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The Potential Benefits of Genetically Engineered Crops for Egypt:

How much can they reduce pesticide use and increase farmers' income?

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February 2002

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The Potential Benefits of Genetically Engineered Crops for Egypt: How much can they reduce pesticide use and increase farmers' income?

Lawrence Kent
Motaz A. Moniem[1]

Introduction

Researchers at Egypt's Agricultural Research Center (ARC) have been developing new and improved crop varieties for over fifty years. Using conventional plant breeding techniques, they have made crosses and selections to develop scores of new varieties of maize, rice, wheat, cotton, sugarcane, vegetables, and other crops. Breeding projects aim to create varieties that are higher yielding and resistant to attacks by pests and other stresses.

In 1991 a new institute was created at the ARC to support the development of more improved crop varieties. This institute – the Agricultural Genetic Engineering Research Institute (AGERI) seeks to employ new techniques in molecular biology to help create new varieties of crops with desirable traits, particularly pest resistance.

Research at AGERI has created great promise. The institute, working in collaboration with international partners, is in the process of creating new genetically engineered varieties of crops with desirable traits, most notably:

- Cotton that is highly resistant to cotton leaf worms and bollworms;
- Potatoes that are highly resistant to the Potato Tuber Moth;
- Maize that is resistant to corn borers;
- Squash that is resistant to viruses; and
- Tomatoes that are resistant to viruses.

Some of these new varieties will take several more years of research to complete. Others will soon be ready to be considered for planting in farmers' fields, once their safety is confirmed and designated government bodies have given approval.

The time is now appropriate to examine the benefits and risks of continuing the development of genetically engineered crops and approving them for commercialization in Egypt.

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In April 2001, the Executive Secretariat of the National Biosafety Committee (NBC) requested the assistance of the Agricultural Policy Reform Program (APRP) to help set guidelines to examine the risks. The Program helped develop detailed guidelines for the assessment of food safety and environmental safety of genetically engineered (GE) plants. These guidelines specify the types of questions that must be answered with testing and scientific data to determine the safety of every genetically engineered crop before its approval for commercial release. It is expected that the National Biosafety Committee will use these new guidelines, once adopted, to guide its risk assessment work. Only crops that are demonstrated to be safe will be approved.

During discussions of the risk assessment guidelines, several observers in both the NBC and APRP suggested that a study should also be conducted on the potential benefits of genetically engineered (GE) crops. Information on benefits will allow decision-makers to balance potential risks with potential benefits when deciding whether or not to approve the use of specific crops. Information on benefits is also relevant to questions of how vigorously to pursue research and development of genetically engineered crops.

APRP accepted the request of the Secretariat of the NBC to attempt to quantify the potential benefits of the five genetically engineered crops where AGERI's research is the most advanced. These are: Cotton, Maize, Potato, Tomato, and Squash. Other crops, such as wheat, banana, and date palm, are at a less advanced state of product development at AGERI and were not addressed in this study.

Methodology

The APRP study team examined each of the five crops separately. For each, we dialogued with the relevant researchers to determine the purpose of the genetic modifications undertaken. In each case, the main purpose was to increase the plants' resistance to pests and thereby reduce losses and increase harvests.

In each case, the new technology offers two primary economic benefits to the farmers who use it:

1. Reduction in the need to spray pesticides, thereby reducing costs of production;
2. Reduction in losses due to pests and thereby increasing yields – this is possible because genetically engineered crops provide better protection against pests than pesticide sprays.

We attempted to quantify these benefits by looking at what can be expected if a farmer with one feddan planted in a non-GE variety switches to the new technology by planting seeds of a GE variety. How much will he save in pesticide costs? How much extra yield can he expect? What is it worth? How much extra will the GE seeds cost? What will be the effect on his net income from that feddan?

We gathered data to address these questions by reviewing government statistical yearbooks, interviewing crop specialists in the government, interviewing pest control experts in the government and donor sectors, gathering price information from pesticide dealers, and interviewing farmers in their fields. We also examined literature from other countries that have already adopted GE crops, such as the United States and China.

We analyzed the data by comparing farm budgets using spreadsheets to estimate the economic effects on a per feddan basis. Sometimes we examined several "cases", i.e., different effects on farmers that use a lot, a little, or no sprayed pesticides. We then multiplied our per-feddan results by fifty percent of the number of feddans grown nationally in each crop. This is our "Fifty Percent Scenario." The results give us an estimate of national economic impacts of a scenario under which half of the feddans grown in each of the five crops switches to growing GE crops.

After estimating economic effects, we also calculated environmental effects. This consisted primarily of calculating an estimate of the reduction in pesticide use that can be expected when GE crops are grown. How many less sprays and how many less liters of pesticide will be applied each year?

Our analysis focused on the adoption of so called "first generation" technologies – the first round of crop improvements expected from current research. A "second generation" of crops improvements is expected to come later, significantly expanding the benefits of growing GE crops.

Summary of Results

Cotton. Farmers who plant GE cotton will no longer need to spray for leaf worms or bollworms, allowing them to decrease their expenditures on pest management by 160-360 LE per feddan. They can also expect increases in harvests by 5 to 10 percent. As a result, adopters can expect their net income to increase by 460 LE per feddan per year, even after paying a premium for the GE seed. Under a 50 percent adoption scenario, cotton farmers' net income is expected to increase by $32 million annually on a national basis.

Under the 50 percent scenario, there will be a reduction of 1.3 million sprays (feddan-sprays) and a reduction in over one million liters of pesticide used annually in Egypt.

Squash. Farmers who plant GE squash will no longer need to spray pesticides to retard the spread of problematic viruses. By switching to GE squash, a farmer can expect to reduce his expenditures on pest control and reduce his crop losses. Overall, a farmer who switches can expect an increase in net income of 325 to 535 LE per feddan, even after paying for the GE seed. Under a 50 percent adoption scenario, squash farmers' net income is expected to increase by $5 million annually on a national basis.

Under the 50 percent scenario, there will be a reduction of 223 thousand sprays (feddan-sprays) and a reduction in over 90 thousand liters of pesticide used annually.

Benefits are expected to expand significantly when other curcurbit crops (such as cucumber) are genetically engineered in a similar way to resist viruses.

Potatoes. Farmers who plant GE potatoes will no longer need to spray pesticides against the Potato Tuber Moth (PTM), one of several problems harming potato yields. By switching to GE potatoes, the farmer can expect to reduce his expenditures on pest control by 76 LE per feddan on average (during the summer). He can also anticipate yields that are 2 to 10% higher. Overall, a farmer who switches can expect an increase in net returns of 213 to 423 LE per feddan, taking account of the higher price of GE seed. Under a 50 percent adoption scenario, potato farmers' net income is expected to increase by $2 million annually.

Under the 50 percent scenario, there will be a reduction of 35 thousand sprays (feddan-sprays) and a reduction in 27 thousand liters of pesticide used annually in Egypt.

Benefits are expected to triple if "second generation" traits can be engineered into potatoes, especially resistance to blights and viruses.

Because Egypt exports about 10% of its potato production, mostly to Europe, the introduction of genetically engineered potatoes may cause trade problems, even if procedures for market segregation can be established. This risk must be weighed against the potential benefits.

