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Three Seasons of Subsistence Insect-Resistant Maize in South Africa: Have Smallholders Benefited?

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White maize is the staple food of the majority of the South African population. We examine if smallholder farmers that adopted insect-resistant (Bt) varieties of white maize benefited from planting Bt over the last three seasons. Commercial farmers are known to benefit from planting Bt maize in high stalk borer or corn borer infestation years, but when planted in locations or years when stalk borers are not a problem, Bt will usually not be profitable because of higher seed costs. In the first two production seasons, small farmers enjoyed higher yields with Bt maize than with conventional hybrid varieties despite lower-than-normal (yet still significant) stalk borer pressure and less-than-ideal maize production conditions. Yield is expressed according to grain per kilogram of seed planted, as seeding rates per land area differ drastically between small-scale farmers. The value of the yield benefit depended on how the farmer utilized the additional grain, with the highest valued use being home grinding and consumption substituting for more expensive store purchases. In the third season, which was also the fourth consecutive drier-than-usual season, the stalk borer infestation level was very low, and farmers who planted Bt maize had yields similar to farmers who planted conventional hybrids.

Key words: Bacillus thuringiensis, Bt, corn, genetically modified, insect resistant, maize, smallholder, South Africa, subsistence.

Introduction

Substantial evidence has accumulated that large commercial farmers in many different locations and conditions can benefit from planting insect-resistant (Bt) maize in high European corn borer infestation years. It is also clear that planting Bt maize in locations or years when corn borers are not a problem will not be profitable. Marra, Pardey, and Alston (2002) found that there were major benefits to planting Bt corn in the United States through increased yields even when borer infestation levels were not great enough to control with insecticides. Marra, Carlson, and Hubbell (1998) reported that the use of Bt corn boosted yields by 4–8% depending on location (and year) under these general conditions. Marra et al. (2002) indicated a range of yield increases in different US states from 444 kg/ha in Iowa to 1,138 kg/ha in Minnesota.

Results from outside the United States show a similar pattern. In the Huesca region in Spain, Brookes (2002) reported a yield increase of 10% over conventional maize protected with pesticides and an increase of 15% when insecticides were not used. Other regions in Spain enjoyed an average Bt yield advantage of 6.3% within a range of 2.9–12.9%. Gonzales (2002) recorded a yield advantage of 41% for Bt maize on field trails in the Philippines, while Philippine farmers indicated an even higher 60% yield improvement.

Bt yellow maize has been produced in South Africa since the 1998/99 season, and large-scale commercial farmers appear to have benefited from its adoption. Despite paying more for seeds, adopters enjoyed increased income over conventional varieties through savings on pesticides and increased yield due to better pest control. Irrigated and dryland commercial farms surveyed in Mpumalanga, Northern Cape, and the North West province enjoyed statistically significant yield increases of 11% and 10.6% respectively (at a 95% confidence level) on average during the 1999/2000 and 2000/01 seasons (Gouse, Pray, Kirsten, & Schimmelpfennig, 2005).

For much of Africa and some parts of Asia and Latin America, an important question is whether Bt maize will be profitable for small farmers. The objective of this paper is to try to answer that question based on three years of survey data on small-scale subsistent and semisubsistent farmers in South Africa. Bt maize was approved for commercial use by the government in 1998, and Bt white maize was planted for the 2001/02 maize production season. Yellow maize, which has been grown in South Africa since 1998/99, is mainly used for animal feed and as an input in the food industry, whereas white maize is the staple food for the majority of the South African population.

Methodology

In 2001, Monsanto held workshops in nine different areas in South Africa. More than 3,000 small-scale farmers attended these workshops, where they were introduced to Bt (Yieldgard) maize and informed of its characteristics. Small bags of seed (250 g) were distributed free of charge to farmers who attended the workshops and wanted to try out the new technology. Farmers received two bags of seed: the Bt variety and the conventional, non-GM isoline (same variety but without the Bt gene). Farmers were asked to plant the seeds and harvest the cobs separately but in all other ways to treat the free-sample maize the same as the rest of their maize.

