CHAPTER 4

FARM-LEVEL EFFECTS

"If it looks like a duck, and quacks like a duck, we have at least to consider the possibility that we have a small aquatic bird of the family anatidae on our hands."
Douglas Adams, 1988

4.1 INTRODUCTION

Bt crops refer to the genetically modified crops that carry the gene from the soil bacterium *Bacillus thuringiensis.* Bt is a bacilliform bacterium that produces spore and crystal protein toxins. Different subspecies produce proteins that are toxic to different insects. The Bt cotton for example produces CRYIA(c) proteins and Bt maize produces either CRYIA(b) CRYIA(c) or CRY9. All these mentioned proteins are toxic to Lepidoptera larvae. Crops containing the Bt gene are able to produce this toxin, thereby providing protection throughout the entire plant. These crops are said to be insect-resistant and are designed to reduce yield losses through better pest control.

Small-scale and large-scale cotton farmers as well as large-scale maize farmers in the previous chapter indicated higher yields and saving on pesticides as reasons for adoption of insect resistant cotton and maize. This chapter indicates whether and how these perceived benefits and advantages financially materialise in farmers' production budgets.

This Chapter will attempt to quantify the benefits as well as the disadvantages of insect resistant cotton and maize as produced by large-scale and small-scale farmers in South Africa.

4.2 FARM-LEVEL IMPACT OF INSECT RESISTANT CROP ADOPTION

Adoption of insect resistant (Bt) crops impacts farm income in at least three different ways:

- Increase in yield due to better pest management
- Decrease in input cost through savings on insecticide chemicals and application costs
- Increase in input cost through a higher seed price and an additional technology fee.

If the particular pests are present but not in sufficient numbers to significantly effect yield, or if the pests affect yield but can be inexpensively controlled by other means, then the producer of the pest resistant crop may not experience a net benefit. If the pests are prevalent to an economically damaging extent in the area, however, then this complete control can result in significant yield increases (Marra, Pardey & Alston, 2002).

Many studies show that the use of insect resistant crops reduces the number of sprays and thus pesticide volumes needed to control problem insects. If the reduced spraying need outweighs the additional cost of seed, then farmers gain. Table 4.1 summarises some studies and their findings. Most of these studies were conducted in the United States where the technology was developed, approved and first adopted.

Table 4.1: A summary of some selected previous farm-level impact studies

Bt Cotton					
Researcher	**Country - state**	**Data source**	**Yield**	**Insecticide use**	**Gross margin**
Stark, 1997	USA, Georgia	Survey	Increase	Decrease	Increase
Gibson et al., 1997	USA, Mississippi	Survey	Increase	N/A	Increase
ReJesus et al., 1997	USA, South Carolina	Experiments	Same	N/A	Increase
Bryant et al., 1998	USA, Arkansas	Experiments	Increase	N/A	Increase
Marra et al., 1998	USA	Survey	Increase	Decrease	Increase
Pray et al., 2000	China	Survey	Increase	Decrease	Increase
Fernandez-Cornejo et al., 2000	USA	Survey	Increase	Decrease	Increase

Bt Maize					
Crop and researcher	**Country - area**	**Data source**	**Yield**	**Insecticide use**	**Gross margin**
Marra et al., 1998	USA, Cornbelt	Survey	Increase	Decrease	Increase
European Commission, 2000		Field trails	Increase	N/A	Increase
Rice et al., 1998	USA	Variety trails	Increase	N/A	N/A
Gianessi et al., 1999	USA	Experiments	Increase	N/A	N/A
Brookes 2002	Spain	Survey	Increase	Decrease	Increase
STRIVE Foundation 2002	Philippines	Field trails	Increase	N/A	Increase

Source: Adapted from Marra, 2001.

4.3 FARM-LEVEL IMPACT OF Bt COTTON IN SOUTH AFRICA

In a field trial conducted by Clark Cotton on their Mpumalanga experimental farm, a comparison was made between the production budgets of Bt cotton (NuOpal) and a conventional cotton variety (Opal) as produced under irrigation. As illustrated in Table 4.2 the main difference between the budgets can be found in yield, insect control and seed cost. It is also interesting to note Bt cotton's increased harvesting cost due to increased yield.

Even though field trails give a good indication of the yield potential of different seed varieties under different production conditions, it is better to look at the production experience of a number of farmers in different areas to come to any conclusion regarding the on-farm effects of Bt cotton.

