BIOTECHNOLOGY IN AFRICA:
THE ADOPTION AND ECONOMIC IMPACTS OF BT COTTON IN THE MAKHATHINI FLATS, REPUBLIC OF SOUTH AFRICA

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Abstract: *The research intends to shed some light on the polarised debate about the use of agricultural biotechnology in the developing world, especially in Africa. The research reported here charts the pattern of smallholder adoption and the agronomic/economic impact in the first two seasons of the release of a genetically-modified (GM) crop – Bt cotton – in the Republic of South Africa. The paper discusses a number of issues concerning the uptake of the technology. The farmers who adopted the Bt cotton variety benefited from the technology. The increased in yields and reduction in pesticide outweighed the higher seed cost, so that the gross margins were also considerably higher for adopters especially in the wet second season.. The result gives considerable cause for cautious optimism regarding the economic impact of Bt cotton. However, further years of data are required before final judgement of the economic benefits of the GM crop can be made.*

1 INTRODUCTION

Genetic engineering is now being heralded as the technology for the future, and promises are already being made that this new technology will solve the problem of world hunger as it revolutionises agriculture. The recent International Fund for Agricultural Development report (IFAD) makes a strong case that the effective use of biotechnology will be essential to the alleviation of rural poverty in the developing countries. Higher yields, lower levels of labour and pesticide use and higher producer prices for cotton are cited as the main impacts of adopting GM crops at the household level [Marra *et al.*, 2000; Fernandez-Cornejo and Klotz-Ingram, 1998; Gianessi and Carpenter, 1999; Fernandez-Cornejo *et al.*, 1999]. But, these benefits must be set against fears of damage to the environment, the breakdown of resistance, reduction in biodiversity, increased profits for multi-national companies and the impoverishment of small farmers in developing countries.

It is certainly the case that the number of different GM technologies and their application are increasing. The area planted to GM crops increased by 11% (4.3 million hectares) between 1999 to 2000, and by 2000 herbicide and insecticide resistant traits account for more than 59 % of the types of GM crops grown worldwide (James 2000). Insect resistance has also been a popular target for the GM companies. Here, the focus has primarily been on the transfer of a set of genes controlling production of a natural insecticide in a bacterium called Bacillus thuringiensis (Bt) to crops. The Bt-toxin acts specifically on Lepidoptera (including bollworm in cotton, stem borers in maize), and is harmless to all other insect species.

Currently, the majority of commercial GM crop releases have been in the USA, Canada and some countries in South America. Indeed, the USA, Canada and Argentina account for 99% of the GM crop area in the world. Outside these areas, GM crop release on a commercial scale has been limited. In Africa, for example, commercial scale release of Bt cotton and maize is only taking place in South Africa. If the use of Bt resistance for control of Lepidoptera pests generates a yield advantage, and Bt technology is cheaper than the use of a pesticide with conventional seed, then Bt-technology should provide farmers with an economic advantage. But, all the studies except Pray, et al. (2000), which examined Bt cotton in China, were conducted in the USA and most of the data comes from the biotechnology industry and it is typically based on controlled conditions and extrapolations from small plots.

Although GM crops offer potential benefits there are also potential problems. These may be environmental, such as the danger that crops may become weeds or transfer genes to other plants thus creating super weeds (John Innes Centre, 1998). It is also possible that pests could overcome the resistance presented by GM crops, and hence the variety will only be protected for a short while (Forrester, 1994; Riebe, 1999; Tabashnik *et al*., 2000). There is a further dimension familiar to those involved in studying the adoption of agri-technologies by farmers in the developing world. Experience has suggested that such uptake tends to be socially differentiated with those less risk averse farmers adopting first. The less risk-averse farmers tend to be the more better off in the society, and they are also the ones most likely to be able to afford a premium. In other words, there are potential socio-economic problems surrounding a widening of the gap between those who can afford the technology and those who cannot (Morse 1995). The Green Revolution in Asia, although founded on non-GM crop varieties, provides some well-researched examples of such differential impact, and various dimensions to this complex debate can be found in Lipton (1989) and Freebairn (1995). Although there is a dispute about the level of inequality introduced by the Green Revolution (Freebairn, 1995), these ideas have been extended to the introduction of GM crops to resource-poor farmers in Sub-Saharan Africa (Arends-Kuenning and Makundi, 2000). As a result some have concluded that such differential impact could have negative consequences (Meagher, 1990). Others question whether Africa can afford to 'miss out' of the benefits afforded by GM crops (Wambugu, 2000). There are many strands to this debate, including issues surrounding the supply of information on the GM varieties to farmers (Tripp, 2000). If the small, resource poor farmers in developing countries reap the same benefits as suggested by the studies carried out thus far, they should have higher incomes, less health hazards and live in a less polluted environment. Thus, the motivation for this study is to provide a sound and impartial account of GM crop adoption based on empirical evidence from a developing country. The focus is on South Africa, but the results should prove relevant to other countries.

