the number of insecticide sprays per season by three sprays. Bt adopters still needed to spray against pests such as aphids, jassids and thrips. Nevertheless, the elimination of three sprays will inevitably affect costs, amount of labour and distance walked given that all spraying is carried out with knapsacks. An average single spray per hectare will take 4.6 hours, 7.2 knapsack loads, 118.1 litres of water and the person spraying would walk over 9000 metres. Taking into account the costs of cypermethrin (the insecticide used for bollworm), water[1] and labour each application would cost the farmer around 67 SAR per hectare. Extrapolation suggests that 3 sprays of cypermethrin would cost around 200 SAR (approximately US$18). Growers of Bt could save this expenditure together with 14 hours of time and the effort of walking 27 km per hectare carrying a heavy knapsack, usually spraying in high temperatures and with no protective clothing.

In South Africa pesticides are used extensively and intensively by small-scale black farmers engaged in cash cropping (Dinham, 1993). Rother (1998) notes that there is a "pesticide culture" in South Africa and that this culture underplays the potential hazards of pesticides by explicitly and implicitly rationalising the support for pesticide use. In South Africa there remains a widespread support for the use of pesticides and they are seen positively as a means for maximising profits and increasing rural household economy (Rother, 1998). However, London (1998) reports that acute pesticide poisoning accounts for 10% of poison centre consultations in South Africa, and is an important reason for admission to respiratory intensive units. Furthermore, Yousefi (2000) notes a high incidence of chemical poisoning (acute and chronic) amongst smallholder farmers in South Africa. Rother (1998) further points out that women and children are more at risks where women and children do most of the farm work, and children would play in the field soon after a pesticide application.

There is some evidence of the benefits of Bt cotton adoption for human health. Figure 1 shows the logarithm of the number of recorded cases of accidental pesticide poisoning in the Makhathini area from local hospital records as a function of the percentage adoption of Bt cotton. The four points in the graph cover the seasons 1997/98 to 2000/2001. A clear (but not proven causal) relationship is shown that strongly suggests that cases of poisoning have declined as Bt adoption has increased.

This suggestion is supported by discussions with smallholders who noted the reduced incidence of skin disorders, feeling generally unwell and other health effects that they had associated with spraying for bollworm. The regression model predicts that if all farmers adopted Bt cotton the number of reported poisonings would fall to just two per season. This compares to a total of 51 reported cases in the 1997/98 season when Bt adoption was only 0.1%.

[1] Note that the costs of spraying contained within Table 2 do not include the costs associated with the water necessary to mix with the insecticide.

The studies in India and South Africa and further studies carried out by the authors (Bennett et al., 2003, 2005, Morse et al., 2004, Ismael et al., 2002) clearly show that producers using Bt cotton technology appears to gain substantial benefits. These benefits include higher yields and increased profitability, despite higher seed costs. There are other indirect benefits such as reduced labour requirement from the reduced need to spray, releasing time for other activities and also likely health and environmental benefits from less chemical spray use. The smallest producers appear to benefit as much, if not more, than those growing larger areas. In addition, current studies been carried out by the authors in India appears to show that Bt cotton could improve livelihood of the poor producers. Bt cotton would appear to be one example of GM technology that can provide very real benefits to some of the world's poorest farmers. Producers appear to reap some benefits from using GM technology. However, such benefits may not be realised if there is no market for GM crops and their products. The decision for SIS to adopt this potentially beneficial biotechnology for agricultural products destined to consumer hostile to GM crops and products is strenuous. The next section explores EU consumer attitudes to GM crops and products and discusses the ramifications for SIS willing to use this technology as well as suggest some possible GM policy decision.

Consumer and biotechnology

Our studies highlight the benefits and opportunities of GM crops at producer level. These GM crops and their products have already or are just beginning to enter the international market. Unless the national and international markets are favourable to GM crops or their products, the use GM technologies in agricultural products could destroy SIS economies that are dependent such agricultural products. The evolution of market opportunities for GM crops and products is difficult to predict, partly because of poor public awareness, pressure from lobby groups and consumer acceptance. If SIS is to harvest the opportunities of GM technologies, they should develop regulatory policies that reflect consumer demands and preferences nationally and internationally. Thus, given some negative attitudes of European consumers towards agricultural biotechnology products, SIS must be cautious to adopt biotechnology techniques for agricultural products destined for the European market. For example, if EU consumers are willing to purchase GM sugar, banana, cocoa, coffee, then SIS would benefit. However, any reluctance by EU consumers to buy such GM crops could have adverse economic consequences to SIS.