Table 4.2: Budget comparison of Opal (conventional) and NuOpal (Bt) cotton

Operation	Unit	Cost per unit	Opal		NuOpal	
			Quantity per ha	Cost in rand	Quantity per ha	Cost in rand
1.PRE –SOWING						
Soil correction (gypsum)	Ton	52.0	3.0	156.0	3.0	156.0
Ripping	Mach/hour	100.0	0.5	50.0	0.5	50.0
Disking	Mach/hour	72.0	2.0	144.0	2.0	144.0
Herbicides Cotonex	Liter	56.0	4.0	224.0	4.0	224.0
Metagan	Liter	118.0	0.7	82.6	0.7	82.6
Sub-total				**656.6**		**656.6**
2. SOWING						
Seeds - conventional	Kg	7.6	18.0	136.8	0.0	0.0
- Bt	Kg	8.4	0.0	0.0	18.0	151.2
Bt licence	R/bag	600.0	0.0	0.0	400.0	400.0
Fertiliser (13:7:10)	Kg	1.9	150.0	285.0	150.0	285.0
Operation	Mach/hour	48.0	1.0	48.0	1.0	48.0
Sub-total				**469.8**		**884.2**
3. GROWING						
Mechanical weeding	Mach/hour	56.0	2.0	112.0	2.0	112.0
Manual weeding	Man/day	24.0	8.0	192.0	8.0	192.0
Fertiliser (LAN:28)	Kg	0.9	380.0	342.0	380.0	342.0
Irrigation	Mm	0.7	260.0	182.0	260.0	182.0
Growth regulator	Liter	106.0	0.940	100.0	0.940	100.0
Sub-total				**928.0**		**928.0**
4. INSECT CONTROL						
Thioflo (Endosulfan)	Liter	75.0	3.7	277.5	0.3	22.5
Agromectin	Liter	352.0	0.3	105.6	0.3	105.6
Cypermethrin	Liter	84.0	0.5	42.0	0.5	42.0
Aerial costs		60.0	6.0	360.0	6.0	120.0
Sub-total				**785.1**		**290.1**
5. HARVESTING						
Hand picking	Kg seed cotton	0.55	6665.0	3665.8	7782.0	4280.1
Seed cotton cost				**6504.5**		**7039.0**
6. ECONOMIC COSTS						
Management &				2344.0		2344.0
administrative				160.0		160.0
Interest on capital invested						
All repairs						
General farm overheads						
7. FIXED COSTS				80.0		80.0
8. TOTAL COSTS				**9088.5**		**9623.0**
9. VALUE OF SEED COTTON	Kg	2.75	6665.0	18328.8	7782.0	21400.0
10. PROFIT				**9240.3**		**11777.0**

Source: Hofs, 2001

4.3.1 YIELD

The yield benefit enjoyed by farmers using Bt cotton differs between countries and between regions within countries. The yield advantage mainly depends on the pest pressure of the pest the Bt gene is controlling for, as well as the insect controlling practises of the farmers. Edge et al., (2001) refer to various studies in which yield increases were found. In the United States significant yield increases have been reported in studies across the Cotton Belt. Kerby (1996) found a yield increase of 20%, while Altman (2001) indicated a 14% yield increase. In China (Buranakanonda, 1999) and Spain (Novillo et al., 1999) yield increases of respectively 15 and 12 percent were found while a study in India recorded a yield increase of between 14 and 38 percent. Another study in India by Qaim (2002), found a yield increase of up to and in excess of 80%. The author contributes this huge yield increase to a very high level of bollworm infestation in the study season as well as ineffective bollworm-related yield loss control methods in conventional cotton due to lower pesticide usage levels, pesticide resistance and human capital as well as institutional constraints.

In Table 4.3 the yields of Bt cotton adopters and non-adopters in South Africa are compared. As Klotz-Ingram et al., (1999) admonish, caution must be exercised in interpreting results. Differences between yields and pesticide applications cannot solely and necessarily be attributed to the use of genetically engineered seed as they are also influenced by other factors. These factors include: irrigation, weather, soils, nutrients, pest management practises, crop management, pest pressure, other-crop practices and operator characteristics. The majority of large-scale cotton and maize farmers used in this study were able to compare Bt and non-Bt varieties as they produced both Bt and non-Bt crops and variation in production practises and conditions were thus kept to a relative minimum. Even though production conditions and practises of cotton farmers on the Makhathini Flats are also rather similar, caution is still advised when data for both large and small-scale maize and cotton farmers are interpreted.

The average cotton yield of South African adopters seems to be significantly higher than that of non-adopters for both the large-scale and the small-scale farmers (Table 4.3). Large-scale irrigation farmers enjoyed an 18.5% yield increase with the use of Bt cotton while field trails on the Clark Cotton experimental farm in Mpumalanga indicated a 16.8% yield increase (Hofs, 2001). Dryland large-scale farmers enjoyed a 13.8% yield increase with the use of Bt seed while dryland small-scale farmers on average experienced a 46% yield increase. The difference in yields was statistically significant at a 95% confidence level for the irrigation and dryland large-scale farmers as well as for the small-scale farmers.