The research reported here charts the pattern of adoption and the agronomic/economic benefits in the first two seasons of the release of a GM crop – Bt cotton – in South Africa. Bt cotton was the first commercial release of a GM variety in Sub-Saharan Africa. The research concentrated on the uptake by small holders and on the economic benefits (if any) that they received from adopting the technology.

2 BACKGROUND

2.1 Genetically Modified Crops in South Africa

The GMO Act [Genetic Modified Organism Act, Act 15 of 1997], passed in 1997 and implemented in 1999, paved the way for the introduction and commercialisation of GM crops in South Africa. The act legislates for the approval for the import, use and supply of the infrastructure required to utilise and evaluate genetically modified seed in South Africa. Although there have been many crop trials, only Bt maize and cotton are grown on a commercial basis.

Approximately 3,000 ha of Bt maize were planted in 1998 [James, 1999], and up to 50,000 ha of GM maize has been planted in 1999 [Thompson, 1999]. This is 'yellow' maize, which accounts for 4% of the total crop, and is used for animal feed, cornstarch and corn syrup. Bt cotton is grown mostly in the Northern Province with some in KwaZulu-Natal and the Free State. Cotton accounts for 1% (100,000 ha grown by 1,530 commercial farmers and 3,000 small-scale farmers) of total South African agricultural production. Cotton generates approximately US$ 50m per annum [Kock, 2000], mostly grown under dryland conditions.

2.2 Farming system

Agriculture is an important source of income in the Makhathini area. It has been noted that over 95% of the household are involved in some form of agricultural production (Metroplan, 1997). However 90% are considered to be deficit farmers, as they do not produce sufficient to meet the household food requirement. The major crops in the area are beans, maize and cotton (*Gossypium hirsutum*). The latter is grown as a commercial crop. Farming is practised on small-scale farms ranging from one to three hectares, and cotton usually occupies most of the farm. The main reason for growing cotton (besides cash) is that the crop needs less intensive management than maize or beans and can survive fluctuating weather. The result of a high cash value and agronomic resilience is that farmers cultivate cotton to the extent of their land holding, and the crop is continuously planted on the same land (i.e. a monoculture).

The family is the main provider of agricultural labour in the region. Labour is hired for certain specific laborious tasks such as ploughing the land, spraying and harvesting. Sprayers are hired for the application of insecticides. None of the household owns any machinery, although farmers hire tractors to help with ploughing.

The lack of working capital is a major hindrance within agriculture in the Makhathini area. A farmers credit worthiness is assessed based on his farming experience, age, area of land owned, amount of livestock, other assets, past history of credit and reference from his chief or the head of his Farmers' Association who act as guarantors.

Vunisa Cotton is at the heart of the farming structure in Makhathini. Vunisa Cotton is a private organisation supplying seed, agrochemical, credit and information to farmers in the region as well as buying the product from farmers. The seed companies, such as Delta Pineland, Clark Cotton and OTK, and agrochemical companies, supply their products to Vunisa who then retail them to the small farmers respectively. In the case of Bt cotton, Monsanto owns the Bt gene which Delta Pineland has used to developed the Bollguard™ variety.

Information on cotton is disseminated to the farmers via extension personnel employed by Vunisa. Each of the extension staff is responsible for a specific area and regularly visits the farmers and holds farmers meetings. The Landbank of South Africa provide the finance (credit) and Vunisa is responsible for allocating finance to farmers following stringent assessment.

All the farmers deliver their cotton to Vunisa who weighs and grades the cotton before paying the farmers. Vunisa is the sole supplier of cotton inputs and buyer of cotton output in the region and are not responsible for other crops grown in the area. Figure 1 summaries the farming structure at Makhathini.