In that first season (2001/02), 368 farmers in six areas across four provinces of South Africa, who had been given introductory free seeds, were surveyed. Dryland subsistence farmers were surveyed on the Northern and Southern Highveld in Mpumalanga, Hlabisa in KwaZulu Natal, Venda in Limpopo and in Mqanduli and Flagstaff in the former Transkei area in the Eastern Cape. Sample sizes were selected at each site to be significant and representative of the farmers who attended workshops and received free seeds.

In the second season (2002/03), free Bt seeds were not available, and farmers who wanted to plant Bt had to buy the seeds. Indications were that smallholder demand for Bt seed would be substantial, but only a small number of small-scale farmers were able to buy Bt seed due to limited supply and increased demand by large-scale farmers. Only in KwaZulu Natal were a significant number of small-scale farmers able to obtain Bt seed. 104 adopters and nonadopters were surveyed in Hlabisa (a site that was surveyed in the first season) and in Simdlangentsha, KwaZulu Natal. Almost all of the farmers who planted Bt maize in these two locations were surveyed. The majority of the farmers planted only one hybrid (conventional or Bt) and/or some traditional seed. Only a small number of farmers planted both Bt and a conventional hybrid variety in 2002/03. In the 2003/04 production season, a greater number of farmers could be surveyed in Hlabisa and Simdlangentsha, and more detailed questionnaires were used. Table 1 summarizes the survey areas and number of farmers surveyed over the three seasons.

Table 1. Areas and number of farmers surveyed in the three research seasons.

Season	Province	Area	No. of farmers surveyed
First (2001/02)	Mpumalanga	Northern Highveld	60
		Southern Highveld	90
	KwaZulu Natal	Hlabisa	58
	Limpopo Province	Venda	60
	Eastern Cape	Mqanduli	40
		Flagstaff	60
Second (2002/03)	KwaZulu Natal	Hlabisa	67
		Simdlangentsha	37
Third (2003/04)	KwaZulu Natal	Hlabisa	130
		Simdlangentsha	66

Determining yield differences for different maize varieties under small-scale conditions can be difficult. Green mealies (immature maize) are consumed early in the season, and the total grain harvest is not delivered to a buyer were it can be measured. Furthermore, there is a problem with expressing yields in standardized units. Most farmers were quite far off of the mark when asked how big their maize plots were. In 2003/04, measurements showed that 95% of the farmers in Hlabisa significantly overestimated their maize plot sizes. It is possible that plowing and planting contractors contributed to this misconception.

Because the farmers in these areas plant relatively small plots (the vast majority plant less than one hectare) and because farmers make use of different planting practices, resulting in significantly different seeding rates, we found that expressing yield per hectare was not an accurate or comparable performance measure. We therefore express yield as kilograms of grain harvested per kilogram of seed planted for all seasons in all areas.

In the first season (2001/02), farmers were able to compare the performance of Bt maize with that of the conventional isoline. The majority of farmers did plant and harvest the varieties separately and were thus able to compare the yield from the different varieties. In the 2002/03 and 2003/04 maize production seasons, the yield of Bt maize seed as produced by a group of small-scale farmers is compared with that of conventional hybrid seed mostly produced by a different group of small-scale farmers in the same area. Only a small number of farmers produced both Bt and a conventional hybrid. In these seasons we also faced the problem of comparing maize varieties of different germplasm, as the conventional isoline CRN3549 has until recently not been widely adopted in these KwaZulu Natal (KZN) areas. Some of the nonisoline hybrids are specifically adapted to Northern KZN's relatively dry and low fertilizer usage conditions. The Bt maize variety used (CRN4549) is a medium-season variety selected for use by commercial farmers. Even though we would prefer to compare Bt with its isoline, the yield gains we estimated by comparing Bt with a better-adapted local hybrid will produce conservative estimates of the Bt yield gain.

In the first season of research (2001/02), farmers were asked to indicate their yields according to the number of bags harvested. In some instances it was not possible to physically count the bags of grain from the different seed types; in such cases, enumerators relied on the memory of the farmer and his or her household. We surveyed the farmers just after harvest time, and most farmers were able to give accurate indications. The following two seasons we were able to measure farmers' yields more precisely by volume and weight. By using a cob-filled bucket (25 l), the weight of a volume and quantity of cobs was measured. By taking various samples from various farmers, an average volume-weight ratio was calculated. By carefully taking measurements of the filled storage containers (maize cage, or *nkholobane*), where farmers keep their maize, the volume of the containers could be calculated. Using the volume-weight ratio, the weight of the cobs was calculated, and using an average cob/grain factor (as derived from publications by Nel and Verwey, 1976, and Möhr, 1974), the weight of the harvested grain was calculated. It was found that when farmers were asked to give their own yield estimates in numbers of bags, they were sometimes above, under, or very close to our calculated figure. Farmers were asked throughout each season how many ears of green mealies had been consumed, and the grain equivalent was added to each farmer's yield.