Tomatoes. Farmers who plant GE tomatoes will no longer need to spray pesticides to control the whitefly which is a vector for the devastating Tomato Yellow Leaf Curl Virus (TLCV). Egyptian farmers spray often and heavily to try to control whiteflies. By switching to GE tomatoes, a farmer can expect to reduce his expenditures on pest control by 700 to 1,755 LE per feddan. He can also anticipate yields that are 7 to 15% higher. Overall, a farmer who switches can expect an increase in net returns of 1,000 to 2,400 LE per feddan, even after paying a 25% premium for GE seed. Under a 50 percent adoption scenario, tomato farmers' net income is expected to increase by $82 million annually.

Under the 50 percent scenario, there will be a reduction of over a million sprays (feddan-sprays) and a reduction in over 730 thousand liters of pesticide used annually in Egypt.

Unfortunately, it will still take a few more years of research to develop a GE virus-resistant tomato. If successful, the development of this product will offer huge benefits to Egyptian agriculture.

Maize: Researchers in both the private and public sectors have genetically engineered maize that is resistant to corn borers. These pests are a severe

problem for many farmers who plant in April, a serious problem for those who plant in July and August, and a minor problem for those planting during a "safe period" between May 15 and June 15. We looked at three different "cases" during each of these seasons to calculate the different levels of benefit that a farmer can anticipate by "switching" to GE, depending on his circumstances and current practices. On a per feddan basis, farmers' net incomes increase from 70 to 176 LE. Under a 50 % adoption scenario, maize farmers' net income is expected to increase by almost $20 million annually.

Under the 50 percent scenario, there will be a reduction of half a million sprays (feddan-sprays) and a reduction in over 160 thousand liters of pesticide used annually.

Results for the five crops are summarized in the following figures.