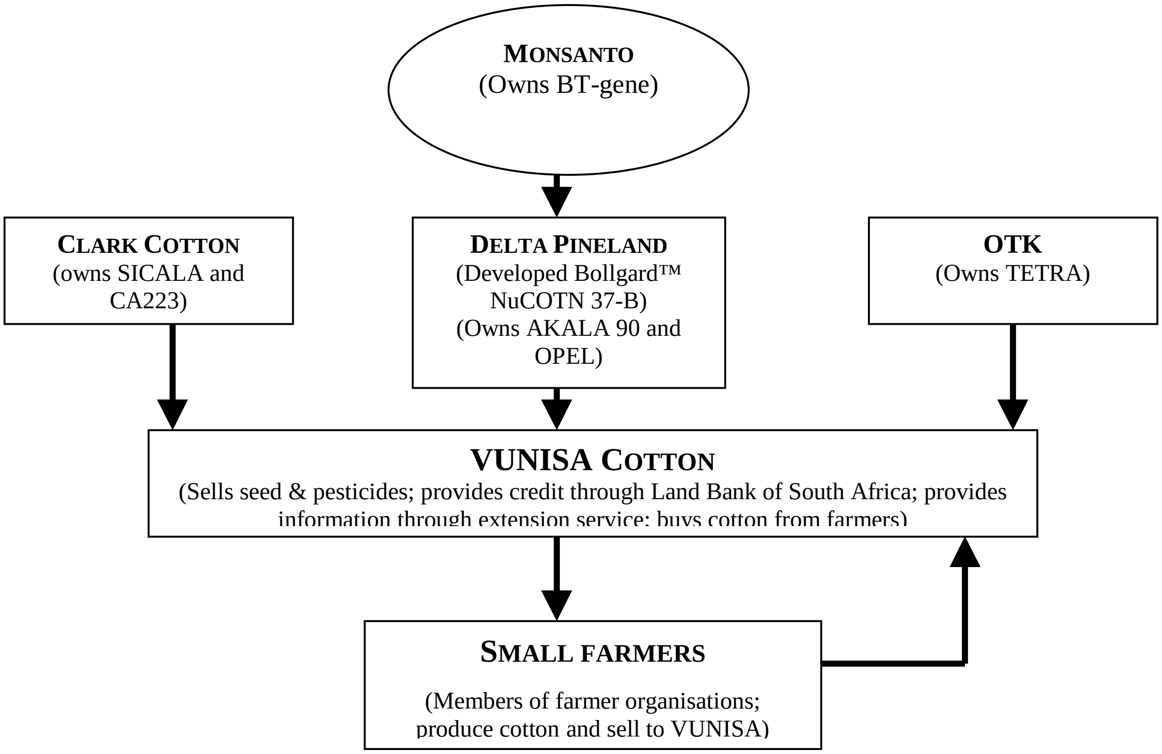

Figure 1. Structure of the farming structure in the Makhathini Flats

2.3 The need for pest control of the cotton crop

Despite many studies that suggest that fertiliser increases yield in cotton, farmers do not use any form of fertiliser in Makhathini, largely because it is too expensive. A similar problem explains why there is little use of herbicide in the area. However, as insect pests are a major cause of yield loss in cotton there was no alternative prior to the advent of the Bt varieties than to apply insecticides to control the major pests of the region – the bollworm complex[1], jassids[2] and aphids[3].

[1] Bollworms consist of a complex number of species, which include American bollworm (*Helicoperva armigera*), Red bollworm (*Diparopsis castenea*) and Spiny bollworm (*Earis biplaga*, *Erias insulana*). Their mature larvae feed on developing buds, squares, flowers and cotton bolls. The damage caused to the buds, flowers and bolls results in their shedding from the cotton plant, with consequent yield reduction. Red and spiny bollworms are the two species that cause the most damage.

[2] Jassids (*Jacobellia fasciallis*), also known as leafhoppers, are sap feeders that remove the sap from cotton leaves. In doing so they introduce toxin to the plant sap resulting in curled up and purple leaves. Jassids attacks plants that are 6-8 weeks old during particularly wet growing seasons.

[3] Cotton aphids (*aphis gossypii*) are found on young shoots, leaves and growing tissue, where they feed on the plant sap. The cotton aphids release salivary toxins, which cause the leaves to curl consequently reducing respiration, photosynthesis and plant growth. Aphids excrete excess sugar, which they have extracted as honeydew. Sooty mould grows on the honeydew and affects the processing of the lint.

The most common insecticides used in Makhathini are Monostem[4] (monocrotophos) Cypermethrin[5] (pyrethroid), Decis[6] (pyrethroid) and Cruiser (thiamethoxam). Monostem, Cypermethrin and Decis have to be mixed with water before application with a knapsack sprayer. Cruiser is a new pesticide, targeting aphids and jassids and is designed to be used solely with Bt cotton. Unlike the other post-emergence pesticides, which are mixed with water and then sprayed, Cruiser comes in the form of a powder which is mixed with the Bt cottonseed prior to planting. Commonly, farmers will spray 5-8 times each season.

3 The Survey

The study was carried out in Makhathini Flats in the North Eastern Province of Kwazulu Natal in the Republic of South Africa . The Makhathini Flats occupies an area of 1800 square kilometres north of Durban in the KwaZulu Natal Province on the Republic of South Africa’s eastern coast (27° East and 32° South). Since 1998, smallholder farmers in the area have been adopting a genetically modified cottonseed variety (NuCOTN 37-B with Bollgard™).