Production Practices of Small-Scale Farmers

The majority of surveyed farmers do not own the land they cultivate. The land belongs to the local tribe; a farmer only receives permission to occupy the land. The vast majority of small-scale farmers in South Africa plant less than one hectare of maize, and the size of the area planted in most cases depends on previous successes (particularly in the previous season) and rainfall indications at planting time. Most farmers do not live close to their main maize fields and subsequently have trouble watching out for maize thieves and roaming livestock or wild animals that can destroy their crops.

It is not uncommon for small-scale farmers to hire tractor contractors for land preparation. Oxen teams may also be hired, and a substantial number of farmers prepare their land with hand and hoe. Farmers indicated land preparation and fertilizer as the most costly inputs. Where animal drawn implements were used for land preparation and where farmers made use of conservation tillage, fertilizer was the major expenditure. In rural areas where family labor usually is abundant, the use of herbicides to control weeds in maize crops is not very common. However, herbicide use by small-scale farmers has increased over the last couple of seasons in some areas due to labor shortages and increased adoption of conservation tillage practices.

The majority of farmers who use hybrid seed also apply chemical fertilizers. Some farmers who do not use chemical fertilizer try to improve soil fertility by adding animal manure collected from night-time kraal enclosures. Some farmers also apply LAN (limestone-ammonium-nitrate) as top dressing, but a number of farmers in Hlabisa in 2003/04 indicated that even though LAN was purchased, it was not applied. These farmers were concerned that as the season was very dry, they might not recover the cost of the top dressing. We also found in the second and third seasons that when farmers in some areas experienced a dry preseason, some chose to plant maize without fertilizer and some even decided not to plant Bt or conventional hybrid seed that they had already purchased, because of the impression that investing in maize production would be too risky that season.

Pests, Pest Pressure, and Insecticide Usage

African maize stem borer (*Busseola fusca*) and the Chilo stem borer (*Chilo partellus*) are the most harmful pests to maize and grain sorghum in South Africa (Kfir, 1997). Damage caused by *Busseola fusca* has been estimated to result in a 5–75% yield reduction; moreover, it is generally accepted that *Busseola* annually reduces the South African maize crop by an average of 10% across years and regions (Annecke & Moran, 1982). This translates into an average annual loss of about one million tons of maize worth approximately US$130 million (Gouse et al., 2005).

Farmers that were interviewed in the first season indicated that stalk borers were the dominant insect problem on maize in their growing areas, but the majority of farmers in all six sites thought that the number of stalk borers present during the 2001/02 season was below normal. The number of farmers who applied pesticides differed drastically between sites. In the Venda area, only 3% of farmers applied pesticides, while 72% of farmers in Mqanduli applied pesticides to their maize. In 2002/03, only 14% of the farmers in Simdlangentsha applied any form of insecticide, while 62% of the farmers in Hlabisa applied insecticides on conventional varieties. The majority of farmers who applied insecticides made use of carbaryl granules that were applied in the maize plant funnel. Almost all the farmers applied these granules only once during the season. Farmers and extension officers in Hlabisa and Simdlangentsha indicated that the stalk borer infestation level in 2002/03 was again lower than normal.

In Simdlangentsha, 50% of surveyed farmers indicated that they observed no stalk borers during the 2003/04 maize production season, and 40% of farmers indicated "few worms." When farmers were asked to compare 2003/04's stalk borer pressure with that of 2002/03, 11% indicated "a lot less than last year," 37% indicated "a bit less than last year," and 44% of the farmers felt that the stalk borer pressure was the same as last year. The same phenomenon was found in Hlabisa, with 83% of farmers indicating "no stalk borers," while 17% of farmers indicated that they observed "few worms." Pesticides were applied on only 14 out of 173 maize plots in Hlabisa in 2003/04 and only on conventional maize.