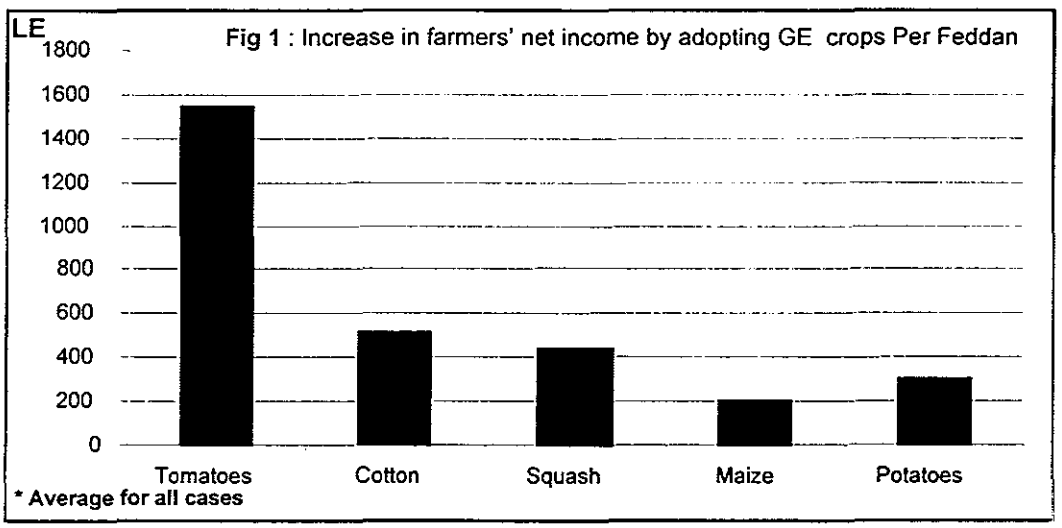


Fig 1 : Increase in farmers' net income by adopting GE crops Per Feddan

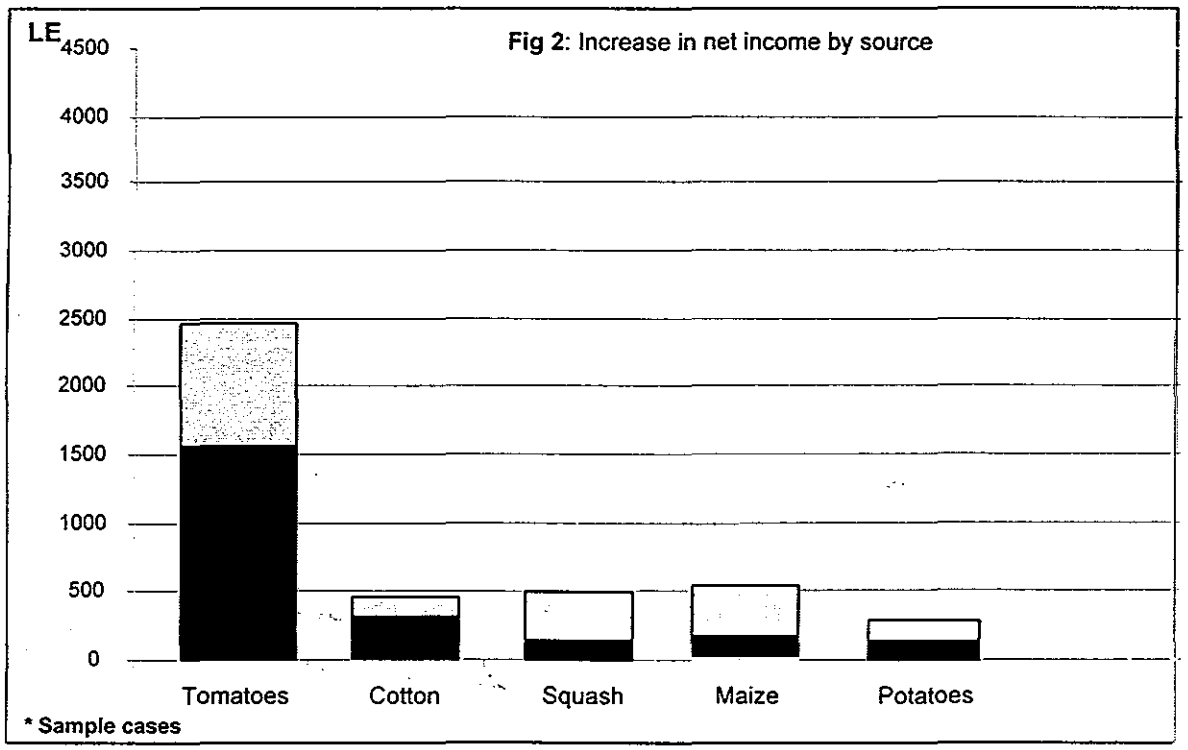


Fig 2: Increase in net income by source

Reduction in pesticide expenditures | Revenue from yield increase

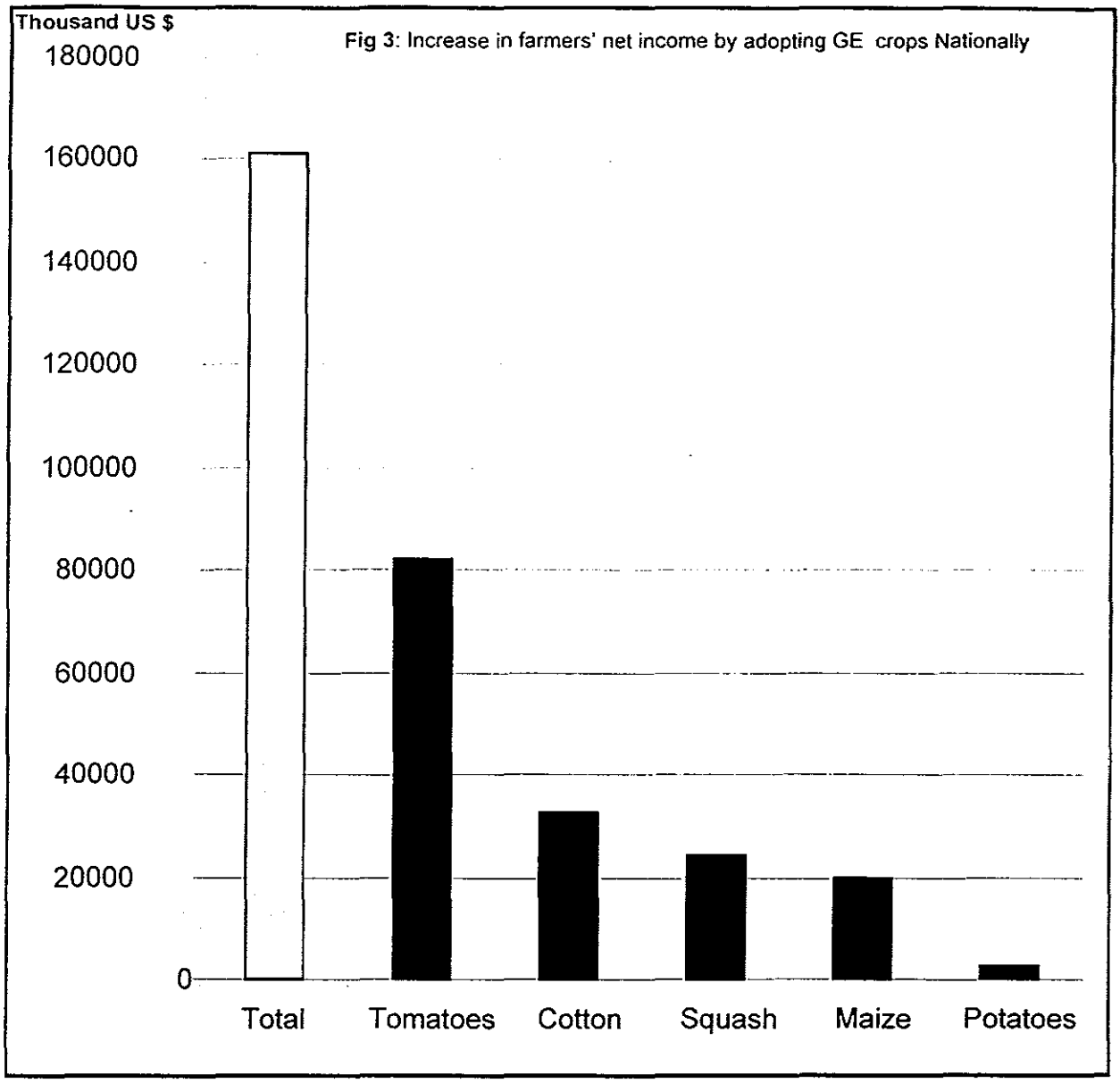


Fig 3: Increase in farmers' net income by adopting GE crops Nationally

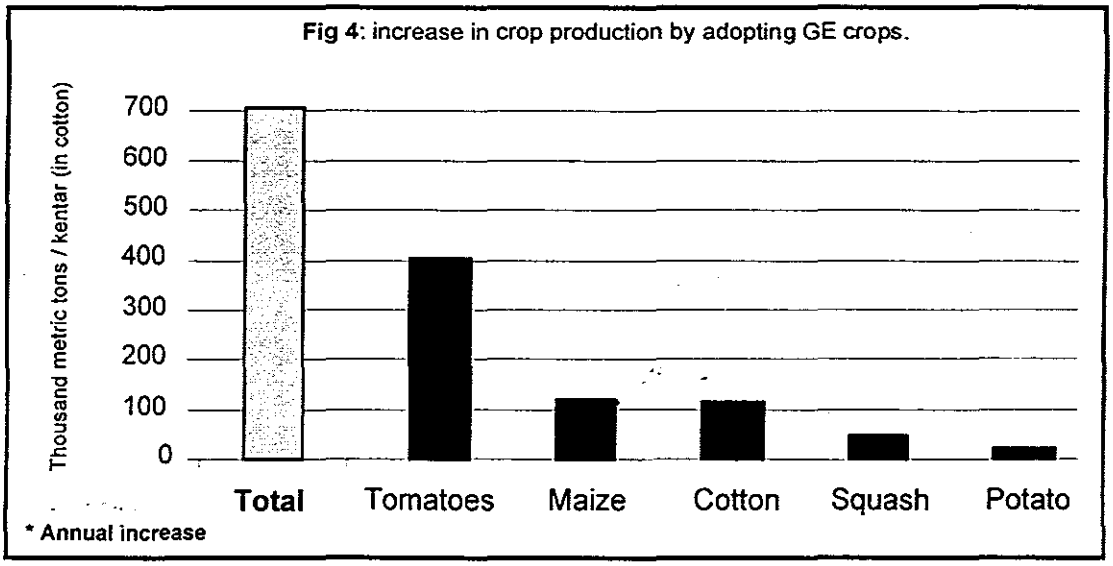
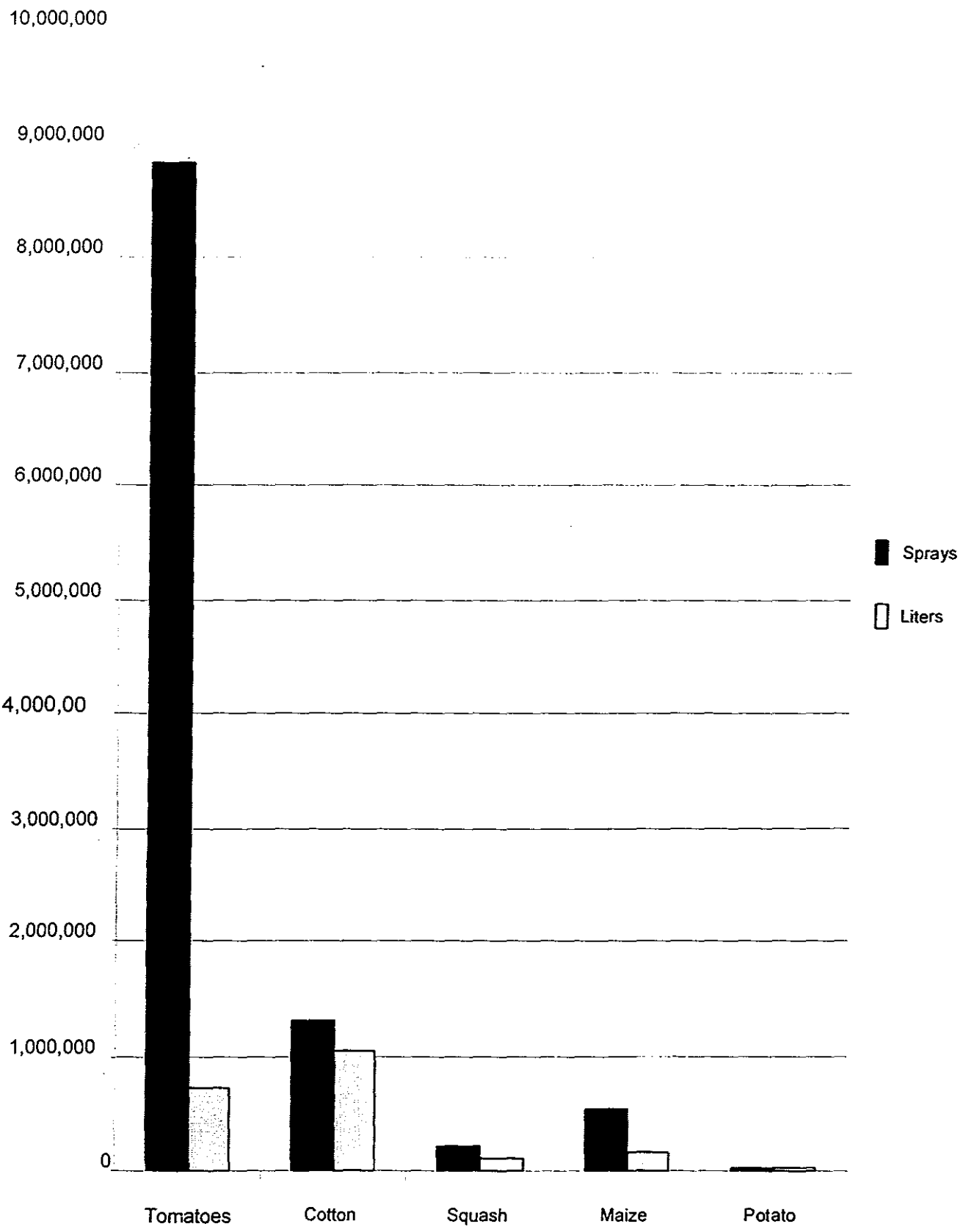