Table 4.3: Comparing the average yield per hectare of large and small-scale adopters and non-adopters in South Africa

		Non-Bt Large-scale 2000/2001 (kg/ha)	Bt Large-scale 2000/2001 (kg/ha)	Non-Bt Small-holder 1999/2000 (kg/ha)	Bt Small-holder 1999/2000 (kg/ha)
Irrigation	**Mean**	3413	4046		
Dryland	**Mean**	832	947	395	576

Source: Large-scale data – own survey
Small-scale data – Ismaël et al., (2001) and own survey

The yield benefit enjoyed by large-scale farmers compares well with that of farmers in the United States. It can be argued that this is because of similar capital-intensive (mechanical) pest control practices. The yield benefit of small-scale farmers on the other hand is more like that of the Indian farmers. Qaim (2002) indicated low pesticide levels, lack of human capital and institutional constraints as some reasons for the large difference between the yield of Bt cotton and conventional cotton with conventional spraying practices. These reasons also apply to South African small-farmers. As was mentioned in Chapter 3, by the time a small-scale farmer has noticed bollworms, bought his pesticides and started to spray, severe damage has already been done. Many farmers indicated that they were not even able to apply pesticides on their whole field due to lack of time, knapsacks, labour and the cost of pesticide. With a low education level causing problems with the mixing of pesticides and the calibration of knapsack spraying nozzles, the efficacy and efficiency of pesticide applications is questionable for a large number of small-scale farmers.

According to Hofs (2001) the yield advantage of Bt cotton can be attributed to a better fruit retention at the first position and a significant higher number of bolls at secondary positions. In laymen's terms this means that the Bt cotton plants have more bolls closer to the main stem where it can take advantage of the maximum nutritional flow and are less sensitive to stress. These bolls are formed first and are the biggest and heaviest and are typically lost due to damage caused by bollworms.

There was also a yield difference between the cotton produced under pivot irrigation and flood irrigation. Some farmers in the Northern Cape use flood irrigation, which is less effective than pivot irrigation, and farmers especially have irrigation-labour problems during the grape season.

4.3.2 PESTICIDE USE

A significant benefit that Bt cotton brings to growers is a reduction in the use of conventional broad-spectrum insecticide sprays and the associated total kilograms of insecticidal active ingredients for control of lepidopteran species. Numerous studies conducted across the United States, Australia, China, Mexico and Spain demonstrated an overall reduction in the application of broad-spectrum insecticide sprays ranging from 1 to 7.7 sprays. In China the adoption of Bt cotton has reduced the total insecticide use by 60 to 80 percent and the applications of insecticides for lepidopteran pests by 90 to 100 percent (Edge et al., 2001). Qaim (2002) reports that on average, Bt cotton in India was sprayed three times less than conventional cotton varieties. The number of saved sprays and thus the pesticide saving benefit due to Bt cotton depends on the infestation level of the particular insect. Due to the cyclical and fluctuating nature of the seasonal emergence and presence of insects in nature and thus on crops, saving on pesticides and sprays will vary between seasons and regions.

Monsanto reports an average saving of 5.8 sprays on dryland field trails on the Makhathini Flats (Bennett, 2001), while Hofs (2001) reports a saving of 4 insecticide applications on irrigated cotton in Mpumalanga. These 4 applications would have consisted of approximately 3.4 litres of endosulfan (organophosphate). South African farmers still need to spray for sucking insects like Jassids and Aphids. With conventional cotton these pests are killed in the crossfire aimed at the bollworm complex but have now become the main cotton pests. Jassids and Aphids can be controlled with relatively inexpensive, environmentally less damaging organophosphates. These insecticides are less effective on bollworms however and most farmers have to apply a pyrethroid to control bollworms. Pyrethroids, rather detrimentally to the celebrated integrated pest management approach, also kill all the beneficial insects like lacewings and ladybirds and thus the risk of a Red Spider Mite invasion is increased due to the removal of the natural predators.

Table 4.4: Cost of insecticides for adopters and non-adopters

		Non-Bt Large-scale 2000/2001 (R/ha)	Bt Large -scale 2000/2001 (R/ha)	Non-Bt Small-holder 1999/2000 (R/ha)	Bt Small-holder 1999/2000 (R/ha)
Dryland	**Mean**	192	79	129	97
Irrigation	**Mean**	519	226		

Source: Large-scale data – own survey
Small-scale data – Ismaël et al., (2001) and own survey

It is important to note that the data shown in Table 4.4 represents the Rand value per hectare spent on chemicals to control insects harmful to cotton. These figures do not include application costs. For large-scale farmers who hire an aeroplane for spraying, 4 less sprays would mean a saving of between R182 and R336 per hectare. It is estimated that large-scale farmers spraying with a tractor save between R52 and R144 on average for diesel, lubrication and mechanical wear and tear. For small-scale farmers, having to spray less means saving labour – in most cases farmers apply the insecticides themselves. Less spraying time means more time for weeding or other activities.