The main focus of the study was to compare the adoption and economic impacts of Delta Pineland’s Bt cotton (Bollguard™) with the non-bt cotton in the region. The survey, carried out in November 2000, covered a stratified sample of forty non-Bt cotton growers and sixty Bt cotton growers. Only 12% of the 4,000 farmers in the region have adopted the new GM-cotton, so the rational for using a stratified sample is to have enough Bt farmers to allow comparisons.

Interview with farmers were carried out with a questionnaire that was designed that covered a range of issues including; family demography and structure, physical characteristics of the farm (e.g. area, number of plots), farmer characteristics (age, gender, experience), cropping management and patterns (e.g. areas of each crop, irrigation, planting and harvesting methods), rationale for adopting Bt cotton and input costs and returns, for the 1998/1999 and 1999/2000-seasons.A number of questions included in the questionnaire were for the purpose of checking responses to key questions. The questionnaire focussed on two growing seasons: 1998/1999 and 1999/2000

4 RESULTS

4.1 General description of the sample

The age group and gender profiles of the two groups of farmers included in the 98/99 and 99/00 surveys are shown in Table 1. For both seasons there were slightly more male than female respondents, and the

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[4] Monostem (sold in 5 litre containers) is a systemic insecticide for the control of red, spiny and American bollworm, aphids and red mites and application takes place as soon as infestation is noted, following regular inspection

[5] Cypermethrin (sold in 2 litre units) is used to control the bollworm complex, and is usually applied during the period of peak flowering until boll spit

[6] Decis (deltamethrin) is sold in 2 litre containers.

majority of respondents were forty years or older. The distribution of cotton areas amongst the respondents is shown in Table 2. As mentioned earlier, most of the farm is planted to just one variety of cotton.. On average, households had more female than male labour. This is typical in South Africa, where a considerable percentage of the males are employed away from their homes, in activities such as mining. Household size is usually positively related to farm size and hence cotton area (Table 3), simply because older farmers tend to have larger farms and families. A minority (approximately 27% of respondents) reported that they did not own any livestock. The remainder owned some cattle, goats and/or chickens. Approximately 70% of the respondents farmed within 5 to 20 km of the Vunisa Cotton depot.

All respondents claimed to have cultivated at least 1 ha of cotton during the first season (98/99) and the second season (99/00), and the maximum area under cotton was 25 ha in both seasons. The major (i.e. ranked first or second) agronomic constraints to cotton cultivation that they reported were insect pests (71%), excessive rain (42%) and drought (12%). Almost all (82%) respondents stated that access to capital is the most significant non-agronomic constraint. The majority of respondents used Vunisa Cotton credit exclusively or in combination with their own financial resources. Some 74% of farmers indicated that they wear protective eyewear and masks when they apply insecticides, and only 3% reported eye problems due to the use of such chemicals.

4.2 Adoption of Bt cotton

The major determinant of Bt adoption was the cotton area to be planted (Table 4); itself largely determined by farm size. In 98/99 57% of those farmers with a cotton area greater than 10ha adopted Bt and this contrasts markedly with an adoption rate of only 7% for those with less than 2.5ha. On average non-adopters had a cotton area of about 4 ha, while adopters had an average cotton area of 6 to 8 ha. This difference was highly significant in 98/99 and almost (P= 0.058) significant in 99/00. It was quite clear that the officials at Vunisa targeted the larger cotton producers in 1998/99, and it is also likely that this group would be more prone to take risks and try a new variety. In the 99/00 season adoption pattern was more uniform across all the cotton area categories (Table 4), ranging from 61, 59, 71 and 89% for categories 1 to 4 respectively. Although the farmers with greater than 10ha of cotton still had the largest adoption rate, the difference between them and the smallest farmers had narrowed substantially. In this season Vunisa officials made more of an effort to target all the farmers, not just the largest, and word had spread amongst the farmers about the potential of the new variety. Wrapped up within the targeting of the larger farmers by Vunisa is the relationship between credit and cotton area. One of the criteria for receiving credit is the farm area along with livestock and other assets.

Beyond cotton area and its association with targeting by Vunisa there was no evidence of any other factor having a major influence on adoption. Both gender and age had no impact, other than due to the obvious relationship between age of farmer and cotton area. The result was usually that the younger farmers had smaller areas of cotton (<2.5 ha) and hence were less likely to adopt Bt cotton in both seasons relative to the other three age groups (Table 5). There was no evidence to suggest that men were more likely to adopt Bt cotton than women. Other factors related to the age of the respondent (and hence farm and cotton area), such as availability of labour (mostly family) and ownership of livestock also showed a weak linkage with adoption.