Fig 4: increase in crop production by adopting GE crops.

Fig 5: Reduction in pesticide use by adopting GE crops , All crops comparison



Conclusion

Economically significant benefits for Egypt can be expected if the genetically engineered crops currently being developed in AGERI and the private sector are commercialized and widely adopted by farmers.

The potential benefits of a virus-resistant tomato are the largest, because tomatoes are currently the most heavily attacked and sprayed crop in Egypt.

The potential benefits of GE cotton are also enormous, because treating cotton leaf worms and bollworms using pesticides is more expensive and less effective than genetically engineered seed.

Economic benefits from adopting GE squash are also important, although only 111,000 feddans are planted with this crop. Benefits will triple when other curcurbits are also genetically engineered for virus resistance.

Economic benefits from adopting GE potatoes are significant, but less than the other crops, because PTM is only one of the pests keeping yields down. Second generations traits that impart blight and virus resistance are more likely to have a large enough positive impact to balance potential negative trade impacts with Europe from the use of GE planting materials.

The economic impact of GE maize varies greatly from season to season and farmer to farmer. For those planting in the early season, when attacks by borers are severe, it will be attractive to plant GE maize instead of spraying for these pests. Because nearly 2 million feddan are planted in maize in Egypt, even small gains on a per feddan basis add up to big gains on the national level.

Overall, under a scenario where 50% of the land in each of these crops is planted in GE varieties, total benefits are estimated to include on an annual basis:

- An increase in net farmer income of $142 million.
- An increase in food production of 589 thousand tons.
- An increase in cotton production by 115,000 kentars.
- A decrease in pesticide use of 10 million feddan-sprays, equivalent to 2 million liters less pesticide applied.

These estimated benefits should be compared with perceived risks when policy makers are debating the wisdom of allowing, delaying, or preventing the commercialization of GE crops in Egypt.

Potential Benefits of Introducing Genetically Engineered Cotton

First generation technology

In March 2000, the Ministry of Agriculture, represented by the Agricultural Genetic Engineering Research Institute (AGERI) and the Cotton Research Institute, entered into an agreement with Monsanto company to develop new transgenic varieties of cotton that incorporate a gene from the bacteria *Bacillus thringiensis* (Bt) into Egyptian varieties of cotton known as Giza. (Monsanto calls its Bt gene Bollgard II) Two back crosses have already been completed and many hope that product development will be completed in two more years. The result will be insect resistant cotton varieties.

The cotton leaf worm, the pink bollworm, the spiny bollworm, and the sucking insects (aphids, thrips, jassids) are the major insect pests of Egyptian cotton. Even when managed by a series of insecticide sprays, these pests cause an estimated five to ten percent losses in production each year, on average.

Cotton pest control in Egypt is conducted by agents of the Ministry of Agriculture. The agents typically spray farmers' fields once to control cotton leaf worms with an insecticide called AGERIN, and three times to control bollworms, using a rotation of phosphorous compounds, pyrethroids, and carbomites. Farmers, on their own, often make one or two additional sprays early in the season to control sucking insects.

Transgenic Bollgard or Bt cotton is highly resistant to the cotton leaf worm and the pink and spiny bollworm. Research plots in the US show 99% resistance to the pink bollworm, which is the most damaging of all cotton pests in Egypt.[2] Once bollworms penetrate the cotton boll on the plant, they become very difficult to kill with pesticide sprays.

It is anticipated that Egyptian farmers who plant Bt cotton will benefit in two important ways:

- Their cotton will no longer need to be sprayed for leaf worms or bollworms, allowing farmers to decrease their expenditures on pest management by between 160 and 360 LE per feddan. (They will still need to control sucking insects).

- The integrated protection of Bt will greatly reduce losses due to leaf worms and bollworms. This will result in increases in harvests by 5 to 10 percent.

Our calculations, appended to this section, indicate that a farmer, who switches from regular cotton to Bt Cotton, can expect 460 LE per feddan in additional profit. This is based on a 5% increase in yield, 360 LE less

[2] Moore et al. (1999) as referenced in Genetically Modified Organisms in Agriculture by Nelson 2001.

expenditure on pest control, and additional expenditure of 56 LE for the Bt cotton seed.

Over the past three years, an average of 651,000 feddan have been planted in cotton annually. In the appended calculations, we examine a scenario where 50% of all land planted in cotton is seeded with the new *Bt* cotton varieties. Under this scenario:

- Expenditure on pesticides decreases by $12.7 million annually (chemical costs only).
- Production increases by 116,000 kentars, worth approximately $11 million annually.
- Farmer income increases by $32 million annually, or roughly $325 million over ten years.

The above calculations are based on a comparison with farmers' current expenditures on pest control, including two supplemental sprays they typically conduct on their own, before the government agents begin "official" spraying. An alternative scenario would only take into account the government spraying, which reportedly costs only LE 160 per feddan – a figure we consider to be an underestimate. Under this alternative scenario, the amount of money saved by replacing spraying with the Bt technology is less; however, it is still very significant. Under this scenario, adoption of the Bt technology increases farmer profits by LE 259 per feddan. Expenditures on pesticides decrease by $52 million annually and farmer income increases by $18 million annually.