4.3.3 COST OF SEED AND THE ADDITIONAL TECHNOLOGY FEE

At this time, little downside risk from Bt cotton use has been documented, other than that the cost of the technology fee, which in seasons when pest infestation is relatively low, can be greater than the cost of conventional broad-spectrum insecticide costs (Edge et al, 2001). The ICAC (1997) indicated that farmers planting Bt cotton in the USA paid US$ 80/ha for Bollgard technology, under the assumption that the technology would save them at least US$ 80/ha in insecticide spraying or bring about an increased yield.

The higher Bt seed price South African farmers have to pay is comprised of a seed price paid to the seed supplier (Delta and Pineland) and a technology paid fee to the technology supplier (Monsanto). In the 1998/1999 season the "seed cost" of Bt cotton seed was R165 for 25kg compared to R150 for the conventional isoline. In 1999/2000 farmers paid R20 more for Bt seed than the conventional variety and in 2000/2001 farmers paid a R25 premium.

Table 4.5 compares the cost of seed and pesticides of non-adopters with the cost of seed, additional technology fee and pesticide cost of adopters. It is clear that neither small-scale nor large-scale farmers were able to cover the higher seed cost and the additional technology fee purely out of savings on pesticide chemicals in either of the surveyed production seasons. If the costs of pesticide application were added for adopters and non-adopters, this table would probably show a different picture. This study has however not been able to quantify the labour-saving aspect for small-scale farmers.

Table 4.5: Comparing the total per hectare cost of seed and pesticides for non-adopters with adopters' seed-, technology- and pesticides cost.

		Non-Bt Large-scale 2000/2001 (R/ha)	**Bt Large-scale 2000/2001 (R/ha)**	**Non-Bt Small-holder 1999/2000 (R/ha)**	**Bt Small-holder 1999/2000 (R/ha)**
Dryland	**Mean**	255	375	254	385
Irrigation	**Mean**	671	796		

Source: Large-scale data – own survey
Small-scale data – Ismaël et al., (2001) and own survey

Another factor that distorts the seed cost, technology fee and pesticide figure of small-scale adopters in Table 4.5 and makes it difficult to make comparisons with large-scale farmers is the fact that large-scale farmers paid a technology fee of R600 / 25kg of Bt seed while small-scale farmers paid a technology fee of only R230 / 25kg. The lower technology fee for small-scale farmers can be explained by a combination of possible factors including willingness to pay, an effort towards poverty alleviation by the multinational technology innovator, but more likely an endeavour to establish a market for transgenic cotton among small-scale producers as the small-holder farming conditions in South Africa are more applicable to the rest of Africa than that of the South African large-scale farmers. The more agriculturally related reason is that large-scale dryland cotton farmers plant between 5.3 and 8 kg of seed per hectare while according to Vunisa many small-scale farmers are known to plant up to a bag (25kg) of seed per hectare. According to Ismaël et al., (2001) adopting small-scale farmers plant 11.5 kg of seed on average. Table 4.6 illustrates that the difference in technology fee per hectare, for small-scale farmers planting between 11.5 and 25 kg of seed per hectare and for large-scale farmers planting between 5 and 9 kg of seed per hectare, is not as substantial as the difference in technology fee per bag would suggest.

Table 4.6: Technology fee per hectare comparison between small-scale and large-scale dryland farmers

	Small-scale dryland farmers R230 / 25kg	Large-scale dryland farmers R600 / 25kg
Kg seed per ha	**Technology fee per ha**	**Technology fee per ha**
5	46	120
6	55	144
7	64	168
8	74	192
9	83	216
10	92	240
11	101	264
12	110	288
18	166	432
25	230	600

Source: Own survey

Many of the large-scale farmers indicated that they felt that Bt cotton could be seen as a kind of insurance against bollworms. In seasons with low bollworm pressure conventional cotton might be more profitable than Bt cotton, but in a season where bollworms cause enough damage to significantly affect the yield, the Bt insurance covers the loss.

4.3.4 THE INCOME EFFECT

Despite the higher seed cost and an additional technology fee, both large-scale and small-scale farmers realised higher net incomes per hectare with Bt cotton due to the higher yield and savings on pesticide chemicals (Table 4.7). This income benefit may be expected to increase if cost of application is taken into account. The advantage of less chemical application for small-scale farmers is both financial and health related. Some other benefits that cannot be directly expressed in monetary terms are less pest control labour needed, less water transport and less exposure to toxic chemicals. Large-scale farmers save on fuel, repairs and maintenance or on flying costs. There is also less tractor traffic in the cotton fields, realising indirect benefits to soil quality.