All the farmers who adopted in the first season continued using Bt cotton in the second season, suggesting that the farmers were satisfied with the performance of the variety. When questioned about the reasons why they adopted Bt cotton, or why they may adopt in the future, the majority of respondents (44%) cited direct savings on the cost of insecticide as the main reason, with 24% citing expected increases in yield. Approximately 10% believed that the labour saving properties (i.e. less time spent spraying) of Bt cotton were critical in the adoption decision. Most of the surveyed farmers did not identify any problems with Bt cotton, other than the cost of the seed being too high. Almost all (90%) of the non-adopters in 99/00 were willing to adopt the technology in the future, but cited cost of the seed as the main reason for not adopting. As already noted the vast majority of respondents felt themselves to be constrained by a lack of capital, and Vunisa officials targeted the larger (more credit worthy) farmers, hence it is perhaps not surprising that credit has played such a major role in the adoption of Bt cotton in Makhathini.

4.3 Yield and economic performance of Bt cotton

Table 6 shows that in the first season 81% percent of the farmers surveyed, cultivated conventional cotton, compared to 19% who grew the Bt variety. In the 1999/2000-season, 65% of the farmers grew the Bt variety. In the first season, the small sample of adopters had yields per hectare that was on average 77 kg (18%) higher than the non-adopters' yields. This is despite a lower seeding rate by adopters (around 21% lower), perhaps because of the higher cost of the seed. Indeed, yield per kg of seed was 25% higher for adopters. In the second year, adopters had an average yield advantage of 156 kg per hectare, an increase of 60%, and a 93% increase in yield per kg of seed over non-adopters. The lower yields in the second season are attributable to the rainfall in the 1999/2000 season that was 50% above average, causing flooding and delayed planting of cotton, as opposed to the lower than average rain at the beginning of the 1998/1999-season, which had favoured the cotton crop. The Bt variety seems to have performed particularly well (relatively) in the wet year.

Yields per hectare decreased with farm size (as expected, given the more intensive cultivation on the smaller land areas) and the smaller producers seem to have gained most yield advantage from the Bt variety.

Table 7 shows that, on average, gross margins of adopters were higher by around R80 (11%) in 98/99 and R276 (76%) in 99/00. Analysis by area shows that producers with the largest areas of cotton have lower yields and gross margins for the Bt variety than for the conventional one. However, sample sizes in this category are very small (just one or two farmers in some cases) and so may not be representative. Generally, gross margins are higher for the Bt cotton because revenues are higher (due to higher yields). There was a reduction in pesticide costs for adopters (of only 13% in 98/99 rising to 38% in 99/00 – see Table 8) of the Bt variety but this benefit was more than cancelled out by the higher cost of the Bt seed (see Table 9) and in the case of the larger size categories (particularly in 98/99) contributed to the lower gross margins of some adopters. However, the pesticide cost data does not include the saving in labour.

It is interesting to note that none of the adopters dropped the Bt variety in the second year and a further 42 farmers adopted it in the second season. The gain in output value and the savings in chemical and spraying labour cost were sufficient to compensate for the higher seed cost.

5 INCOME DISTRIBUTION AND INEQUALITY

The introduction of new technologies can have adverse effects on the distribution of income, as the voluminous literature on the green revolution showed. The farmers who have the resources to adopt may become richer, thus increasing inequality, even if the non-adopters do not suffer a reduction in income. If they are disadvantaged and actually lose land to the better off, this situation is exacerbated and their income levels may actually fall. In this case, data is available from the first year of adoption, when very few farmers used the new technology. Thus, 1998/1999 can serve as a benchmark for tracking the changes in the distribution of land and incomes that result from the introduction of the Bt variety.

The measures of inequality used are the Gini-coefficient and the Lorenz curve. The Gini is defined as the ratio of the area between a Lorenz curve and the diagonal and the total area under the diagonal, where the Lorenz curve is the cumulative shares of income/wealth attributable to proportions of the population. The Gini coefficient is bounded by zero and one, where zero identifies absolute equality in the distribution of income/wealth and 1 absolute inequality.

The Lorenz curve for the distribution of household per capita income is shown in figure 2. The cumulative percentage distribution of per capita income is measured on the vertical axis and that of the population on the horizontal axis. The greater the area between the Lorenz curve and the diagonal, the greater the level of inequality is. The Gini-coefficient can be stated: GINI = A/(A+B). For this sample, the Gini has a value of 0.484 for 1998/1999 and 0.478 for 1999/2000, suggesting that the per capita distribution of income from cotton in this area is about as unequal as the distribution of per capita incomes in the Western European countries.

The distribution becomes slightly less unequal in the second season, so there is no evidence to suggest that the gains are biased in favour of the better off households. However, this is still a very early stage in the adoption process, so although there is no cause for concern at present, the results for the 2000/2001 season will give a better clue as to the longer term consequences of the new technology on equality.