Annecke and Moran (1982) point out how difficult it is to predict seasonal stalk borer infestation levels due to a complicated relationship between rainfall, variable season dates, and maize maturation rates; the impact on yield then depends on the effects of the borers on the maize plant and the effect of natural enemies of the borers on the host maize plant. However, it is generally accepted that stalk borer pressure is lower in drier production areas and seasons, as the moths prefer moist conditions. A number of consecutive dry seasons usually cause a decline in stalk borer pressure. That is also why irrigated maize usually suffers higher stalk borer infestations than dryland maize (J. Van Rensburg, personal communication, 2004). The relatively low stalk borer infestation level in Hlabisa the last three seasons can, to a large extent, be explained by lower-than-average rainfall the last four maize production seasons. According to comprehensive rainfall records maintained by the Hlabisa Department of Agriculture's offices, the last four seasons saw average rainfall 20% less than the 10-year average. The rainfall for 2002/03 and 2003/04 was 25% and 24% lower that the 10-year average, respectively. Similar conditions prevailed in Simdlangentsha over the last two seasons.

Most farmers were able to give recollections of stalk borer pressures, as most who planted Bt maize also planted traditional seed. Their opinions were quite consistent that stalk borer pressure in Hlabisa and Simdlangentsha was higher in 2001/02 and 2002/03 than it was in 2003/04. They also seemed to agree that all three seasons had lower-than-usual infestation levels.

Yield Effect

Table 2 shows first season reported average yields from "own," CRN3549 (conventional isoline) and Bt (Yieldgard) seed for farmers who were able to give accurate yield indications. Own seed was planted in addition to the free seed farmers received. It is clear that in all six sites, the yield from own seed is much lower than that of both the isoline CRN and Yieldgard varieties. There are various reasons for this lower yield, the most important being that own seeds are usually traditional (nonhybrid) varieties saved under less than ideal conditions and intercropped with vegetables.

CRN yields are closer to that of Bt. Table 2 shows mean yield differences, percentage differences, and significance level for these varieties. Even though stalk borer numbers were fairly low in the first season, yield differences were substantial. Farmers in all six sites reported higher yields with Bt. The yield differences were statistically significant (at a 95% level) in all the sites except Mqanduli, where only a relatively small number of farmers could supply yield comparison data. Bt maize produced a statistically significant average yield increase of 32% over the conventional isoline for the South African small-scale farmers that we sampled.

In the second research season, the yield differences in Simdlangentsha and Hlabisa were individually substantial but not statistically significant due to relatively small sample sizes (drawn from small populations) and a high level of variability in the data caused by variable production conditions and low rainfall. When the data for Simdlangentsha and Hlabisa are pooled, a statistically significant yield increase of 16% was calculated (at a 95% confidence level) for this northern KZN area. To express this yield advantage in hectare terms, in 2002/03 on average, a farmer planting a 10 kg bag of Bt seed per hectare compared to a 10 kg bag of conventional hybrid seed would enjoy a yield increase of 110 kg of grain per hectare.

The third research season (2003/04) was again a rather dry season, and farmers in Simdlangentsha and Hlabisa planted late due to late rains. Late plantings in most of South Africa have commonly been associated

Table 2. Yield indications for the first research season for the different survey areas.

Site	Variety	Mean yield (kg/kg)	*n*	Yield difference (kg/kg)	*t*-value	% yield difference
Avg. all farmers	Own seed	63				
	CRN seed	187	175	59	8.679	32%*
	Bt seed	246				
Northern Highveld	Own seed	32				
	CRN seed	90	33	56	4.490	62%*
	Bt seed	146				
Southern Highveld	Own seed	162				
	CRN seed	278	57	57	4.332	21%*
	Bt seed	335				
Hlabisa	Own seed	78				
	CRN seed	196	33	58	3.966	30%*
	Bt seed	254				
Venda	Own seed	42				
	CRN seed	136	20	84	5.117	62%*
	Bt seed	220				
Mqanduli	Own seed	44				
	CRN seed	70	10	18	1.862	26%
	Bt seed	88				
Flagstaff	Own seed	69				
	CRN seed	95	22	32	2.084	34%*
	Bt seed	127				

**Yield difference statistically significant at a 95% level.*

with high levels of stalk borers. In this KZN area, probably due to three years of dry conditions, the stalk borer infestation level was the lowest it had recently been. Neither Simdlangentsha nor Hlabisa had significant yield differences between Bt maize and conventional hybrids. When all the surveyed farmers who planted Bt maize were pooled and compared with all conventional maize samples, Bt maize had an insignificant 5% yield advantage. The conclusion for the third season is that there was no discernible difference in the yields of Bt and conventional maize, with the caveat that both varieties were affected by higher than normal rates of cob rot and ear rot caused by late rain.