Table 4.7: Income effect of adoption of Bt cotton

	Small-scale farmer	Large-scale farmer	
	Dryland (R/ha)	**Dryland (R/ha)**	**Irrigation (R/ha)**
Yield Benefits per hectare @ R2.75/kg	498	314	1741
Reduced pesticides benefit	32	114	293
Increased seed and technology fee detriment	(163)	(234)	(419)*
Income advantage / disadvantage	367	194	1615

* This is a revised figure from an earlier publication (Kirsten, Gouse and Beyers, 2002)

In a country like South Africa where unemployment is a huge and very real problem, labour saving due to a lower need for insecticide applications cannot be good news for an already struggling rural labour force and community. However with a yield increase in excess of 40%, additional labour would be needed for harvesting. Thirtle and Shankar (2003) estimate the net effect of Bt cotton adoption is to increase hired labour on the Makhathini Flats by about 15%. Due to the mechanised pest control methods of large-scale farmers, the labour saving / job loss concern for farm workers is not significant. However with approximately 40% of South Africa's cotton being harvested by hand, a yield increase means an increase in the demand for labour. In a simplified example of a Bt adopter, a yield increase of 633 kilograms per hectare under irrigation and at an average picking cost of R0.55 per kilogram of seed cotton, would mean that a large-scale farmer making use of manual harvesting would have to spend R348 per hectare more on labour.

A high percentage of large-scale farmers have indicated peace of mind about bollworms as a very important benefit of Bt cotton. Peace of mind about bollworms gave large farmers more managerial freedom; thus more time to spend on the production of other crops or farming activities. This chapter did not attempt to quantify the value of peace of mind but it is suggested that this value can be expressed as a percentage of the income from other farming activities. This percentage represents the value of production that might have been lost if less time were spent on the management of other crops or activities.

4.4 FARM-LEVEL IMPACT OF BT MAIZE IN SOUTH AFRICA: LARGE-SCALE MAIZE FARMERS

According to Marra (2001) the only major benefit to date of Bt maize in the USA has been an increase in yield, because in most areas and over most years the European corn borer infestation level has not been significant enough to control with insecticides. However, in South Africa and other southern African countries the losses sustained in maize crops due to damage caused by the African maize stalk borer (*Busseola fusca)* are estimated to be between 5 and 75 percent and even higher (Annecke & Moran, 1982). According to Annecke and Moran (1982), it is generally accepted that B. fusca reduce the South African maize crop by an average of 10%. According to Kfir (1997), *Busseola fusca* and the *Chilo* stalk borer (*Chilo partellus)* are the most important pests of maize and grain sorghum in South Africa. A seemingly conservative estimation of 10% for damage caused by both B. fusca and C. partellus means an average annual loss of just under a million tons of maize with an approximate value of above R810 million. According to unpublished "Crop production guidelines" of the South African Department of Agriculture (1991), it is especially the November plantings on the Highveld that four in every five seasons come under considerable pressure from second generation stalk borers known as "kopruspe".

4.4.1 YIELD

The yield advantage created by the use of Bt maize depends on the stalk borer infestation level and the conventional pest management efficiency of the farmer, as the Bt gene does not increase maize yield but only decreases yield loss caused by stalk borers. The yield advantage thus differs between regions and between farmers within regions. Large-scale yellow maize farmers were asked to compare the yield of Bt maize with that of their conventional varieties. There is however an important difference to note between the maize yield comparisons and the cotton yield comparison discussed above. Cotton farmers were able in most cases to compare the Bt variety with either the conventional isoline (Acala 90) or the most popular conventional variety at the time, Delta Opal. Maize farmers however have a wide range of maize seed varieties marketed by a number of seed companies to choose from. Each season a number of new, genetically improved through conventional breeding but not genetically modified, maize varieties come onto the market. Each maize production area has certain maize varieties specifically bred to suite the production conditions of the area. In 2000/2001 when the survey was conducted only a limited number of Bt varieties were available for commercial production and farmers thus had to compare relatively older varieties containing the Bt gene with newer, in many cases better adapted, conventional varieties. Despite this fact the majority of large-scale farmers surveyed enjoyed yield increases with Bt maize and only about 10% indicated lower yield with Bt maize.

Marra, Carlson and Hubbell (1998) report that the use of Bt corn resulted in better control of the European corn borer, boosting yields in the US by 4 to 8 percent depending on location and year. Marra, Pardey and Alston (2002) indicate a range of yield increases in different US states, from 1138 kg/ha in Minnesota to 444 kg/ha in Iowa. In the Huesca region in Spain, Brookes (2002) reports a yield increase of 10% where pesticides where used on conventional maize and an increase of 15% where insecticides where not used. Other regions in Spain enjoyed an average of 6.3% with in a range of 2.9 and 12.9 percent. Gonzales (2002) recorded a yield advantage of 41% with Bt maize on field trails in the Philippines while Philippine farmers indicated a 60% yield benefit. According to Mr JHE Barry (2002), a large-scale maize, dairy and pork farmer close to Bergville in KwaZulu Natal, his Bt yellow maize outperformed his conventional maize varieties by over 8% on average over the last five seasons.