Some believe that the integrated protection of Bt cotton will increase yields by more than 5%. In China, Bt cotton has resulted in increases of 12-14% (while reducing the number of sprays dramatically). If we redo our Egyptian calculations based on a 10% increase in yield, farmer profits will increase by LE 615 per feddan. This means an increase in Egyptian farmer income by over $43 million annually.

A last scenario presented in the calculations looks at a lower adoption rate – only 20% of all feddans in cotton. Under this scenario, farmer income increases by only $13 million a year.

Environmental Benefits

Under the first 50% adoption scenario mentioned above, pesticide applications on cotton are reduced by the equivalent of:

- 1.3 million feddan sprays, equivalent to:
- Over one million liters of pesticide annually.

This reduction will mean less pesticide run-off into waterways, where it can negatively effect human, fish, and other wildlife health. Some of the pesticides routinely sprayed on cotton are suspected carcinogens. The reduction in pesticide applications will almost certainly mean a reduction in illnesses suffered by workers and farmers who apply pesticides and a

reduction in children's exposure to pesticides in fields or in homes where they are often stored.

A word should also be added regarding beneficial insects. These insects are common in Egyptian fields and can help control pest insects by eating or otherwise killing them. Surveys by the GTZ Cotton Sector Support Program show that "beneficials" are abundant in Egyptian cotton fields until the spraying begins. Spraying a pesticide like Dursban (Chlorpyrifos) kills both target worms and beneficial insects. *Bt* cotton has no undesirable effects on beneficial insects. It leaves them to do their natural work in controlling secondary pests. It allows for integrated pest management (IPM).

Resistance Concerns

Insect pests often build up resistance to new pesticides if they are used too often and too widely. There is concern that the pink bollworm could develop such resistance to Bt if Bt cotton was planted too widely in Egypt. Cotton is the only host for the pink bollworm. If resistance develops, the effectiveness of Bt would diminish. To avoid this problem, scientists recommend that an entire area not be blanketed with Bt cotton; instead, the Bt cotton should be planted within a reasonable distance of non-Bt cotton. This approach diminishes the chances that only Bt-resistant insects will survive and breed. In the United States, where 78% of all cotton grown in Bt, farmers are required to grow 5-20% of their fields in non-Bt varieties to hinder the development of resistance. In Egypt, it may be necessary to take similar measures, e.g., make sure there is a mixture of non-Bt and Bt varieties growing in each governorate. The fiber and ginning characteristics of a Bt-Giza 86 and a traditional Giza 86 should be identical.

Export and marketing concerns

Because cotton fiber is not a food product, there should not be food-safety concerns for exports. Nor should there by quality issues, as recent research shows that Bt does not affect fiber quality.[3] While it is probable that certain buyers may prefer non-Bt varieties for specialized markets, general discrimination against Bt cotton is not expected. Cottonseed oil, a by-product of Egypt's cotton crop, is processed locally for domestic consumption. In the US and other countries producing such oil, there have been no food safety issues. In fact, the presence of the modification is extremely difficult to detect at all in cottonseed oil. It will be up to Egypt's National Biosafety Committee to assess the safety of such oil for consumption in Egypt.

[3] O. Lloyd May, "Issues with Genetically Modified Cotton – Perspectives of a Cotton Geneticist," The University of Georgia, 2001.

Second generation technologies

The Bt cotton currently being developed for Egypt incorporates Bollgard II, the second generation of Bt genes developed by Monsanto. In the future, it is likely that a Bollgard III will become available with resistance to secondary insect pests, e.g., cutworms. Herbicide resistance traits are also available, although this trait does not address an important need in Egypt, where herbicides are rarely used on cotton.

Introduction to the Cotton Calculations

Our calculations look at a scenario where 50% of the area currently planted in cotton is converted to *Bt* cotton. What would be the effects of such a conversion?

Certainly pesticide use would decline, reducing the cost of production. Yields would also increase, as losses due to pests are reduced. The *Bt* gene provides better protection than sprayed pesticides for lepidopteran pests.

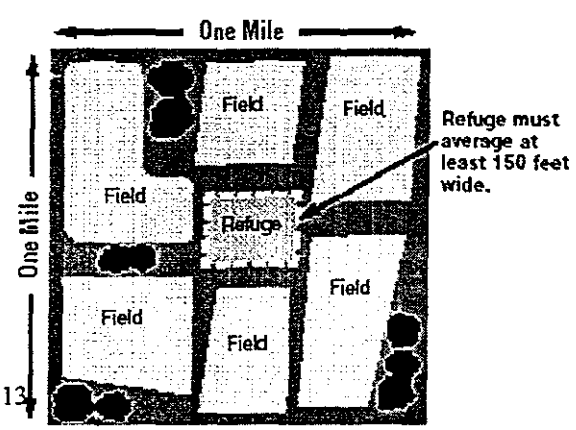
We look at four scenarios in our calculations. Under the first scenario, we compare the costs and returns of GE cotton with those of non-GE cotton that is sprayed five times during a season. The costs of spraying are estimated at 451 LE feddan, a figure justified in detail in the GTZ's Hannover report (2001). GE cotton is sprayed only once, for sucking insects, for LE 90. Accordingly, using GE saves the farmer the difference: 361 LE. The superior protection of the GE varieties also will decrease losses (thereby increasing yield) by 5%.

Under a second scenario, we compare GE cotton with non-GE cotton that is sprayed three times for leaf and bollworms. Using data supplied by the Ministry of Agriculture, the cost of these sprays is only LE160. These costs are saved when planting GE. Yields increase by 5%.

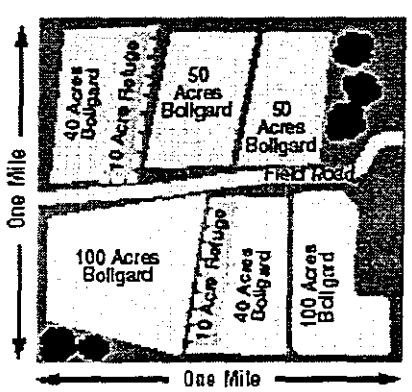
Under a third scenario, we use the same pesticide cost savings numbers as in the first scenario, however, we are less conservative in our estimate of yield gain. We use a figure of 10%.

Under a fourth scenario, we make the same assumptions as in the first; however, we look at an adoption rate of only 20% instead of 50%.

