

Genetically Engineered Corn in South Africa

Implications for Food Security in the Region

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Corn is the staple food in most Southern African countries, accounting for more than a third of calorie consumption in recent years. Its importance in the diet ranges from 17 percent in Angola to 60 percent in Lesotho. Given the region's financial constraints and limited import capacity, domestic production is critical to the supply of corn.

Corn production has declined since 1990 in 3 countries (7 of the 70 study countries were included in the analysis for this article) in the region—Swaziland, Zambia, and Zimbabwe. In Angola, Lesotho, Malawi, and Mozambique, growth in corn output has been heavily dependent upon increases in area. In Angola, for example, area growth has accounted for more than 80 percent of the growth in corn production since 1995. In Mozambique, more than half of the growth stemmed from area growth. In Lesotho and Malawi, corn output rose based on area growth alone as yields have declined since 1995. This dependence on area growth is not sustainable. Farmers in the region are already planting on marginal land, resulting in low yielding crops.

For production growth to keep pace with demand in these countries, yields need to improve. At this point, yields are among the lowest in the world. Even in South Africa, which has the highest yields in the region and where yield growth rather than area growth has accounted for the gains in production, yields pale in comparison to other regions of the world. Corn yields in the country were equal to 63 percent of the world average in 2001-03 (fig. A-1). They were just below those in Latin America and the Caribbean, and about even with those in East and Southeast Asia. Corn yields in the neighboring countries were even lower than those in South Africa, ranging from Zambia (53 percent of yields in South Africa) to Angola (20 percent).

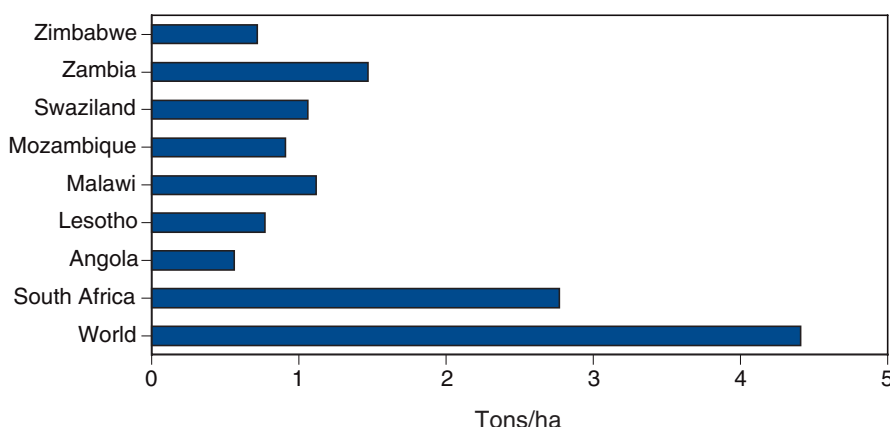
Low levels of fertilizer use and limited technology adoption both contribute to these low yields. Sub-Saharan Africa as a whole, with more than 10 percent of the world's arable land, accounts for less than 1 percent of the world's fertilizer use, and use is growing slowly. Since 1980, fertilizer use in the region has grown only 1.3 percent per year, less than half the rate of population growth. In addition, this growth has slowed over time, and use has remained fairly flat since the early 1990s.

Given low yields, low levels of input use, and financial constraints on imports, securing sufficient food for the region seems contingent on higher yielding technologies. Here we review the use of genetically engineered corn in South Africa, and examine the potential implications of its use in other countries in the region.

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Figure A-1

Corn yields (2001-03) in Southern Africa are far below world levels



Source: Economic Research Service, USDA.

Introduction

Many contend that biotechnology companies have not produced genetically engineered (GE) crops that will boost production of basic foods in developing countries or increase the income of small farmers. GE corn in South Africa is an exception, and could be an important proving ground for GE food crops in Africa and the rest of the developing world. South Africa was the first developing country to grow GE cultivars of corn. The staple food of South Africans is white-grained corn. Yellow-grained corn is also grown in large quantities, but primarily for animal feed and as an input in processed foods. In 1998, corn hybrids with a *Bacillus thuringiensis* (Bt) gene¹ to make them resistant to the corn stalk borer were approved for commercial use by the South African Government. (The stalk borer is a pest that damages the corn stalk, stunting or killing the crop). The first Bt corn hybrids were yellow-grained. In 2001, seed companies started selling white-grained Bt corn hybrids in South Africa. In 2003, Honduras, the Philippines, and Uruguay planted Bt corn for the first time. Argentina also plants Bt corn.