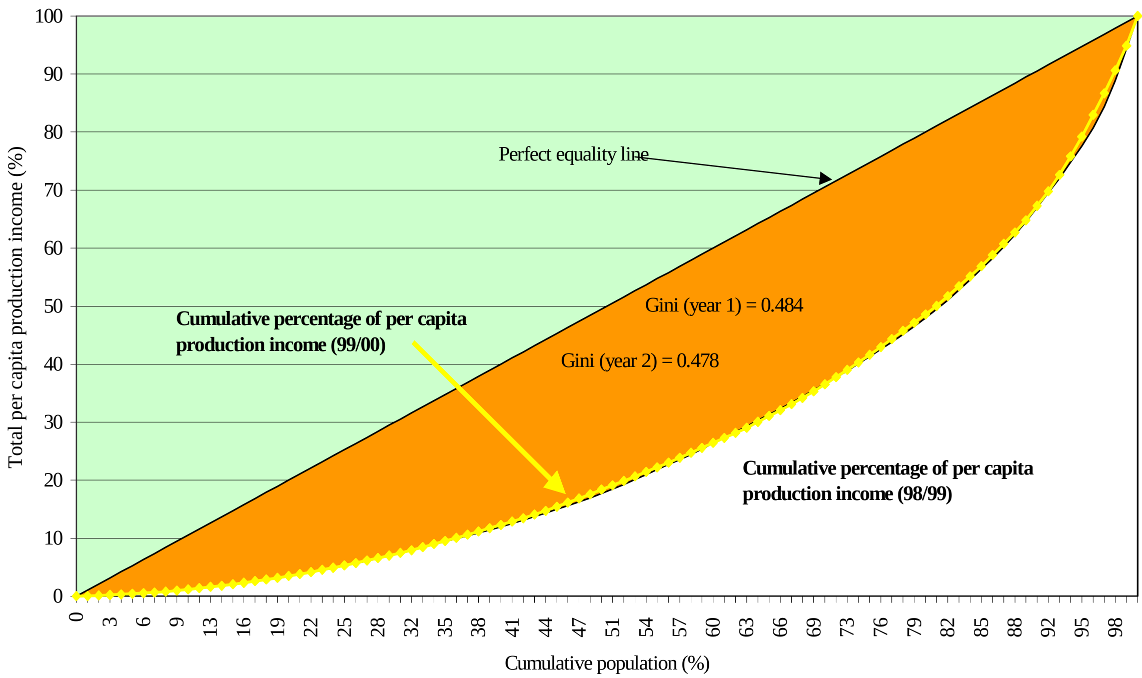

Figure 2: Distribution of per capita production income (Year 1 and 2)

5 DISCUSSION

In a system such as that of cotton production on the Makhathini Flats, with only one supplier of inputs and source of credit, it is perhaps not surprising that the main dynamics at play in adoption of Bt cotton were as they were. Vunisa staff clearly wished to promote the technology, and the larger cotton growers were a clear target in 98/99. These farmers are also likely to be more prone to take risks, and if told that they will see higher gross margins through the use of less pesticide it is not surprising that they adopted the Bt variety - despite the high cost of the variety relative to the non-GM types. They would also be the most credit worthy given their larger farm sizes and ownership of assets. All of this (targeting, credit worthiness, risk taking) resulted in a clear relationship between cotton area (farm size) and adoption. In the following season the promotion campaign extended to all farmers, no doubt aided by farmer-farmer communication and Vunisa publicity extolling the virtues and successes of Bt cotton. In this second season adoption was more uniform across farm sizes, although farmers with the larger farms still had the highest rates of adoption.

As well as the yield gains and chemical cost savings mentioned above, there are other potential benefits for adopters of the Bt cotton. Although the farmers had participated in training sessions, actual practices concerning pesticide use and seeding rates deviated considerably from the recommendations. A quarter of the sample was using more chemicals than was recommended and 3% were using less. This is an understatement of the error, in that the overuse is almost entirely a matter of a minority of Bt adopters applying two chemicals (Monostem and Cyper) that are specifically intended to control bollworms, when the whole point of the variety is that these chemicals are not jointly needed. Yet, in a considerable number of cases, the Bt users followed their non-adopting neighbours in spraying for bollworms. This may indicate that the information provided during training and on the packaging is not effective or it is unclear, or farmers are not adhering to the information provided for reasons such as illiteracy.

Alternatively, farmers may be following a risk-reducing strategy, especially in the first year of adoption. Also, a reduction in the need for insecticide will mean a reduction in the labour required to apply it. One application of pesticide (by hand) takes around 4 hrs per hectare on average. The use of Bt cotton could save 2-5 applications per year compared to a conventional variety (some spraying for other pests will still continue), giving a labour saving of 8-20 hours per hectare. The value of this saving will depend on the opportunity cost of labour time for each smallholder.