Fig 6: Refuge options for GE Cotton



Example:
5% Embedded Refuge Option for Smaller Fields or Fields That Are Closely Associate



Cotton Calculations

One feddan of cotton: Giza Bollgard Cotton Sprayed One Time Compared to Non-GE Cotton Sprayed Five Times

	Non-GE Cotton		GE Cotton		Difference	
Relevant pesticide costs:	451	LE	90	LE	-361	LE
Extra cost of GE seed:	0.00		56		56 LE	
Yield:	7.11	Kentar	7.47	Kentar	0.36	Kentar
Value of yield:	3,102	LE	3,258	LE	155	LE

Total financial gain for farmer per feddan **460** LE

Assumptions: Yield increase: 5%
Price of product: 436 LE/Kentar

Area planted in summer:	650,849	fd				
Area adopting:	50%		325,425	fd		
Financial gains for farmers:	149,589,264	LE	32,519,405	US $	**325,194,051**	US $ over 10 years
Reduction in pesticide costs:	58,576,440	LE	12,678,883	US $	**126,788,831**	US $ over 10 years
Increase in Production:	115,743	Kentar	10,926,663	US $	**109,266,626**	US $ over 10 years
Reduction in pesticide use:	1,301,699	sprays	1,041,359	liters	**10,413,589**	liters over 10 years

Under an alternative scenario with relevant pest control costs based on government estimates of only LE 160/fd

Financial gains for farmers:	84,243,991	LE	18,313,911	US $	**183,139,110**	US $ over 10 years
Reduction in pesticide costs:	52,067,947	LE	11,270,118	US $	**112,701,183**	US $ over 10 years
Increase in Production:	115,743	Kentar	10,926,663	US $	**109,266,626**	US $ over 10 years
Reduction in pesticide use:	976,274	sprays	781,019	liters	**7,810,192**	liters over 10 years

Under an alternative scenario with production increasing by 10% instead of 5%:

Financial gains for farmers:	200,070,445	LE	43,493,575	US $	**434,935,750**	US $ over 10 years
Reduction in pesticide costs:	58,576,440	LE	12,678,883	US $	**126,788,831**	US $ over 10 years
Increase in Production:	231,485	Kentar	21,853,325	US $	**218,533,253**	US $ over 10 years
Reduction in pesticide use:	1,301,699	sprays	1,041,359	liters	**10,413,589**	liters over 10 years

Under an alternative scenario with adoption of only 20% of all feddans in cotton, and yield gain of only 5%:

Financial gains for farmers:	59,835,705	LE	13,007,762	US $	**130,077,621**	US $ over 10 years
Reduction in pesticide costs:	23,430,576	LE	5,071,553	US $	**50,715,532**	US $ over 10 years
Increase in Production:	46,297	Kentar	4,370,665	US $	**43,706,651**	US $ over 10 years
Reduction in pesticide use:	520,679	sprays	260,340	liters	**2,603,397**	liters over 10 years

Notes:

- Pesticide cost based on 1 spray for sucking insects, 1 spray for leaf worms, 3 sprays for bollworm. The total cost of 451 LE/feddan includes all labor and machinery hire, based on Hannover report 2002 GTZ CSPP
- Price of GE seed is assumed to be set at 25% of the cost of average pesticide costs in Hannover 2002 i.e., 225 LE pesticide cost only. This is three times the current price of subsidized regular seed.
- Average cotton yield of past three years from the Egyptian Cotton Gazette, ALCOTEXA
- Average price of cotton is an estimate derived from 2001 CATGO price tables for cotton of "good plus 1/4, outurn ratio of 120, varieties Giza 89 and 85", plus 10% announced increase for 2002 season.
- Average area planted in cotton during past three years from Agricultural Statistics book of Economic Affairs Sector, MALR
- Reduction in pesticide use based on 0.8 liters/spray

Potential Benefits of Introducing Genetically Engineered Potatoes

First generation technology

AGERI, working in cooperation with Michigan State University has developed a genetically engineered (GE) potato incorporating a *Bt* gene that imparts resistance to the potato tuber moth (PTM).

The PTM is one of many problems affecting potatoes during the Summer season. The PTM also damages potatoes during storage; however, this damage has become less problematic in recent years, because more and more farmers are storing their potatoes in refrigerated cold stores. In the field, potato tuber moths damage the tubers and can be a vector for disease. Most farmers in Egypt, although not all, spray pesticides to reduce the negative effects of PTM during the Summer season.

A farmer planting Bt potato seed will have excellent protection against PTM and will not need to spray pesticides. He will save LE 152 per feddan in pesticide costs compared to a farmer who sprays twice during the Summer season. He will save LE 76 compared to a farmer who sprays only once. We estimate that one third of Summer potatoes is sprayed twice, one third is sprayed once, and one third is not sprayed at all.

The farmer's yield is also likely to increase, because the integrated protection of the Bt gene is more complete than that obtained from pesticides. Yield is expected to be 2.5% higher than potatoes sprayed twice, 5% higher than those sprayed once, and 10% higher than those that are not sprayed at all.

If Bt potatoes were adopted on 50% of the area planted in potatoes for the Summer season:

- Approximately 27,000 liters less pesticide would be applied each year.
- Annual expenditure on pesticides would decrease by $585 thousand.
- Annual potato production would increase by 21,000 metric tons (worth $2.5 million).
- Farmer income, after subtracting out the extra cost of transgenic seed, would increase by $2.3 million annually.
- Farmer income would increase by $23 million over ten years.

It is worth noting that these calculations are base on zero benefits during the Nili and Winter seasons, when PTM losses are minimal. A 50% adoption rate in Summer means only 21% adoption during all three seasons combined.

Additional benefits are likely to accrue during the winter season. Although PTM is not generally a problem during the winter, some farmers who plant late suffer losses. Some spray pesticides once, shortly before harvesting.

These farms, estimated at only 20% of all potato plantings in Winter, may also benefit from Bt potatoes.

Lastly, the minority of farmers that continue to store their harvested potatoes in traditional mud storerooms – *nawallas* – will dramatically reduce their losses due to PTM if they plant Bt potatoes. Losses in *nawallas* frequently are in the range of fifteen percent.

Second Generation Technologies

Currently, AGERI is undertaking research aimed at developing additional traits to incorporate into its transgenic potatoes. These traits include resistance to viruses and blights. AGERI is making good progress on virus resistance while researchers at the International Potato Center in Peru are working on blight resistance. These problems are more serious menaces than PTM for most Egyptian potato growers. Eventual introduction of a virus and blight-resistant potato will greatly enhance yields (by reducing losses) and reduce expenditures on pesticides.

Currently, Egyptian potato farmers apply about LE 130-225 per feddan in pesticides to control viruses and blights. For blights, farmers apply a fungicide called Copper Galibin. Despite this significant expenditure, losses of 20% are typical. Viruses and blight affects all three potato seasons – Summer, Winter, and Nili. Adoption of a transgenic virus and blight-resistant potato on 50% of the planted area, could result in:

- savings of $900 thousand annually in pesticides,
- increased production of 57 thousand tons, worth $6.5 million,
- $7 million in increased farmer income, after subtracting out the extra cost of transgenic seed.
- $71 million increase in farmer income over ten years.

Environmental Benefits

These benefits will accrue by replacing pesticide sprays with transgenic protection. If half of Egyptian farmers switch to Bt potatoes, pesticide applications will decrease by approximately 27,000 liters. This reduction will involve mostly Selecron (profenfos), a strong pesticide considered dangerous and even carcinogenic by some.

Threat to Exports?