If GE corn proves beneficial to small farmers and poor consumers in South Africa, then the rest of Africa may be more inclined to adopt GE food crops. Bt white corn has the potential to greatly increase yields, boost income for farm families, reduce pesticide use, and improve the health of the rural poor by reducing their exposure to mycotoxins in corn.

Development and Spread of Bt Corn

Research on medical and agricultural biotechnology in South Africa started in the late 1970s. The first experimental plantings of GE plants were in 1990 with U.S. Bt genes in U.S. cotton varieties. In 1997, Bt cotton was approved by the South African Government for commercial planting, and 1997/98 was the first growing season for this crop. One year later, Bt corn, which is resistant to stalk borer, became the second GE crop approved for commercial use and was planted in the 1998/99 cropping season.

¹ *Bacillus thuringiensis* refers to a group of rod-shaped soil bacteria found all over the earth, which produce “cry” proteins that are indigestible by—yet still “bind” to—specific insects’ gut (i.e., stomach) lining receptors. Those “cry” proteins are toxic to certain classes of insects (corn borers, corn rootworms, mosquitoes, black flies, some types of beetles, etc.), but are harmless to mammals. Genes that code for the production of these “cry” proteins have been inserted by scientists since 1989 into vectors (i.e., viruses, other bacteria, and other microorganisms) in order to confer insect resistance to certain agricultural plants.

In South Africa and other Southern African countries, yield losses from the African corn stalk borer are estimated to be between 5 and 75 percent. In South Africa, the yield loss averages 10 percent, equating to an average annual loss of nearly a million tons of corn worth about \$130 million.

The initial spread of Bt corn in South Africa was quite slow. In 2000/2001, after 2 years of experience with Bt corn, farmers planted 75,000 ha of Bt corn, or less than 3 percent of the total corn area (table A-1). When surveyed by representatives of the University of Pretoria's Department of Agricultural Economics, Extension and Rural Development, both seed companies and farmers suggested three main reasons for the slow spread of Bt corn. First, the Bt hybrids on the market were not well adapted to the South African consumer market or to local agricultural conditions. White corn usually comprises 50-60 percent of total corn area in South Africa, but Bt white corn hybrids were not sold to farmers until 2001.

A second reason for slow adoption was that stalk borer is not a significant pest problem every year, so many farmers did not see a big productivity advantage from the Bt gene. Many farmers find that if they plant at the recommended time, they will miss the first moth flight and have limited damage whether they plant Bt varieties or not. Rainfall is the main factor controlling planting date. In years when planting windows are reduced by inadequate rain or pest pressures are higher, farmers might value Bt varieties more highly. For the few years that Bt corn has been available so far, many large farmers felt that the increased yield from Bt corn varieties was not enough to pay for the company's technology fee. Thus, at first Bt will probably only be adopted in those places where stalk borer is a particularly difficult problem.

The third reason for the slow spread of Bt corn was farmers' concerns that they would be unable to sell their crop at the local elevator because of consumer concerns about GE food. Several African countries have said that they will not import animal feed with GE ingredients, and Zambia rejected U.S. food aid because it contained GE corn.

In 2000, firms started selling Bt yellow corn hybrids that were specifically developed for South Africa's dry windy conditions. In 2001, the first Bt white corn hybrids were released. The second constraint on Bt use—farmers' perception of low profitability—changed in the 2001/02 season. That season there was a particularly severe attack of stalk borers, and commercial farmers suffered extensive damage and yield losses. As a result, many more commercial farmers opted to use Bt corn.

Table A-1—Estimated area planted to transgenic crops has risen considerably

Crop	1999/2000	2000/2001	2001/2002	2002/2003
Bt yellow corn (ha)	50,000	75,000	160,000	197,000
% of yellow	3	5	14	20
Bt white corn (ha)	0	0	6,000	55,000
% of white	0	0	0.4	2.8
Total Bt corn (ha)	50,000	75,000	166,000	252,000
% of total	1.3	2.3	4.7	7.1

Source: SANSOR and Monsanto.

Farmers' concern about demand and consumer acceptance has not proved to be a major factor in Bt adoption so far. There is currently no premium for non-GE corn in South Africa, and farmers are easily selling their GE crops. South African consumers scrutinize corn products carefully, but appear to value whiteness and other physical properties over lack of GE traits. In addition, the countries that are refusing GE corn imports or food aid are too small to have much impact on Bt corn prices.

GE corn area grew again in the 2002/03 planting season. Seed firms estimate that the area could double (to half a million hectares or more) in the next few years. The main constraint appears to be the supply of seed, particularly Bt white corn seed, which has not kept up with demand.

