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Review

Bt maize for small scale farmers: A case study

Keetch DP, Webster, JW, Ngqaka, A, Akanbi, R and Mahlanga, P.

AfricaBio, P.O. Box 873, Irene, South Africa 0062.

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The role of biotechnology in small holder agricultural systems has been the subject of much debate in South Africa and the Southern African Development Community (SADC) region as a whole. The debate has centered on the suitability of biotechnology crops in small holder agricultural systems. In South Africa, genetically modified (GM) white maize was approved for commercial production in 1998. To educate and inform small-scale farmers and to give them the opportunity to evaluate GM white maize for themselves, six demonstration plots were planted at strategic locations. This communications presents the results obtained from these six demonstration plots. In all plots it was found that GM maize gave higher yields and had less stalk borer damage than the comparable non GM variety. GM white maize can be beneficial to small scale farmers located in areas where maize stalk borer is a major production factor. However, it is important that the authorities provide an effective extension service and financial support in order that the full potential of GM white maize can be experienced.

Key words: Bt maize, GM white maize, small scale farmers.

INTRODUCTION

The role of biotechnology in small holder agricultural systems has been the subject of much debate in South Africa and the Southern African Development Community (SADC) region as a whole. The debate has centered on the suitability of biotechnology crops in small holder agricultural systems. The officially approved genetically modified (GM) crops in South Africa have the potential to assist both commercial and small-scale farmers to improve their productivity, quality and returns from farming in the region. The current GM crops were developed with commercial farming in mind, but already insect tolerant cotton is having significant positive impact on rural farmers in resource poor regions of the country. Field studies and the rapid adoption of GM cotton among small scale farmers have indicated the positive impact this technology has had on these farmers.

Maize is South Africa's most important field crop. White maize is the staple food for the major part of the population while yellow maize is mainly cultivated for animal consumption. Maize contributes approximately 35% to the gross value of South Africa's field crops, and the average annual gross value of maize for the past five years amounts to R5 481 million. Over the past five years there has been a swing towards the production of white maize. The present ratio of production is 71% white and 29% yellow maize.

Maize production in South Africa is hampered by a number of factors but one of the most important is stalk boring insects. Stalk borers are mainly African species that have moved over to maize from related grasses. The most important of these are the maize stalk borer, *Busseola fusca,* and the sorghum stem borer, *Chilo partellus.*

Maize stalk borer moths lay their eggs between the leaf sheaths. After about nine days the eggs hatch and the young caterpillars make their way up the plant to feed on the young unfurled upper leaves. These feeding caterpillars produce irregular holes that become visible when the leaves unfold. The older caterpillars move down in the stalk of the plants, usually finishing up one to a stalk. Maize stalk borer moths also lay their eggs on the tender growth in the cobs and the enveloping leaves. Considerable damage is caused to the cob and young seeds. As the caterpillars grow they may invade adjoining

*Corresponding Author. E-mail: goldamer@mweb.co.za.

Table 1. Yield of Bt and non-Bt maize at Buhle Farmers' Academy, Delmas. Mpumalanga.

Subplot No.	Non-Bt Maize			Bt Maize		
	Wt (kg)	No. cobs	Dam -age	Wt (kg)	No. cobs	Dam- age
1	12.1	67	4	13.4	65	0
2	10.7	57	6	14.6	74	1
3	12.1	68	9	15.6	77	0
4	10.6	59	5	16.4	77	0
5	11.5	58	4	14.1	70	5
6	12.1	60	9	14.7	78	0
7	11.9	59	9	16.4	83	0
8	12.9	65	11	16.5	79	0
Total	**93.9**	**493**	**57**	**121.7**	**603**	**6**
Average	**11.7**	**61.6**	**7.1**	**15.2**	**75.4**	**0.8**

Date of planting: 1 December 2004.
Date of harvest: 1 July 2005.
Total mass of cobs harvested from eight 10 m^2 Bt maize subplots was 29.9% greater than that harvested from the non-Bt subplots.
11.6% of the cobs harvested from the non-Bt subplots had been damaged by maize stalk borer.
1.0% of the cobs harvested from the Bt maize subplots were damaged.

Table 2. Yield of Bt and non-Bt maize at Fairdeal, Zuurbekom, Gauteng.