Egypt exports between 120 thousand and 400 thousand tons annually to Europe. In 2000, exports were 120 thousand or seven percent of all Egyptian potato production. In the near term, Europe is unlikely to agree to purchase transgenic potatoes. Therefore, Egypt will need to carefully segregate its production of transgenic potatoes from its regular production. Such segregation should be possible, because potatoes for export are already grown in separate "pest free" zones, during a separate season, and usually with separate varieties. However, the possibility will always exist that some mixing may occur in advertantly and some transgenic potatoes could be

exported accidentally to Europe. This would provoke a negative reaction in Europe and potentially a suspension on the import of Egyptian potatoes. Even the possibility of such an event occurring could reduce European interest in buying Egyptian potatoes. Egyptian policy-makers will need to take into account this risk, and compare it to the potential benefits of GE potatoes, when deciding whether or not to allow the commercialization of GE potato seeds.

Introduction to the Potato Calculations

Our analysis of the potential benefits of adoption of *Bt* potato assumes that potato tuber moth (PTM) is only a serious problem during the Summer crop. It is not a problem during the Winter and Nili crops. An average of 71 thousand feddans is planted during the Summer crop.

Our calculations look at a scenario where 50% of this area convert to *Bt* potato. What would be the effects of such a conversion?

Certainly pesticide use would decline, reducing the cost of production. Yields would also increase, as losses due to pests are reduced. The *Bt* gene provides better protection than sprayed pesticides.

Estimating the magnitude of these effects requires us to look at different cases. Our analysis of the potential benefits of adoption of *Bt* potato recognizes that the degree to which a farmer benefits from the new technology depends on his current farming practice. A farmer who plants non-*Bt* potato in the Summer season and does not spray for PTM suffers significant crop losses. If he adopts *Bt* potato he will benefit significantly. A farmer who plants non-*Bt* potato and sprays it correctly, suffers very little crop loss. If he switches to *Bt* potato, he will reduce his pesticide costs but increase his yield only slightly.

To calculate overall benefits, we established three "cases". These are as follows:

Case 1: One feddan of non-*Bt* potato, sprayed twice for PTM, coverts to *Bt* potato. Such a conversion results in significant savings in pesticide costs but little additional yield.

Case 2: One feddan of non-*Bt* potato, sprayed once for PTM in a typical but sub-optimal way, coverts to *Bt* potato. Such a conversion results in some savings in pesticides and some additional yield.

Case 3: One feddan of non-*Bt* potato, not sprayed at all, converts to *Bt* potato. Such a conversion results in no pesticide savings but significant increases in yield.

In all cases, we assume the cost of one pesticide application to be LE 76/feddan, based on the use of Selecron. [4] We estimate the cost of *Bt* seed to be ten percent higher than regular seed or an extra LE 98 per feddan.

After calculating the potential benefits on a per feddan basis in each of these cases, we multiplied the results by the total number of feddans to which each case applies. Finally we totaled the estimated benefits.

[4]Pesticide costs based on using Selecron at cost of 75 LE/bottle of 900 ml. To spray one feddan requires 750 ml at a cost of 62.5 LE. To hire a motorized sprayer it costs 7.5 LE/fd with man power costing 6 LE/fd. Total cost is 76 LE.

Potatoes Calculations

SUMMER PLANTING

Case 1: One feddan of potato: Bt Potato compared to potato sprayed twice using Selecron:

	Non Bt Potato		Bt Potato		Difference	
PTM pesticide costs:	152	LE	0	LE	-152	LE
Extra cost of GE seed:	0		98		98	LE
Yield:	12.10	MT	12.40	MT	0.30	MT
Value of yield:	6,373	LE	6,532	LE	159	LE

Total financial gain for farmer per feddan **213** LE

Assumptions:	Yield increase:	2.5%	
	Price of product:	527	LE/MT

Case 2: One feddan of potato: Bt Potato compared to potato sprayed one time using Selecron:

	Non Bt Potato		Bt Potato		Difference	
PTM pesticide costs:	76	LE	0	LE	-76	LE
Extra cost of GE seed:	0		98		98	LE
Yield:	11	MT	11.55	MT	0.55	MT
Value of yield:	5,794	LE	6,083	LE	290	LE

Total financial gain for farmer per feddan **267** LE

Assumptions:	Yield increase:	5.0%	
	Price of product:	527	LE/MT

Case 3: One feddan of potato: Bt Potato compared to potato not sprayed using Selecron :

	Non Bt Potato		Bt Potato		Difference	
PTM pesticide costs:	0	LE	0	LE	0	LE
Extra cost of GE seed:	0		98		98	LE
Yield:	9.90	MT	10.89	MT	0.99	MT
Value of yield:	5,214	LE	5,736	LE	521	LE

Total financial gain for farmer per feddan **423** LE

Assumptions:	Yield increase:	10%	
	Price of product:	527	LE/MT

Area planted in summer:	71,654	fd		
Areas converting to BT:	35,827	fd	50%	
Area under case 1 adopting:	33%		11,823	fd
Financial gain under case 1:	2,518,714	LE	547,547	US $
Area under case 2:	33%		11,942	fd
Financial gain under case 2:	3,193,320	LE	691,195	US $
Area under case 3:	33%		11,942	fd
Financial gain under case 3:	5,053,314	LE	1,093,791	US $

Total for all seasons:

Financial gain for farmers:	10,765,348	LE	2,330,162	US $	23,301,620	US $ /10 yrs
Reduction in pest control costs:	-2,704,700	LE	-585,433	US $	-5,854,328	US $ /10 yrs
Increase in production	21,968	MT	2,504,404	US $	25,044,040	US $ /10 yrs
Reduction in pesticide use	35,588	Sprays	26,691	Ltrs		

Notes

- Price of GE seed is assumed to be 10% higher than the non GE
- Price of potatoes 526.70 ton according to the Agricultural Statistics Book, Economical Affairs Sector, MALR

Potential Benefits of Introducing Genetically Engineered Squash

First Generation Technology

Researchers at the Agricultural Genetic Engineering Research Institute (AGERI), working with collaborators under the Agricultural Biotechnology Support Program (ABSP), have developed a genetically Engineered (GE) squash variety that is highly resistant to the Zucchini yellow mosaic potyvirus (ZYMV). Within the next three years it is expected that the GE squash will be assessed for safety, registered and commercialized in Egypt.

The GE squash employs coat protein-mediated protection, which stops the spread of the virus. ZYMV is the major pest of squash in Egypt. We estimate average losses in the summer to be between 10 and 15 percent, even when the farmer sprays pesticides to try to kill the vector for the virus – aphids. In the winter, losses are less – we estimate between 5 and 10 percent on average.

A farmer who switches to GE squash will benefit in two ways. First, he will not need to spend time or money on pesticide applications, which cost between 69 and 191 LE per feddan. Second, he can expect much lower levels of infection by ZYMV and hence less losses; as a result he will harvest 5-15 percent more squash.

Overall, we calculate that by switching to GE squash, the farmer will increase his net return by between 325 and 535 LE per feddan, even after paying a price premium for the GE seed (estimated at 25% above regular price).

Over the past three years, an average of 111,000 feddan are planted in squash annually. In the appended calculations, we examine a scenario where 50% of all land planted in squash is seeded with the new GE variety. Under this scenario:

- Expenditures on pest control decrease by $1.7 million annually.
- Production increases by 46,000 tons, worth approximately $ 4.6 million annually.
- Farmer income increases by $ 5.2 million annually, or roughly $ 52 million over ten years.