Quality and Benefits

In the first research season, farmers were asked to judge the quality of grain from their own seed and any conventional isoline and Bt seed they had grown. Table 3 shows that farmers rated Bt maize superior in quality to local seed and the non-Bt isoline. The majority of farmers thought the grain produced from Bt seed was excellent quality, whereas the grain from conventional seed was only good quality.

Figure 1 illustrates subsistence farmers' perceived benefits of Yieldgard maize. Percentages are the proportion of farmers from each site that reported the specific benefit. The "other" benefits category includes ease of management, insecticide savings, and reduced need for applied water. In all sites except the Southern Highveld, after the first season, farmers indicated that the most important benefits of Bt maize were higher yield and increased quality. Poorer areas tended to emphasize yield, whereas farmers in more affluent areas tended to emphasize grain quality.

In the second season, farmers were questioned regarding green mealie preferences. They indicated that green mealies from Bt maize were tastier than that of conventional varieties. The Bt variety, based on the hybrid CRN3549, is not really known to produce sweet green mealies, but Bt ears might have seemed tastier or more appetizing with less worm damage or physical worms present on the mealies.

Problems with Bt Maize

In the first research season, the one big problem farmers indicated with Bt maize was damage caused by birds. In

Table 3. Grain quality (as percentages) reported by small-scale farmers, 2001/02.

Seed	Excellent	Good	Average	Below average	Bad
Own seed	15%	48%	21%	12%	4%
Conventional seed	23%	54%	17%	3%	2%
Bt seed	70%	20%	8%	1%	2%

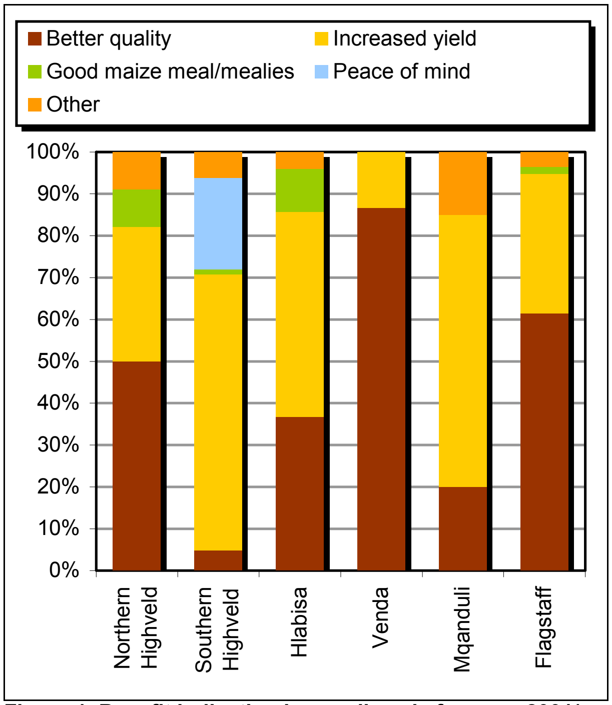

Figure 1. Benefit indication by small-scale farmers, 2001/02.

the Southern Highveld, Hlabisa, and Venda areas, where farmers enjoyed the highest yields, the maize cobs (ears) were longer than the husk, and birds fed on the part of the cob that protruded from the husk. However, farmers had this same problem with the conventional CRN3549 seed, which probably indicates that the problem is with the specific variety and not with the Bt gene.

In 2003/04, the protruding cob problem became more damaging. A number of farmers who planted Bt and CRN3549 varieties indicated that their maize suffered from cob rot (ear rot). Due to a rather dry season, the maize cobs were in some cases not heavy enough to hang (pointing downwards); rain that fell in June and July penetrated the husk and spoiled the grain. This is part of the reason why Bt maize did not perform as well in 2003/04. This problem does not appear to be associated with the Bt gene either, as the conventional isoline had similar problems.