Subplot No.	Non-Bt Maize			Bt Maize		
	Wt (kg)	No. cob s	Dam- age	Wt (kg)	No. cob s	Da m- age
1	7.6	74	4	13.5	82	2
2	9.4	68	9	12.2	66	2
3	5.8	59	4	11.1	72	0
4	6.7	55	6	12.2	62	3
5	7.2	80	2	10.8	68	0
6	8.2	64	2	11.4	65	0
7	6.6	45	13	10.6	56	0
8	5.9	53	2	10.7	55	0
Total	**57.4**	**498**	**45**	**92.5**	**526**	**7**
Average	**7.2**	**62.3**	**5.6**	**11.6**	**65.8**	**0.9**

Date of planting: 25 November 2004.
Date of harvest: 27 June 2005.
Total mass of cobs harvested from the eight 10 m^2 Bt maize subplots was 61% greater than that harvested from the non-Bt subplots.
9% of the cobs harvested from the non-Bt subplots had been damaged by maize stalk borer.
1.3% of the cobs harvested from the Bt maize subplots were damaged.

plants while others make their way into and down the stalks of the plants they are on, feeding as they go.

Depending on the severity of infestation, stem borer damage may reduce yields by 10 to 45%. Furthermore, damage to the cob creates conditions suitable for secondary fungal infection that in turn can lead to the production of mycotoxins – fungal toxins that are known to cause adverse medical problems in people that consumer the contaminated product (Gelderblom et al., 2001; Marasas, 1993, 1996, 2001; Marasas et al., 2003; Rheeder et al., 1992; Sydenham et al., 1990).

Table 3. Yield of Bt and non-Bt maize at Madinyane, Brits.

Subplot No.	Non-Bt Maize			Bt Maize		
	Wt (kg)	No. cobs	Dam age	Wt (kg)	No. cobs	Dam age
1	7.1	33	5	8.5	45	0
2	9.0	36	4	9.8	46	0
3	6.7	26	3	11.3	4.9	0
4	6.1	29	7	12.3	51	0
5	7.7	37	5	10.5	47	0
6	5.9	26	6	9.6	47	0
7	8.8	38	7	8.9	38	0
8	6.3	26	3	9.5	43	0
Total	**57.5**	**251**	**40**	**80.4**	**366**	**0**
Average	**7.2**	**31.4**	**5**	**10.1**	**45.8**	**0**

Date of planting: 30 January 2005
Date of harvest: 7 June 2005
Total mass of cobs harvested from the eight 10 m^2 Bt maize subplots was 40.3% greater than that harvested from the non-Bt subplots.
16% of the cobs harvested from the non-Bt subplots had been damaged by maize stalk borer.
No damage was recorded from the cobs harvested from the Bt maize subplots.

Table 4. Yield of Bt and non-Bt maize at Sannaspos, Free State Province.

Subplot No.	Non-Bt Maize			Bt Maize		
	Wt (kg)	No. cobs	Dam -age	Wt (kg)	No. cobs	Dam -age
1	2.8	28	0	4.8	32	0
2	3.5	43	0	5.4	36	0
3	4.9	39	2	5.8	47	0
4	3.9	36	4	4.6	41	0
5	3.5	36	3	3.7	32	0
6	3.6	27	1	4.4	36	0
7	4.2	37	2	5.3	40	0
8	3.4	34	4	4.5	41	0
Total	**29.8**	**280**	**16**	**38.5**	**305**	**0**
Average	**3.7**	**35**	**2**	**4.8**	**38**	**0**

Date of planting: 7 December 2004
Date of harvest: 14 June 2005
Total mass of cobs harvested from the eight 10 m^2 Bt maize subplots was 29.7% greater than that harvested from the non-Bt subplots.
5.7% of the cobs harvested from the non-Bt subplots had been damaged by maize stalk borer.
No damage was recorded from the cobs harvested from the Bt maize subplots.

Table 5. Yield of Bt and non-Bt maize at Bathurst, Eastern Cape.