The differences in yield enjoyed by surveyed large-scale yellow maize farmers are indicated in Table 4.8. These data were calculated using farmers' collected production data for both the 1999/2000 and 2000/2001 production seasons and thus represent an average for the two seasons. Irrigation farmers in the Northern Cape and Mpumalanga are included while the sample of dryland farmers consists of farmers in Mpumalanga and North West Province. A 1200 kg/ha and 326 kg/ha yield increase translates to an 11.03 and 10.60 percent yield increase on irrigation and dryland respectively. It is important to note that even though these figures are accurate and give a good indication of the performance of Bt yellow maize varieties compare to conventional varieties, the statistical significance is questionable due to the small sample size.

Table 4.8: Yield differences between Bt and conventional maize - average for 1999/2000 and 2000/2001

Province	Conditions	Yield with Bt maize kg/ha	Yield with conventional maize kg/ha	Percentage yield advantage
Mpumalanga	**Irrigation**	11 280	10 500	7%
Northern Cape	**Irrigation**	12 160	10 860	12%
Average for total irrigation	**Irrigation**	12 081	10 881	11.03%
Mpumalanga	**Dryland**	5 000	4500	11%
North West	**Dryland**	3 130	2 920	7%
Average for total dryland	**Dryland**	3 398	3 072	10.60%

Source: Own survey

From these data it is clear that the surveyed large-scale yellow maize farmers benefited from the use of Bt maize through increased yields. The size of the yield benefit will however vary between seasons, regions, farmers and the conventional variety a farmer is comparing the transgenic variety to. Due to the more humid conditions on Mpumalanga irrigation schemes, which favour stalk borers, it might be expected that the yield benefit of Mpumalanga farmers will exceed the yield benefit of Northern Cape farmers over the longer term. In neither of the two survey seasons did farmers in any survey region indicate a high level of stalk borer infestation. One can thus expect that the yield benefit might increase in seasons with higher stalk borer pressure.

4.4.2 PESTICIDE USE

Brookes (2002) estimated that farmers in the Huesca region in Spain save on average approximately R364 (42 Euro's) in pesticide cost per hectare with the use of Bt maize. According to Marra (2001) the adoption of Bt maize in the US has not been associated with a significant decrease in insecticide usage due to the fact that the European corn borer infestation level very seldom reaches the point where it becomes economically beneficial to apply pesticides.

Stalk borers were indicated to be the dominant problem insect by 70% of the surveyed South African yellow maize farmers. In the Northern Cape, with its dry and very warm climate, 40% of the farmers indicated that they did not apply any pesticides on maize whatsoever. Of the farmers who did apply, 50% applied an aldicarb at planting time to control nematodes and in most cases only a single spray of endosulfan or a pyrethroid to control cutworm and stalk borers on their conventional varieties. None of the Northern Cape farmers sprayed any pesticides on their Bt maize but 25% still planted with aldicarb. Table 4.9 compares the average expenditure per hectare on chemical insecticides for conventional maize and Bt maize.

Insects prefer the more humid conditions in Mpumalanga, especially in the regions of the irrigation schemes at Groblersdal and Marblehall. All the surveyed farmers plant with aldicarb for nematodes and most had to spray at least once with both an endosulfan and a pyrethroid. Most large-scale farmers, dryland and irrigation, make use of seed treatments to control ground weevils, maize beetles and false wireworms amongst other pests. Of the dryland farmers surveyed in the North West Province 46% did not apply any pesticides while most of the remaining 54% applied a single organophosphate spray and / or a single pyrethroid spray to control stalk borer and cutworm. Where Bt maize was planted, farmers in most cases applied only one spray to control cutworm. In Mpumalanga where second generation stalk borers are sometimes a problem, farmers would apply an additional pyrethroid spray early in the new year if maize is not in seed at the time (if maize was planted late).

Table 4.9: Conventional vs. Bt maize – cost of applied pesticides comparison

	Irrigation	Insecticide cost with conventional maize (R/ha)	Insecticide cost with Bt maize (R/ha)
Northern Cape	Irrigation	178	73
Mpumalanga	Irrigation	225	80
Mpumalanga	Dryland	93	46
North West	Dryland	68	13

Source: Own survey

In Table 4.9, again, the application costs of insecticides are not taken into account. Large-scale farmers also indicated that one should not forget about the cost of application water. According to a dryland farmer in Mpumalanga, water pumping and transport costs amount to about 7 cents per litre. With the use of approximately 200 litres of water for spraying per hectare of maize per season, the cost of water adds up to a significant amount.