Small-scale farmers were able to obtain Bt white corn seed for the first time in 2001/02. Small-scale farmers in Mpumalanga, KwaZulu Natal, Eastern Cape, and Limpopo were given small packets of white Bt corn and the isoline (the same hybrid that does not include Bt). In 2002/03, many small-scale farmers were unable to buy Bt corn seed due to a limited seed supply and the increased demand by large-scale farmers.

Impact of Bt Corn on Large-Scale Farmers

Did the adoption of Bt corn have a measurable impact on farmers' yields and pesticide use? The main target of Bt corn in South Africa is the African corn stalk borer (*Busseola fusca*) and the Chilo borer (*Chilo partellus*); they are estimated to be responsible for a 10-percent loss in yield each year, even though chemicals are used to control them. In the United States, where Bt was designed to control similar pests, farmers failed to achieve the expected gain in benefits: surveys of U.S. farmers show a small increase in yields, but little reduction in insecticide use. Since the infestation level of European corn borers is low in most areas in most years, and pesticides are not very effective, few farmers used pesticides even on their conventional corn hybrids. Therefore, the adoption of Bt corn did not result in a discernable reduction in pesticide.²

Data on the impacts of GE corn in South Africa are from a sample of 33 large-scale corn producers, who were surveyed by representatives of the University of Pretoria about the 1999/2000 and 2000/2001 production seasons. All but one of the farmers grew both Bt and conventional yellow corn. The irrigated farms in the sample were from the Northern Cape and Mpumalanga, and the dryland farms from Mpumalanga and the northwest Provinces.

Yields increased 11 percent on irrigated land and 10.6 percent on dry land for large-scale farmers who planted Bt corn. The differences in means of Bt and conventional were statistically significant (at the 5-percent level) only in the total irrigation and the total dryland calculations. Thus, large-scale yellow corn farmers were seemingly able to increase their yields with Bt corn. Farmers did not report a high level of stalk borer infestation in either season or survey region. Yield benefits would likely increase in seasons with higher stalk borer pressure.

In addition to the yield gains from Bt yellow corn, large-scale farmers were also able to save on their plant protection operations. Seventy percent of the

² Jorge Fernandez-Cornejo and William McBride, *Adoption of Bioengineered Crops*, Agricultural Economic Report No. 810, May 2002, pp. 22-24. This analysis was done prior to the 2003/04 release of a new variety of Bt corn with corn rootworm resistance, which has stimulated increases in adoption. See "Data: Adoption of Genetically Engineered Crops in the U.S.", <http://www.ers.usda.gov/Data/BiotechCrops/adoption.htm>.

large-scale yellow corn farmers in our survey indicated stalk borers to be the dominant insect problem in corn production and, unlike in the U.S., South African farmers sprayed substantial amounts of pesticide to control them—particularly in the irrigated areas. The reduction in pesticide cost is only part of the farmers’ actual reduction in pest management costs. Other savings include lower costs for labor and fuel in the application of pesticides and less time spent scouting fields for pest buildup. As expected, reductions in costs were highest in irrigated regions, where moist conditions are more favorable to insect growth and reproduction.

Large-scale farmers who planted Bt yellow corn enjoyed more income from Bt than from conventional corn fields, despite paying a technology fee along with the seed price. They received the same price for Bt and conventional corn, so the difference in revenue is directly due to yields. The price difference between conventional yellow corn seed and Bt corn seed (plus technology fee) varied among the different seed companies. The difference in 2000/2001 ranged between R130 (\$21) for a bag of 80,000 seeds to R220 (\$36) for a bag of 60,000 seeds. As a result, the increase in net income ranged from R170 (\$28) per hectare in dryland areas to over R1,000 (\$162) per hectare in the Northern Cape irrigated regions.

Can Small-Scale Farmers Also Benefit?

South Africa’s commercial farmers are adopting Bt corn and benefiting from it. However, of greater interest to those working on the economic and social development of Africa is whether small-scale farmers can benefit when Bt is incorporated into a subsistence crop such as white corn.

We analyzed farm-level data from the 2001/02 planting season in six areas where Monsanto distributed white Bt and non-Bt corn seed free of charge. Monsanto worked with local extension agents and provided a 2-day training program to farmers selected by the extension system. The company provided small packets of Bt hybrid seed and the isoline and asked farmers to plant these seeds next to their usual corn seed in their usual corn fields so that agronomic practices and the impact of weather would be comparable.