Higher seed cost is another disadvantage of Bt maize. Some conventional maize farmers indicated that they would have bought Bt seed, but it was too expensive. As farmers were given Bt seed in the first season, no seed cost comparison could be made between Bt and conventional maize in 2001/02. In 2002/03, CRN3549 (non-Bt isoline) was sold to large-scale commercial farmers for R10.11/1,000 kernels, while Bt seed (CRN4549) was sold for R13.78/1,000 kernels. In 2002/03, Monsanto charged a technology fee of R3.63/1,000 kernels; for 2003/04, the fee increased to R3.85/1,000 kernels. The same technology fee is charged to both small-scale and large-scale farmers. In 2002/03, a 10 kg bag of Bt seed was sold for R250, while a 10 kg bag of CRN3549 was sold for R190.

Some farmers bought Bt maize in 2003/04 but decided not to plant it, as they anticipated a dry season. They felt that they would not be able to utilize the yield potential in a dry season and may have also predicted that stalk borers would not be a problem. In seasons like 2003/04, when Bt maize does not provide many yield benefits and stalk borer infestations are low, farmers that plant Bt maize are financially slightly worse off than farmers planting less expensive conventional seeds. The problem that farmers have is that low rainfall at planting time may not always result in a dry season with low stalk borer pressure. In fact, late maize plantings have often suffered more stalk borer pressure in South Africa.

Another problem for small-scale farmers who wanted to plant Bt maize in the 2002/03 season was limited availability of Bt seed for purchase. The seed shortage was caused by problems with seed multiplication by Monsanto SA, increased demand by commercial farmers for white Bt seed, and sometimes late or inept seed ordering by either small-scale farmers or their farmer associations. Communication and ordering seemed better in the 2003/04 season, with Bt white maize joining usual hybrid seed distribution channels.

Income and Food Security Effect of Bt Maize

Maize milled into maize meal serves as a staple food for the majority of the population in South Africa. Even though most maize meal is bought from supermarkets and local shops, a large number of rural smallholders produce and store maize for consumption on a small scale and subsistence level. According to a generally accepted rule of thumb commonly used for planning purposes, a household of seven people in a rural area needs about 14 80 kg bags of maize meal per year for household consumption. In Simdlangentsha and Hlabisa, most households that produce maize had to buy additional maize meal, because they had insufficient quality or quantity to feed their families between harvests. Some larger farmers were able to produce a surplus and sold their grain directly to others in the community or to a local shop.

A monetary value of the yield advantage from Bt maize can thus be quantified in two ways: in terms of income generated by selling extra grain, or in terms of cost saving from not having to purchase maize meal. A farmer's ability to sell grain at the average maize spot price in June (harvesting month) is a conservative but necessary assumption, as the prices in these informal maize transactions vary dramatically, but the spot price is quite low and farmers are usually able to negotiate a better local price for their grain. Maize meal is priced according to the average maize meal price reportedly paid by farmers in 2002/03.

When farmers buy more meal to supplement their own self-milled maize meal, they reported that they tend to buy the more expensive "super" maize meal. This meal is more expensive than "special" or "sifted" meal and is seen as a luxury by the poorer households. The quality of the self-milled maize meal usually compares well with store-bought sifted maize meal, so the value of the yield increase due to Bt is calculated using the price of sifted maize meal. There is no formal market for unsifted maize meal (the meal farmers mill themselves). Table 4 shows that the value of maize is much higher when expressed in terms of meal than in terms of the value of the grain when sold. To subsistence farmers, the value of maize meal is higher than the income generated when grain is sold. Because rural households can mill the grain themselves or through local millers, it is much more cost effective to keep and mill maize than it is to sell grain and buy meal. Our calculations assume that farm families grind the maize they intend to consume by hand, and the cost of milling has not been included. In both Simdlangentsha and Hlabisa, a large number of farmers are known to have hand mills at home.