4.4.3 COST OF SEED

Bt maize seed prices are not as clear-cut as that for Bt cotton. Different companies charge different prices for their Bt seed and it is not clear what part of this price accrues to the particular seed company and what part to the technology developer (Monsanto). According to the Monsanto affiliate in South Africa they receive no income domestically from Bt maize seed sold by other seed companies. For seed companies using Monsanto's Bt gene technology in their maize the technology cost is specified and paid according to an agreement with Monsanto in the US.

The price difference between conventional yellow maize seed and Bt yellow maize seed varies between the different seed companies. The price difference in 2000/2001 typically ranged between R130 for 80 000 seeds to R220 for 60 000 seeds. At a yellow maize grain spot price of R800 / ton this means that a dryland farmer in the North West Province planting 10 kg of seed per hectare would have to realise a yield increase of at least 1.8% (based on the 2 year average) to cover the extra seed cost if the saving on pesticide cost and other costs associated with pesticide application are not taken into account. An irrigation farmer in Mpumalanga would have to realise a yield increase of at least 1.5% to cover the extra seed cost. Comparing these figures with the yield increase percentages quoted in Table 4.8, it becomes clear that large-scale Bt maize farmers are benefiting financially from the use of Bt maize despite the additional seed cost.

4.4.4 THE INCOME EFFECT

Despite paying more for seeds, Bt adopting yellow maize farmers enjoyed increased income on Bt maize compared to conventional maize (Table 4.10).

Table 4.10: Income effect of adoption of Bt yellow maize – average for 1999/2000 and 2000/2001

	Mpumalanga Dryland (R/ha)	North West Dryland (R/ha)	Mpumalanga Irrigation (R/ha)	Northern Cape Irrigation (R/ha)
Yield Benefits per hectare @ R800/ton	400	168	624	1040
Reduced pesticides benefit	47	55	145	105
Increased seed cost detriment*	(120)	(53)	(175)	(101)
Income advantage / disadvantage	327	170	594	1044

*As indicated by surveyed farmers in different provinces
Source: Own survey

According to surveyed farmers no premiums for GM-free maize were realised in either of the two production seasons. Some GM-free maize has been exported to Japan and other countries but the premium was captured by the exporter or trading company. The future will tell whether the production of non-Bt maize for niche markets may become more profitable than Bt maize production for South African farmers. The benefit of being able to stretch the production season to make best use of early or delayed rainfall cannot be quantified using data from only two seasons. To measure the impact of this benefit, a longer time series will have to be analysed.

With more than 95% of South Africa's total maize harvest being harvested mechanically, the increased yield will probably not create increased demand for harvest labour as was the case for cotton. The remaining 5% or less, mainly white maize, produced by subsistence and small-scale farmers however is a different story as yield increases could cause an increased demand for picking hands in the rural areas.

4.5 FARM-LEVEL IMPACT OF BT MAIZE IN SOUTH AFRICA: SMALL - SCALE FARMERS

This section will briefly mention some of the yield findings of the current Bt white maize study. As only findings of the first season's survey are currently available, great care should be taken in interpreting these data. Most farmers planted and harvested the different maize varieties separately and were thus able to compare the yields from the different varieties, but due to different planting dates within sites, different harvesting practises and different maize grain usages, we had to trust on yield perceptions of farmers for yield data.

Farmers pick dried maize cobs by hand, remove the husks and store them in old maize meal bags or "containers" built out of corrugated iron, wood or woven branches. Depending on what farmers plan to do with their maize, the grain is removed from the stalk and transported to the miller or stored. Where it was not possible to physically count the bags of grain from the different seed types we had to trust on the memory of the farmer and his or her household. Women were more often than men able to recall specific quantities.

Table 4.11 summarises the average yields from own (hybrid, open pollinated or traditional saved seed), CRN 3549 (the isoline), and Yieldgard (Bt) seed:

Table 4.11: Yield comparison between own, conventional and Bt maize seed

				95% Confidence Interval of the Difference	
	Variety	Mean yield *	Std. Deviation	Lower	Upper
Northern Highveld	Own seed	33.69	32.22	21.20	46.19
	CRN seed	95.40	88.88	64.87	125.93
	Yieldgard seed	148.36	119.54	107.30	189.42
Southern Highveld	Own seed	116.89	105.26	87.58	146.19
	CRN seed	190.25	110.13	156.77	223.73
	Yieldgard seed	204.25	121.43	167.33	241.17
Hlabisa	Own seed	79.90	100.29	43.74	116.06
	CRN seed	121.23	80.47	91.71	150.75
	Yieldgard seed	177.73	116.58	134.97	220.49
Venda	Own seed	46.55	67.24	20.48	72.62
	CRN seed	114.14	66.41	83.91	144.38
	Yieldgard seed	178.26	97.92	133.69	222.83
Mqanduli	Own seed	45.57	36.72	30.07	61.08
	CRN seed	64.79	68.39	21.34	108.25
	Yieldgard seed	79.66	79.83	26.03	133.29
Flagstaff	Own seed	69.40	83.36	39.35	99.46
	CRN seed	112.18	61.02	87.53	136.83
	Yieldgard seed	129.29	88.59	96.79	161.79