There is also another advantage to the adoption of Bt in the area. A drop in the use of insecticide must be beneficial in health terms, for the farmer, the environment and for society as a whole (Betz *et al*., 2000; Wilkins *et al*., 2000). Many countries in Africa suffer from the environmental and human health problems caused by pesticides (Yousefi, 1999). Pesticides have acute and chronic effects and some effects occur after repeated exposure. Symptoms of acute effects such are vomiting, eye and skin complaints, convulsions, coma, and even death. Chronic effects may take days or even months to occur. Troubled farmers often resort to using pesticide to commit suicide (Yousefi 2000). A study carried out in Makhathini by Rother (2000) found that although women and children generally do not apply pesticides, they are at risk of accumulated exposure because of their long working hours and because their exposure starts at an earlier age (foetal age). In Makhathini farmers believe that the chemical containers are cleaned and can be reused, for example, for storing water and brewing beer. Similarly farm workers in the area ate the edible Cadolo weed that have been sprayed with pesticide (Rother, 2000). Pesticides not only affect people working with them but also can enter the environment in several ways. The foliar application of Monotem and Cypermethrin followed by a heavy downpour of rain leads to the pesticide running to nearby streams or water sources. Similarly farmers often wash their containers in the nearby water source without realising the consequence. This causes water pollution and affects the health of those who use the water source. Indeed, there is evidence that fish and beef in South Africa have high levels of pesticide residue (Yousefi, 2000). Yousefi argues that pesticide contamination constitutes a severe threat to wildlife, particularly to fish and birds. Clearly Bt cotton should have some external benefits, although whether the reduction of pesticide usage can be sustained is an entirely different matter.

Unfortunately, a reliance on just one supplier for all inputs and the credit necessary to purchase them may simplify matters for the producer, but also creates dependency between the farmers and supplier. If Bt resistance breaks down, then the suppliers need to be adaptable. It is here that the dangers may reside. A rapid increase in popularity of Bt cotton could result in a decline in the use of other varieties, and a commercial decision throughout the supply chain to concentrate on Bt and carry less pesticide stock. If there is a shortage of pesticide, or even non-GM seed, then the farmers of the area could be highly vulnerable. In that sense the Bt cotton is something new in the Makhathini Flats - a variety that can more radically change the nature of production and the input supply chain. Although farmer livelihood impacts of GM crops has received some attention, little is known in the developing world about the more retail and marketing side impacts that could happen.

6 CONCLUSION

There would appear to be yield, cost and gross margin benefits for small holders of growing Bt cotton compared to the conventional alternatives, especially for the smallest producers – which has important implications for livelihoods. Moreover, there should be associated environmental and human health benefits.

However, the highlighted benefits does not necessarily imply high rates of adoption and overall financial success. Given the short study period (two years), no definitive conclusions can be drawn about the adoption dynamics in the region. Some farmers may have decided to return to non-GM varieties in the long run, if the seed suppliers decide to appropriate a greater share of the benefits by raising their prices. If this were to happen, it would be unfortunate, as this pilot study shows that there are gains at the farm level. However, in any adoption studies of GM crops, the exclusion of some farmers due to the inability to meet the initial higher seed costs and the resulting impact on income inequality must be a crucial part of the analysis.

Finally further years of data are required for a larger sample of farmers, together with more detailed data on the labour and other aspects of adoption before final judgement of the benefits of Bt cotton to small holders can be made. Moreover, it would be interesting to gauge the relative benefits of uptake of the crop for larger, commercial farmers compared to small holders, and this research is currently being undertaken.

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Map 1 Makhathini Flats

Table 1: Age categories of males and females in the sample.

		Age group category				
Season	Sex	20-29	30-39	40-49	> 50	Totals
98/99	M	2	6	20	23	51
	F	5	9	16	10	40
	Totals	7	15	36	33	91
99/00	M	2	5	20	26	53
	F	4	9	15	10	38
	Totals	6	14	35	36	91

Table 2: Age category and cotton area category.

	Cotton area	Age group category				
Season	Category (ha)	20-29	30-39	40-49	> 50	Totals
98/99	<2.5	6	8	9	6	29
	2.5 - 5	1	3	15	16	35
	>5 - 10	0	3	8	9	20
	> 10	0	1	4	2	7
	Totals	7	15	36	33	91
99/00	<2.5	4	6	8	10	28
	2.5 - 5	2	2	16	17	37
	>5 - 10	0	4	7	6	17
	> 10	0	2	4	3	9
	Totals	6	14	35	36	91

Table 3: Household size and relationship to cotton area categories in 1998 and 1999.

	98/99		99/00	
Cotton area	Mean	SD	Mean	SD
<2.5	6.3	0.86	6.8	0.75
2.5 - 5	6.9	0.75	6.6	0.65
>5 - 10	9.3	0.91	8.0	0.97
> 10	9.7	1.46	9.2	1.35
F-value	3.18		1.35	
df	3, 86		3, 86	
Significance	P < 0.05		not significant	

Table 4: Relationship between adoption of Bt and area of cotton cultivated.