Subplot No.	Non-Bt Maize			Bt Maize		
	Wt (kg)	No. cobs	Damage	Wt (kg)	No. cobs	Dam-age
1	9.2	50	9	10.0	50	1
2	7.0	51	18	11.8	50	0
3	7.2	59	19	12.8	57	0
4	7.4	54	7	9.1	50	1
5	9.8	46	6	8.3	51	1
6	7.4	47	5	9.2	55	1
Total	**48.0**	**307**	**64**	**61.2**	**313**	**4**
Average	**8.0**	**51.2**	**10.7**	**10.2**	**52.2**	**0.7**

Date of planting: 2 December 2004
Date of harvest: 14 and 15 June 2005
Total mass of cobs harvested from the six 10 m^2 Bt maize subplots was 27.5% greater than that harvested from the non-Bt subplots.
20.8% of the cobs harvested from the non-Bt subplots had been damaged by maize stalk borer.
1.3% of the cobs harvested from the Bt maize subplots were damaged by stalk borer.

GM MAIZE IN SOUTH AFRICA

There are approximately 3 million communal or subsistence farmers and their dependents rely on maize for their survival. However, most small-scale farmers do not control stalk borers because:

The damage caused by the caterpillars is hidden and difficult to detect;
Heavy infestations are unpredictable;
Checking the fields multiple times each summer takes time and skill;
It is difficult spraying in windy and wet conditions; and
High costs of conventional and organic chemical treatment.

Small-scale farmers that do spray, often risk exposure to the chemicals because they use unsuitable equipment and/or fail to use protective clothing. GM maize provides a new management tool for small-scale farmers and has the potential to increase yields where stalk borer is a problem and the decrease the need for chemical applications (Kirsten and Gouse, 2003; Pilcher et al., 1997).

Bt MAIZE

Bt maize is maize that has been genetically modified to express the *cry 1Ab* gene that confers resistance to a number of major Lepidopterian pests, especially the stem borer complex. During the past eight years Bt maize varieties expressing the *cry 1Ab* gene have been adopted commercially in the USA, Canada, Spain, Argentina South Africa, Honduras and the Philippines (James, 2003).

In developing countries, the production of Bt maize offers the following advantages: Pest damage is significantly higher in developing countries because of more intensive infestations and overlapping generations. Therefore effective pest control is a major factor in efficient crop production.

Depending on the intensity of infestation, two or more insecticide sprays may be required to control stem borer damage. With Bt maize there is a significant reduction in pesticide use.

Increased yields with Bt maize are significantly higher in developing countries although the average yield may be lower.

Bt maize is more suitable for small farmers because it does not require the equipment, knowledge and information required for insecticide applications. It also reduces the farmers' exposure to chemical pesticides.

Given that maize is a staple food in Africa and that mycotoxin levels are significantly higher in developing countries, the use of Bt maize to lower mycotoxin levels is important (Pietri and Piva, 2000).

Increased yield directly affects food security and food/feed safety. Increased income from higher yields contributes to the alleviation of poverty in those cases where the need is the greatest.

Demonstration of bt maize to small scale farmers

In the 2004/2005 season, demonstration plots of GM and conventional maize were planted at six sites in South Africa. These sites were:

Buhle Farmers' Academy, Delmas, Mpumalanga.
Fairdeal Training Center, Zuurbekom, Gauteng.
Madinyane Village, Brits, North West Province.
Sannaspos, Bloemfontein, Free State Province.
Nolukhanyo Administrative Area, Bathurst, Eastern Cape.
Cedara College of Agriculture, Pietermartizburg, KwaZulu Natal.

The following (Tables 1 to 6) is a summary of the yield (in kgs), number of cobs and the percentage cobs damaged by stem borer in 10 m^2 subplots of conventional and Bt maize planted at the various sites.

Reduced mycotoxin levels

Damage to maize tissue by stem borers allows fungi, particularly *Fusarium* species, to colonise the damaged tissue leading to stalk and cob rots and the accumulation of harmful mycotoxins. Fungal infection can result in degraded and toxic grain that contributes to food and feed safety hazards. Studies in France, Spain and Italy with *Bt* maize have shown that there was a significant reduction in the damage caused to the cobs by stem borers and a corresponding reduction in the amount of

Table 6. Yield of Bt and non-Bt maize at Cedara Research Station, Kwazulu/Natal.