*Expressed as kilogram of yield harvested per kilogram of seed planted
Source: Own survey

Yields are expressed per kilogram of seed planted. It is clear that in all six sites the yield from own seed is much lower than that of both the CRN and Yieldgard varieties. There are various reasons for this lower yield. The main reason is that saved seed planted year after year in most cases does not have the genetic potential to deliver the higher yields and intercropping also influences yield negatively. A small number of farmers planted the Monsanto seeds in their backyards instead of in their main maize fields. Many farmers in all six sites lose a substantial amount of maize annually due to cattle, goats, wild animals as well as theft, and additional management attention to CRN and Yieldgard maize may have kept them from experiencing the normal losses to animals and thieves. Another possible reason for the lower indicated yield with own seed is that some farmers only harvested green mealies from their own seed and not from the Monsanto seed.

A paired means analysis comparing the Bt and conventional maize yields indicated a significant yield advantage with Bt seed. The mean yield increases with Bt seed were statistically significant at a 95% confidence level in all sites except Mqanduli. A considerable number of outliers indicating erroneously high yields for both CRN and Yieldgard seed were excluded from the data set but even with these steps Table 4.12 indicates why the means in Table 4.11 present a distorted picture.

Table 4.12: Percentage of farmers indicating yield differences between conventional and Bt maize

	Mpumalanga		KwaZulu Natal	Limpopo	Eastern Cape	
Yield difference with Bt	**Northern Highveld**	**Southern Highveld**	**Hlabisa**	**Venda**	**Mqanduli**	**Flagstaff**
% Farmers with lower yield	3%	0%	3%	0%	9%	0%
% Farmers with same yield	37%	89%	56%	30%	45%	80%
% Farmers with yield increase between 1 and 50kg / 1kg seed used	23%	2%	13%	15%	37%	4%
% Farmers with yield increase above 50kg / 1kg seed used	37%	9%	28%	55%	9%	16%

Source: Own survey

A small number of farmers out of the total sample indicated that CRN seed rendered higher yields than the Yieldgard seed while a substantial number of farmers, especially in the Southern Highveld, Hlabisa and Flagstaff areas, indicated that they did not find a significant difference between the yield of the CRN and Yieldgard maize. In a production season where stalk borer numbers were abnormally low, and with a rough yield measure we expected not to find a substantial yield difference. However, substantial yield increases with Yieldgard maize seed were indicated by a large number of farmers in all six sites. Despite the low stalk borer numbers, 60% of farmers in the Northern Highveld area, 70% of farmers in the Venda area and 41%

and 46% of farmers in the Hlabisa and Mqanduli areas respectively indicated a yield advantage.

It is suggested that the Bt maize yield advantage perception, as indicated by subsistence farmers for the first production season, might be erroneously amplified. The results might be influenced by a combination of factors including a possible bias on the side of the farmer due to the Monsanto workshop; the free seed and the expectation of higher yields with Yieldgard as well as a possible bias in the method of yield measurement as a small advantage might be amplified when measured in maize bags.

After only one season of study it is concluded that for the first season of Bt maize production under subsistence conditions the Bt variety performed at least as good as the conventional variety. This conclusion is however already contradicted by the large number of farmers who ordered and bought Bt maize seed for the 2002/2003 production season, as well as preliminary findings in the current season indicating a significant yield advantage with Bt maize.

4.6 CONCLUSION

This chapter focused on the quantification of the direct farm-level benefits and costs of the adoption of insect resistant cotton and maize in South Africa. Despite higher seed costs, large and small-scale cotton farmers as well as large-scale maize farmers enjoyed a higher net income per hectare, due to higher yields through better pest management, and savings on pesticides and pesticide application related cost. Subsistence maize farmers indicated a yield advantage with the production of Bt white maize, but further study will be necessary to confirm these results.

Where Chapter 4 measured the direct benefits accruing to the farmer, Chapter 5 endeavours to discuss how the additional total benefit or "economic rent" created by the introduction of a new technology, in this case Bt cotton, is divided between the farmer, the seed company (Delta Pineland), the innovator (Monsanto) and the consumers of seed cotton (the cotton gins).