(a) Category distribution

Adopter		Year	Cotton area category <2.5	2.5-5	>5-10	>10	Totals
No		‘98	27	29	15	3	74
		‘99	11	15	5	1	32
Yes		‘98	2	6	5	4	17
		‘99	17	22	12	8	59
As percentage	No	‘98	93	83	75	43	81
of totals	Yes	‘98	7	17	25	57	19
As percentage	No	‘99	39	41	29	11	35
of totals	Yes	‘99	61	59	71	89	65
Totals		‘98	29	35	20	7	91
		‘99	28	37	17	9	91

(b) Cotton area (ha)

Season	Adoption	Mean	SD	F-values (df) Significance
98/99	No	4.3	0.5	14.37 (1, 89) $P < 0.001$
	Yes	8.6	1.0	
99/00	No	4.0	0.9	3.7 (1, 89) $P = 0.058$
	Yes	6.1	0.6	

Table 5: Age categories of adopters and non-adopters.

			Age group category				
Adopter		Year	20-29	30-39	40-49	> 50	Totals
No		‘98	7	11	30	26	74
		‘99	4	5	10	13	32
Yes		‘98	0	4	6	7	17
		‘99	2	9	25	23	59
As percentage	No	‘98	100	73	83	79	81
of totals	Yes	‘98	0	27	17	21	19
As percentage	No	‘99	67	36	29	36	35
of totals	Yes	‘99	33	64	71	64	65
Totals		‘98	7	15	36	33	91
		‘99	6	14	35	36	91

Table 6: Yield (kg/ha) of cotton cultivated.

		98/99			99/00		
adoption	area	N	mean	SD	N	mean	SD
no	1	27	576	65	11	330	65
	2	29	447	63	15	327	56
	3	15	366	87	5	178	97
	4	3	468	195	1	628	-
yes	1	2	839	239	17	565	53
	2	6	598	138	22	480	46
	3	5	354	151	12	319	63
	4	4	326	169	8	273	77
no		74	434	49	32	261	43
yes		17	511	82	59	417	30
	1	29	628	75	28	456	42
	2	35	499	65	37	403	37
	3	20	382	79	17	246	54
	4	7	382	127	9	252	76

Note: The relationship between farm size and average yield was statistically significant at the 5% level for the 99/00 season

Table 7: Gross margin (Rand) per hectare of cotton cultivated

		98/99			99/00		
adoption	area	N	mean	SD	N	mean	SD
no	1	27	915	137	11	413	137
	2	29	742	132	15	457	117
	3	15	652	184	5	253	203
	4	3	840	411	1	1079	-
yes	1	2	1485	503	17	811	110
	2	6	875	291	22	744	97
	3	5	608	318	12	504	131
	4	4	507	356	8	434	160
no		74	731	104	32	362	90
yes		17	811	173	59	638	63
	1	29	989	157	28	625	87
	2	35	791	136	37	601	76
	3	20	661	166	17	373	113
	4	7	644	267	9	399	157

Note: These relationships were not statistically significant at the 5% level.

Table 8: Cost of seed (Rand) per hectare of cotton planted.

		98/99			99/00		
adoption	area	N	mean	SD	N	mean	SD
no	1	27	149	10	11	149	27
	2	29	116	10	15	129	23
	3	15	80	14	5	58	39
	4	3	73	31	1	95	-
yes	1	2	232	38	17	286	21
	2	6	285	22	22	231	19
	3	5	115	24	12	139	25
	4	4	152	27	8	128	31
no		74	100	8	32	91	17
yes		17	202	14	59	197	12
	1	29	199	13	28	221	17
	2	35	179	11	37	180	14
	3	20	115	13	17	93	22
	4	7	111	22	9	83	30

Note: The difference of seed costs for adopters vs non-adopters was statistically significant at the 1% level for 98/99 and 99/00.

Table 9: Cost of pesticide applied (Rand) per hectare of cotton cultivated.

		98/99			99/00		
adoption	area	N	mean	SD	N	mean	SD
no	1	27	189	11	11	156	16
	2	29	114	10	15	125	14
	3	15	63	15	5	77	24
	4	3	105	33	1	192	-
yes	1	2	108	40	17	131	13
	2	6	140	23	22	70	12
	3	5	48	25	12	52	16
	4	4	50	28	8	31	19
no		74	112	8	32	116	11
yes		17	98	14	59	72	8
	1	29	177	13	28	145	10
	2	35	114	11	37	96	9
	3	20	56	13	17	69	14
	4	7	75	22	9	66	19

Note: The difference of pesticide costs for adopters vs non-adopters was statistically significant at the 1% level for 99/00 but not significant (at the 5% level) for 98/99.