Results suggest that Bt corn has a large yield advantage over conventional hybrids even for small-scale farmers. In Northern Highveld (Mpumalanga), Hlabisa (KwaZulu Natal), and Venda (Limpopo Province), the Bt seed *Yieldgard* showed yields of nearly 50 percent over the isoline (table A-2).

Small-scale farmers were able to reduce pesticide costs in most areas except in Venda, where very little pesticide was used in that particular season. About half of the farmers surveyed used insecticides (in granular form) intermittently. They reported that the main pest was indeed the stalk borer, followed by cutworm. In contrast, only 5 percent of small-scale farmers who planted *Yieldgard* corn reported using pesticides. It proved difficult to obtain precise estimates of amounts of pesticides used on any of the three different cultivars, and therefore, it is not possible to calculate the potential change in farmers’ net income due to the adoption of Bt corn.

The survey also found that small-scale farmers liked the **quality** of the corn produced by *Yieldgard*. At harvest, farmers were shown their own grain and

Table A-2—Average corn yields for Bt higher than isoline hybrids, 2001/02

Area	Yield with isoline corn	Yield with Bt corn	Yield advantage
	————— <i>Kg/kg seed</i> —————		<i>Percent</i>
Northern Highveld	95.4	148.4	56
Southern Highveld	190.3	204.3	7
Hlabisa	121.2	177.7	47
Venda	114.1	178.3	56
Mqanduli	64.7	79.7	23
Flagstaff	112.2	129.3	15

Source: Authors' survey.

the *Yieldgard* grain and asked to judge the grain according to quality. Most farmers rated the *Yieldgard* grain to be of excellent quality and CRN/local grain as good quality. The Bt corn had less pest damage on the grain than the others. When asked what they liked best about the Bt hybrid corn, farmers at three sites chose better quality, while higher yield was the most cited at the other three sites. The farmers did not place much importance on the benefits from pesticide reduction (probably because only half of them used pesticides prior to the availability of Bt seeds).

Scenarios for Adoption in Other Countries

Yield increase is perhaps the most important benefit of Bt with respect to improving food security in the region. To illustrate the potential impact of introducing genetically engineered corn in other countries in Southern Africa, we ran two scenarios of yield implications using the USDA-ERS Food Security Assessment model. The results reported above indicate wide variability in yield response—from 7 percent to 56 percent—among small farmers to the improved seeds. Since large farmers were able to more consistently obtain 11-percent yield gains—and since small farmers under most conditions can get higher yields than large farmers—we chose 11 percent as a conservative across-the-board yield gain for the surrounding countries of Angola, Lesotho, Malawi, Mozambique, Swaziland, Zambia, and Zimbabwe. We also ran a scenario reflecting a 5-percent yield increase. We then examined the implications of these yield increases on consumption and food security relative to the baseline scenario—the original model results.

The greatest change to consumption was in Lesotho, with a 14.6-percent increase in consumption given a 5-percent increase in corn yields and a near 16-percent increase under the 11-percent increase in yields scenario. In this case, base production is so low that any boost to production will stimulate a spike in consumption. The smallest response—less than 1 percent under both scenarios—was in Swaziland, where domestic production plays a minor role in consumption relative to imports. As a result, the jump in production had little impact on overall consumption. Malawi and Zambia each had similar results—with roughly 3-percent increases in consumption under the 5-percent yield scenario and greater than 6-percent increases in consumption under the higher yield scenario. While these responses are much smaller than those in Lesotho, the increases are much higher than the rate of population growth—which is under 2 percent in each country—meaning positive per capita growth in consumption. In a similar vein,

Zimbabwe’s consumption response—although smaller than in Malawi and Zambia—far exceeds its population growth.

To measure the implications of these yield increases on food security, we review changes to the distribution gap, or the amount of food needed to raise consumption in each income group to meet nutritional requirements. This measure aspires to meeting nutritional standards, versus simply maintaining consumption levels (status quo) that may fall short in some countries. This measure also addresses uneven purchasing power or food distribution problems within a country.

The yield increases had reasonably significant results in all but one country, Swaziland (table A-3), where domestic production contributes very little to consumption. Results for Angola were the most pronounced, with a 28- and 32-percent drop in the distribution gap due to the 5- and 11-percent increases in corn yields. In this case, the gap is almost negligible relative to the size of estimated consumption, so the increase in production has a major impact on the size of the gap. The opposite is true for Lesotho where the gap is large relative to estimated consumption levels, so the increase in production has a much smaller impact—the gap falls roughly 9 percent when corn yields increase 5 percent.