Due to a low average yield achieved by small-scale farmers in the dry 2002/03 season, a statistically significant yield increase of 110 kg (16%) hardly seems economically significant. A 16% yield increase in a season with good rainfall could result in a substantial increase in food security because of a higher base yield. As it is, if the norm that 14 80 kg bags of maize meal are needed for a year for a household of seven is used, then a 110 kg yield advantage enjoyed in KZN resulted in approximately 36 more days of maize meal for a household in 2002/03. As shown in Table 4, Bt maize-planting farmers in northern KZN who sold surplus maize were marginally better off than conventional hybrid seed planting farmers in the 2002/03 season despite the Bt technology fee. Farmers who consumed their additional maize enjoyed a bigger income benefit.

Table 4. Monetary equivalent of yield benefit, 2002/03.

	Northern KwaZulu Natal area
Yield advantage with Bt for household planting 10 kg seed	110 kg
Value of the yield advantage @ R731/ mt[a]	R80.41
Yield advantage in terms of maize meal quantity[b]	108.57 kg
Value of the yield advantage in terms of "sifted" maize meal cost @ R168 for 80 kg	R228
Value of the yield advantage in terms of "super" maize meal cost @ R240 for 80 kg	R326

[a] Maize spot price at closest silo (Safex price minus transport and handling).
[b] Unsifted, self-milled maize meal at 98.7% extraction rate.

Conclusion

Based on findings of three years of research, it is possible to conclude that small-scale subsistence farmers in South Africa can benefit from the use of genetically modified insect-resistant white maize. In the first two production seasons, farmers enjoyed higher yields with Bt maize than with conventional hybrid varieties despite lower-than-normal (but still significant) pressure from stalk borers and otherwise less-than-ideal rains and maize production conditions. The value of the yield benefit depended on how the farmer utilized the additional grain, with home grinding and consumption substituting for more expensive store purchases being the highest valued use. In the third season, which was also the fourth consecutive drier-than-usual season, the stalk borer infestation level was very low, and farmers who planted Bt maize had yields similar to farmers who planted conventional hybrids. Even though farmer perception suggested otherwise, documented savings on insecticides were not found to be substantial due to low levels of application (linked to low stalk borer pressure). The synopsis, then, is that Bt increases small-holder maize farmer income except in years with especially low borer infestation levels. Because a dry early season does not necessarily portend a dry season throughout, Bt might serve as affordable insurance against unforeseeable pest outbreaks, but increases in seed cost or technology fees could easily outstrip that insurance value to small farmers in South Africa.

References

Annecke, D.P., & Moran V.C. (1982). *Insects and mites of cultivated plants in South Africa*. Durban, South Africa: Butterworths.

Brookes, G. (2002). *The farm level impact of using Bt maize in Spain*. Brussels: EuropaBio. Available on the World Wide Web: http://www.europabio.org/documents/gbgmcrops/BTmaizeinspainreport.pdf.

Gonzales, L. (2002, March). *Likely transcendental effects of agribiotechnology: The case of Bt hybrid corn in the Philippines*. Paper presented at the Symposium on Bt Technology, UPLB-CA Foundation, Laguna, CA. Available on the World Wide Web: http://www.seedquest.com/News/releases/2003/march/5459a.htm.

Gouse, M., Pray, C., Kirsten, J.F., & Schimmelpfennig, D. (2005). A GM subsistence crop in Africa: the case of Bt white maize in South Africa. *International Journal of Biotechnology*, *7*(1/2/3), 84-94.

Kfir, R. (1997). Natural control of the cereal stemborers *Busseola fusca* and *Chilo partellus* in South Africa. *Insect Science and its Application*, *17*(1), 61-67.

Marra, M.C., Carlson, G., & Hubbell, B. (1998). *Economic impacts of the first crop biotechnologies*. Raleigh: North Carolina State University.

Marra, M. C., Pardey, P.G., & Alston, J.M. (2002). *The payoffs to agricultural biotechnology: An assessment of the evidence* (EPTD discussion paper no. 87). Washington, DC: International Food Policy Research Institute Environment and Production Technology Division. Available on the World Wide Web: http://www.ifpri.org/divs/eptd/dp/papers/eptdp87.pdf.

Möhr, P.J. (1974). As seen in "Mielieproduksie en die mielierekenaar", 'n MVSA Publikasie, nr 61.

Nel, P.C., & Verwey, J.F. (1976). The role of water nutrition and the yield level in the grain-stalk ratio of maize. *Agropantae*, *8*(4), 65-68.