Subplot No.	Non-Bt Maize			Bt Maize		
	Wt (kg)	No. cobs	Dam -age	Wt (kg)	No. cobs	Dam -age
1	4.8	48	18	6.7	51	4
2	4.4	43	14	7.4	56	2
3	5.6	47	12	6.7	50	2
4	4.4	46	31	6.8	53	1
5	5.3	47	16	7.5	65	5
6	4.4	45	20	6.9	53	2
7	5.0	47	18	8.6	75	2
8	5.5	59	20	10.2	81	3
Total	**394**	**382**	**149**	**60.8**	**484**	**21**
Average	**4.9**	**47.8**	**18.6**	**7.6**	**60.5**	**2.6**

Date of planting: 3 December 2004
Date of harvest: 21 June 2005
Total mass of cobs harvested from the eight 10 m^2 Bt maize subplots was 55.1% greater than that harvested from the non-Bt subplots.
38.9% of the cobs harvested from the non-Bt subplots had been damaged by maize stalk borer.
4.3% of the cobs harvested from the Bt maize subplots were damaged by stalk borer.

tissue infected by *Fusarium* (Pietri and Piva, 2000; Bakan et al., 2002; Hammond et al., 2002).

Lower mycotoxin levels are of particular significance to maize growers in developing countries with warm and humid climates that are conducive to the accumulation of these toxic compounds. Inadequate storage conditions increase the problem leading to losses as a result of contaminated grain that fails to meet food and feed standards. Rejection of grain as food leads to downgrading and a lower of price; rejection as feed leads to major economic loss.

It is largely unknown that the level of fumonisin mycotoxin contamination of maize has been reduced by up to 93% with the reduction in insect damage and therefore decreased fungal spore infections, realised by the introduction of European Corn Borer resistant *Bt* maize (Munkvold et al., 1999). This reduction in fumonisin levels has direct safety benefits to humans and animals because those mycotoxins are some of the most noxious substances on crops, resulting in ailments from liver cancer to brain damage. Most consumers are also unaware of the significant reduction in the use of chemical insecticides (Gianessi et al., 2002).

Economic advantage

Significant economic benefits are derived from increased yields and reduced pesticide applications (Table 7). In a study of the bio-economic impact of biotechnology in EU agriculture using the example of transgenic *Bt* maize (Demont et al., 2004), it was found that GM maize is able to control maize stalk borers that cause economically important damage to maize grown in Spain. Since 1998, Spain has grown the GM maize variety Compa CB commercially on about 25 000 ha, annually. During the 6-year period 1998- 2003, the authors estimated a total welfare gain of 15.5 million euros from the adoption of *Bt* maize, of which Spanish farmers captured two thirds and the seed industry one third.

Table 7. Cost of planting *Bt* maize (in South African Rands).

Item	Conventional maize	GM maize
Seed cost per hectare*	210	280
Insecticide cost (2xR40)	80	none
Application cost (tractor)	80	none
Crop yield value**	3900 (3 tons)	4290 (3.3 tons)
Gross profit	3530	4010

*Based on an average seeding rate of 12 kg/ha, average yields of 3 tons/ha and an average grain price of R1300/ton.
** An average yield increase of 10% is used. If conventional maize is not treated against stalk borer attack yield losses could range from 20 to 80%.

In Argentina, where Bt maize comprises about 50% of the 3 million ha of maize grown in the country, 79% of the benefits accrued to the input provider (sale of seed) and 21% to the farmer (increased production) (Hopp, 2004). In a survey of Argentina farmers on the direct benefits of growing GM crops, 65% of respondents mentioned the reduction in production costs, 63% that GM crops were easier to work with than the conventional counterpart and 50% the increased yields. Indirect benefits mentioned were greater crop yields available for export, increased employment in the agricultural sector and environmental benefits (Hopp, 2004; Anon, 2002).

Safety of Bt maize

Bt maize has been grown internationally for over seven years (Anon, 2002 ; James, 2003). It is officially approved for cultivation in the United States, Canada, the European Union, Argentina and South Africa. It is approved for food and feed imports in Australia, Japan and many other countries. The approval mechanism for any GM crop requires extensive testing and independent scientific review of safety to human health and the environment.

More recent studies on the direct effects of Bt crops on organisms that feed on crop tissues has shown no short-term negative impacts (Losey et al., 2004). However, a complete assessment of non-target impacts needs to include measures of how ecological functions are impacted by transgenic crops in comparison to how they are impacted by conventional pest management tactics.

The adoption of Bt maize will play a key role in achieving increased food security in Africa. Significant benefits include yield increases, reduced pesticide usage and lower mycotoxin levels.

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