EU Consumer perception of Biotechnology

Consumer attitudes towards GM products have largely been negative in the EU and consumer scepticism in the EU is usually attributed to unknown health and environmental consequences of GM crops such as unanticipated allergic responses, spread of pest resistance or herbicide tolerance to wild plants, and toxicity to wild life (Curtis et al., 2003). Moreover, the lack of confidence by consumers resulting from the BSE (linking it with variant Creuzfeld-Jacob Disease vCJD) and foot and mouth crisis has also enhance a negative view of GM products and the companies that create and market such products, for instance Monsanto. Such negative views are further enhanced by some environmental groups, and have been assisted by the ongoing efforts by the EU to maintain trade barriers against agricultural imports (Abare, 2003). Consequently, EU consumers have been exposed to propaganda against GM technology and thus, contributed to a low uptake of GM crops and products.

Nonetheless, studies in the EU provide evidence that consumers are willing to take unknown risks of consuming GM products only theses products offered significant cost savings over nonGM products (Curtis et al., 2003). On the other hand, Burton, Rigby, Young, and James (2001), in a study of consumer attitudes toward genetically modified foods in the United Kingdom, concluded that male shoppers were willing to pay an extra 26% to avoid animal and plant GM technology, whereas female shoppers were willing to pay an extra 49.3%. Nelson (2001) compared the differences between EU and US consumers and concluded that EU consumers generally focused on the unknown risks associated with genetically modified products, not the benefits, whereas US consumers generally evaluated neither the risks nor the benefits. An extensive international study of consumer attitudes towards biotechnology was conducted by Environics International (2000). Some 35, 000 respondents from 35 countries were asked whether they agree that the benefits of biotechnology outweigh the risks. The Europeans, Japanese and South Koreans were negative about biotechnology than other parts of the world. The Eurobarometer Surveys, a survey of consumer attitudes conducted biannually throughout Europe since 1973, also confirm the negative attitudes of European consumers towards GM technologies. In the 1991 survey, levels of support for biotechnology differed according to application, with research into micro organisms receiving more support than plant research, food research, and research involving farm animals. Regardless of application, there was strong support for government control of genetic engineering. In 1996, the results showed that although the public's knowledge of biology had increased, people were less optimistic that applications of biotechnology would improve living conditions. There was strong support for labelling of products and of the need for public consultation (Wagner et al., 1997). The 2002 survey showed, again, that a majority of Europeans do not support genetically modified foods or products.

A survey of 100 consumers who shopped at two Sainsbury stores in the in south-east England town of Reading was undertaken by the University of Reading in 2004. The survey found that when informed about a new variety of cotton which used less insecticide and provided higher returns for resource-poor small farmers in developing countries, over 80% were interested in buying cotton products from this new variety but when told that the variety was GM around half of those said that they would not now want to purchase cotton products from the new variety.

The way forward with GM technologies

What does such negative EU consumer attitudes mean to SIS? SIS would be affected differently depending on whether or not they are net exporters of agricultural products to the EU. For example, Thai rice exporters has been warned by the EU that all Thai rice will be rejected if any GM organisms are found in it (Pinstrup-Andersen, 1999). This is an illustration of what may become the rule for any SIS wishing to export agricultural products to the EU. Using the precautionary approach, the EU, or any other importing country, may discriminate against any potential exporters of GM products without having any scientific evidence of harm. Therefore, SIS wishing to use an agricultural export-led growth strategy will be faced with the choice between adopting modern biotechnology in agriculture or maintaining the possibility of a GM-free products export to the EU. Of course, SIS could choose to differentiate and label GM crops and products and, to the extent that they can manage such a differentiated system, they would be able to capture the benefits from modern biotechnology and agriculture for domestic consumption (provided the domestic consumer are not anti GM crops and products) while maintaining an export market for GM-free products. SIS may also decide to label products in the domestic market to provide the choice to domestic consumers. Given that GM technologies can increase productivity and increases competitiveness, it is hard to believe that SIS would refrain from utilizing appropriate modern biotechnology in agriculture within reasonable biosafety limits and policies choices.