The impact in Malawi is of a similar scope to that in Angola, but for a different reason. Here, domestic production accounts for a large share of consumption, so the jump in production results in a significant drop in the distribution gap. This situation is nearly replicated in Mozambique and Zambia, where reliance on domestic production is high and the resulting decline in the food gap is nearly as large as in Malawi. Zimbabwe has by far the largest gap of all the countries studied here. However, the country has become increasingly reliant on imports to boost consumption as the role of production has declined. Consequently, the boost to production, while important, did not play as significant a role in reducing the food gap as in most of the neighboring countries.

Encouraging Small Farmers To Adopt Bt Corn

Small farmers who will purchase hybrid Bt corn are likely those already convinced of its value. At present, officials at Pannar Seed Company estimate that about 10 percent of small-scale South African farmers plant their land with non-Bt hybrids, primarily Pannar hybrids, while 90 percent of the

Table A-3—Distribution gap falls as yields rise

	Base	Yield change scenarios	
		5%	11%
1,000 tons			
Angola	67	48	46
Lesotho	271	246	243
Malawi	192	161	123
Mozambique	132	110	96
Swaziland	15	15	15
Zambia	487	440	383
Zimbabwe	830	777	713

Source: ERS calculations.

small farmers' land is planted with open-pollinated varieties (OPVs) and saved seeds of hybrids and OPVs. Thus, it is likely that initial adoption of Bt hybrids would be limited to areas already growing hybrids and that adoption would be much slower in less developed areas like the Eastern Cape.

The area under Bt corn could be expanded if companies are willing to segment the Bt corn seed market and charge a lower price to small farmers than to large. The South African Government is pressuring agribusiness to assist small holders, and this is one option. Pannar has a program similar to this with conventional hybrid corn seed. For small farmers, Pannar offers double-cross hybrids or OPVs that are inexpensive to produce, and sells them to small farmers at low prices (R 350/bag (\$57) for double-cross hybrids and R170/bag (\$28) for OPVs). At the same time, it produces triple-cross hybrids and charges premium prices (R 700/bag (\$113)) to large commercial farmers.

However, this type of pricing may not be possible if the regulatory process is structured so that it is more expensive to provide technology to small-scale than to large-scale producers. Under the current system in South Africa, every farmer who plants Bt crops must sign a contract with the companies that are selling GE seeds, identifying the area where the seed will be planted and agreeing to abide by the refuge requirements.³ This is relatively easy for large companies who are selling directly through their marketing agents to large producers. However, if companies are dealing with thousands of small farmers, this expense could very well preclude the sale of GE seeds to the smaller farmers.

Another way to encourage small farmers to adopt Bt corn would be for private firms or government research institutes to put Bt into corn OPVs. Then small farmers could save their seed and still get the benefit of the Bt. However, it would be almost impossible for the government to enforce any type of Bt corn refuge without keeping track of the farmer-to-farmer sale of Bt corn. This lack of oversight might increase the speed at which Bt-resistant stalk borers would develop. Until more is known about the development of resistance, this option is probably not realistic.

Another way to improve the acceptance of Bt corn would be for the government to subsidize the purchase of seed, technology fees, or credit for the poorer farmer. The experience of Bt cotton in Makhathini suggests that credit, which has been subsidized by various government banks to purchase Bt seeds and complementary inputs, can influence the adoption of Bt crops by small-scale farmers. Seeds, pesticides, and other inputs were provided in-kind by a co-op, which then purchased the crop and kept enough money from the sale of the cotton to pay for the value of the inputs. This allowed small-scale farmers to adopt Bt cotton very rapidly. However, in recent years, when farmers did not have access to credit, the area under Bt cotton dropped dramatically. Although researchers on the Makhathini Flats in Kwa-Zulu Natal indicate that the farmers who planted self-financed cotton all planted Bt, the lack of credit has caused a substantial reduction in the planting of cotton altogether.

In sum, Bt white corn can benefit Africa because it can substantially increase crop yields and reduce pesticide use. This could increase small

³ Farmers are required to plant 20 percent of their Bt area with conventional hybrids if they spray the refuge with pesticides or 5 percent if they do not spray.

farmers' incomes if seed cost is not too high. If Bt corn does turn out to be profitable for small farmers in South Africa, farmers who already use hybrids are likely to adopt it quickly elsewhere in Africa. In Zimbabwe, 91 percent of the corn area was planted with hybrids in 1997-99; in Kenya, 85 percent; and in Zambia, 65 percent. As the scenario results suggest, increased yields from the use of improved seeds can improve food security by boosting consumption. Proliferation of adoption will depend on whether policymakers can establish credible biosafety regulatory systems and base their decisions about GE crops on scientific evidence of the risks, costs, and benefits of these technologies.

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