SIS face a variety of policies that will determine the uptake and spread of GM technologies. The success of GM technologies will depend not only on the availability of suitable technologies, and the willingness of governments to allow their cultivation but also on external factors and influences such as consumer acceptance nationally an internationally. Thus SIS should have well thought policies in order that the adoption of biotechnology does not damage their economies. Paarlberg (2000) has graded some policy choices that might be open to developing countries are highly relevant to SIS. His policy choices are based on whether countries will promote or prevent the use of biotechnology and ranked them from 'promotional' (policies that accelerated the spread of GM crops and food), to 'permissive' (policies that are neutral towards the new technology), to 'precautionary' (policies that tend to slow the spread of GM crops and products), and preventative (policies that tend to block or ban the spread of biotechnology). He identified key regulatory areas that SIS need to consider if they are to adopt GM technologies and they are intellectual property rights, biosafety, food safety and consumer choice, trade and public research investment. Specifically on trade he agued that policies of a country adopting GM technologies will be influenced by the degree of consumer (national or international) and importer acceptance of GM crops. For example, countries that rely heavily on exporting commodities to Europe might need to steer away from encouraging the use of GM technologies in agricultural products destined for export.

Conclusion

The two studies in South Africa and India highlighted the potential benefits of a particular GM crop. Indeed, GM technologies has the potential to increase productivity and competitiveness that many SIS desperately need, especially with the phasing out of many preferential prices they have enjoyed over decades. The decision to grow GM crops will depend not only on the availability of suitable technologies, and the willingness of governments to allow their cultivation but also on external factors and influences such as consumer acceptance nationally an internationally and whether the crop is destined for export. At present the anti GM stance by many EU consumers will certainly deter many SIS to introduce GM crops destined to EU market even though there is segregation or labelling. Growing GM crops destined for EU consumers at present could be highly damaging to their economies and the decision to grow GM crops will certainly have to be postponed. If GM crops are destined solely for domestic consumption and consumers are willing to accept the GM crops and their products, and if GM crops or products destined for export to countries where consumers are willing to consume such products, then SIS will certainly benefit by growing GM crops. On a caution note, GM technologies are not the solution to the existing problems faced by SIS.

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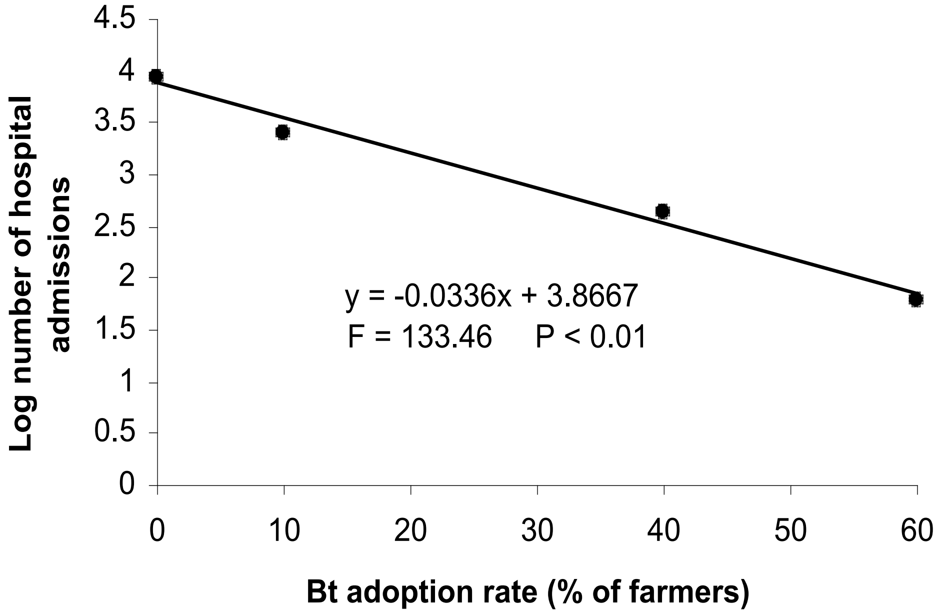
Figure 1: Logarithm of the number of local hospital admissions in Makhathini Flats categorized as 'cotton' (i.e. accidental pesticide poisoning) as a function of the adoption of Bt cotton.



Hospital admissions were recorded for the months December to March over the seasons 97/98 to 00/01.

Table 1. Economic and agronomic performance of Bt cotton vs. non-Bt cotton, Maharashtra, India

	Season 2002			Season 2003		
Variables	non-Bt	Bt	Sig.	non-Bt	Bt	Sig.
Cotton area (acres)	2.4 (1.6)	1.56 (1.7)	***	2.76 (3.2)	2.37 (3.4)	***
Soil type (3 categories)	2.22 (0.6)	2.23 (0.6)	ns	-	-	
No. irrigations	3.29 (1.7)	3.23 (1.6)	ns	-	-	
Cost of cotton seed (Rupees)	460.3 (106.1)	1,527 (333.8)	***	470.5 (39.0)	1,491 (112.9)	***
No. sucking pest sprays	2.25 (0.8)	2.24 (11.0)	***	2.2 (0.9)	2.37 (1.1)	**
Cost of sucking pest sprays (Rupees)	633.5 (318.6)	568.3 (321.6)	***	520.1 (309.3)	528.6 (289.2)	ns
No. bollworm pest sprays	3.84 (25.6)	1.44 (16.5)	***	3.11 (1.1)	0.71 (0.8)	***
Cost of bollworm pest sprays (Rupees)	984 (576.3)	280 (294.7)	***	1,166 (657.9)	195 (278.2)	***
Total costs (seed plus insecticide)	2,048 (840.8)	2,349 (638.2)	***	2,160 (823.3)	2,206 (431.7)	***
Cotton yield (quintals/acre)	6.09 (9.0)	8.83 (12.8)	***	5.59 (2.5)	9.1 (3.6)	***
Price of cotton (Rupees)	2,037 (224.6)	1,953 (415.1)	***	2,499 (90.9)	2,504 (90.5)	ns
Revenue from cotton yield	12,577 (20,195)	18049 (26,945)	***	14,001 (6,361)	22,807 (9,216)	***
Gross margin (revenue - costs)	10,524 (20,177)	15,700 (26,869)	***	11,849 (6,257)	20,600 (9,204)	***

ns = not significant at 5%
** $P < 0.01$
*** $P < 0.001$

Results are means and standard deviations in parentheses. Raw data failed Anderson-Darling test for normality, even with transformation, therefore data have been compared with the Kruskal-Wallis non-parametric test.

Table 2: Mean yields, input use and gross margins of smallholder cotton producers 1998/1999 to 2000/01. (Standard deviations are given in brackets).

	SEASON 1 (1998/1999)		SEASON (1999/2000)		SEASON 3 (2000/01)	
	Non-Adopters N=1196	Adopters N=87	Non-Adopters N=329	Adopters N=112	Non-Adopters N=254	Adopters N=245
OUTPUT HA	Mean	Mean	Mean	Mean	Mean	Mean
Yield (kg)	452(465)	738***(554)	264(212)	489***(364)	501(657)	783***(740)
Total Revenue (TR) (SAR)	984(1011)	1605***(1206)	574(461)	1064***(791)	1090(1428)	1704***(1610)
INPUT COST /HA (SAR)						
Seed	138(162)	278***(214)	190(178)	413***(346)	176(146)	260***(168)
Pesticide	153(195)	72***(96)	222(137)	104***(100)	305(241)	113***(125)
Bollworm Pesticide	73(96)	38***(58)	91(81)	5***(24)	138(236)	26***(53)
Non-Bollworm Pesticide	81(121)	34***(58)	131(83)	100*(99)	167(192)	87***(105)
Harvest	113(116)	184***(139)	66(53)	122***(91)	125(164)	196***(185)
Weeding	211(308)	174(210)			71(111)	99*(184)
Spray labour	77(100)	38***(50)	108(69)	49***(47)	135(103)	45***(54)
Bollworm Spray Labour	38(53)	20***(33)	46(44)	3***(16)	50(56)	11***(23)
NonBollworm Spray Labour	39(59)	17***(29)	62(40)	46**(46)	85(73)	34***(44)
TOTAL COST	692(671)	746(530)			813(476)	712*(420)
TOTAL COST (No Weeding)	481(459)	572*(388)	586(329)	688*(461)	741(500)	613**(378)
GROSS MARGIN /HA(SAR)						
GM (TR- All Cost)	292(999)	859***(977)	-11(487)	376***(764)	277(1202)	992***(1344)
GM (No weeding)	502(915)	1033***(970)	-11(487)	376***(764)	348(1207)	1090***(1329)

* Significantly different from Non Adopters at 5% Confidence level.
**Significantly different from Non Adopters at 1% Confidence level.
***Significantly different from Non Adopters at 0.1% Confidence level.
All costs are in South African Rand (1US$=11 SAR in October 2002).
Per kg is the unit amount per kilogramme of seed sown.
GM is the Gross Margin.
Bollworm control is the insecticide cost or amount for controlling bollworm only. Non-bollworm control is the insecticide cost or amount for controlling Non-bollworm only.