Environmental Benefits

Under the first 50% adoption scenario mentioned above, pesticide applications on squash are reduced by the equivalent of:

- 223 thousand feddan sprays, equivalent to:
- Over 90 thousand liters of pesticide annually.

Export and Marketing Concerns

In Egypt, squash is produced for the domestic market. Before the GE squash will be approved for planting, it will need to undergo a food safety assessment and receive approval from the National Biosafety Committee. No problems are anticipated, as transgenic curcurbits have been assessed and judged safe in other countries. The reaction of Egyptian consumers to GE squash cannot be predicted at this time. On one hand, consumers may be wary about a novel food. On the other hand, they may be attracted to the higher quality produce, unblemished by viral damage.

Second Generation Technologies

The process used to create virus-resistant GE squash can also be used to create other virus-resistant curcurbits, such as cucumber, watermelon, and cantaloupe melon. AGERI is working on these crops and may come out with new GE varieties in the next few years. This will be significant, because of the large number of feddans planted in these crops:

Watermelon	161, 579	feddan
Cucumber	59, 747	feddan
Cantaloupe	59, 312	feddan

Under a scenario where 50% of the feddans planted in these crops switches to GE varieties, we could expect benefits for all curcurbits to be roughly three times higher than the benefit numbers calculated for 111,000 feddans of squash alone. This would mean more than $ 15 million in extra net returns for Egyptian farmers each year.

Introduction to the Squash Calculations

Our calculations look at a scenario where 50% of the area currently planted in Squash is converted to ZYMV-resistant Squash. What would be the effects of such a conversion?

Certainly pesticide use would decline, reducing the cost of production. Yields would also increase, as losses due to pests are reduced. The GE squash provides better protection than sprayed pesticides for the vectors of the virus.

Estimating the magnitude of these effects requires us to look at different cases. Our analysis of the potential benefits of adoption of GE squash recognizes that the degree to which a farmer benefits from the new technology depends on his current level of pesticides used:.

To calculate overall benefits, we established two "cases". These are :

Case 1: One feddan of squash, sprayed by using a combination of Actellic and Marshal 6 times per season, converts to GE squash. Such a conversion results in significant savings in pesticide costs and increase in yield

Case 2: One feddan of squash, sprayed by using Malathion, converts to GE squash. Such a conversion results in less savings than the first case in pesticide costs increase the yield

In case 1 pesticide cost are 110.25 LE. Hiring men and a motorized sprayer costs 13.5 LE per application. There are 6 applications yielding a total cost of 191.25 LE. These costs are avoided by planting GE squash

In case 2 pesticide cist are 21.25 LE per feddan sprayed plus 13.5 LE for labor and equipment hire, the spray per season total cost are 69.5 LE / Feddan.

After calculating the potential benefits on a per feddan basis in each of these cases, we multiplied the results by the total number of feddans to which each case applies. Finally we totaled the estimated benefits.

Squash Calculations

SUMMER PLANTING

Case 1: One Feddan of squash: GE Squash compared with Squash sprayed by using a mixture of Marshall and Actellic

	Non GE		GE		Difference	
ZYMV pesticide costs:	191	LE	0	LE	-191	LE
Extra cost of GE seed:	0		75		75	LE
Yield:	7.80	MT	8.58	MT	0.78	MT
Value of yield:	3613	LE	3974	LE	361	LE

Total financial gain for farmer per feddan **478** LE

Assumptions:			
	Yield increase:	10%	
	Price of product:	463	LE/MT

Case 2: One Feddan of squash: GE Squash compared with Squash sprayed by using Malathion

	Non GE		GE		Difference	
ZYMV pesticide costs:	69	LE	0	LE	-69	LE
Extra cost of GE seed:	0		75		75	LE
Yield:	7.80	MT	8.97	MT	1.17	MT
Value of yield:	3613	LE	4155	LE	542	LE

Total financial gain for farmer per feddan **535** LE

Assumptions:			
	Yield increase:	15%	
	Price of product:	463	LE/MT

WINTER PLANTING

Case 1: One Feddan of squash: GE Squash compared with Squash sprayed by using a mixture of Marshall and Actellic

	Non GE		GE		Difference	
ZYMV pesticide costs:	191	LE	0	LE	-191	LE
Extra cost of GE seed:	0		75		75	LE
Yield:	9.00	MT	9.45	MT	0.45	MT
Value of yield:	4169	LE	4377	LE	208	LE

Total financial gain for farmer per feddan **325** LE

Assumptions: Yield increase: 5%
Price of product: 463 LE/MT

Case 2: One Feddan of squash: GE Squash compared with Squash sprayed by using Malathion

	Non GE		GE		Difference	
ZYMV pesticide costs:	69	LE	0	LE	-69	LE
Extra cost of GE seed:	0		75		75	LE
Yield:	9.00	MT	9.90	MT	0.90	MT
Value of yield:	4169	LE	4586	LE	417	LE

Total financial gain for farmer per feddan **410** LE

Assumptions: Yield increase: 10%
Price of product: 463 LE/MT

Area planted in Summer:	57,404	fd		
Areas converting to GE seeds:	28,702		50%	
Area under case 1 adopting:	50%		14,351	fd
Financial gain under case 1:	6,853,263	LE	1,489,840	US $
Area under case 2:	50%		14,351	fd
Financial gain under case 2:	7,684,157	LE	1,663,237	US $

Area planted in Winter:	54,056	fd				
Areas converting to GE seeds:	27,028		50%			
Area under case 1 adopting:	50%		13,514	fd		
Financial gain under case 1:	7,235,990	LE	1,573,041	US $		
Area under case 2:	50%		13,514	fd		
Financial gain under case 2:	5,545,875	LE	1,200,406	US $		
Total for all seasons:						
Financial gain for farmers:	24,471,155	LE	5,296,787	US $	52,967,869	US $/ 10 yrs
Reduction in pest control costs:	-7,237,934	LE	-1,566,652	US $	-15,666,523	US $/ 10 yrs
Increase in production	46,228	MT	4,634,842	US $	46,348,424	US $/ 10 yrs
Reduction in pesticide use	222,920	Sprays	93,348	ltrs		

Notes

- Price of GE seed is assumed to be 25% higher than the non GE
- Price of Squash 463.20 LE/ ton according to the Agricultural Statistics Book,

Potential Benefits of Introducing Genetically Engineered Tomatoes

The emerging technology

Researchers at the Agricultural Genetic Engineering Research Institute (AGERI) are working to develop genetically-Engineered tomato varieties that are resistant to the Tomato Yellow Leaf Curl Virus (TYLCV). They are testing both an antisense viral replicas gene and a "suicide cell" strategy to impede the spread of the virus. Within the next five years, it is hoped that development of the GE tomato will be completed and the new variety will be assessed for safety, and registered for commercialization in Egypt.

TYLCV is the major pest problem for tomato growers in Egypt. Untreated, it can cause losses of 70-100% of the crop. The virus is transmitted by the whitefly, which is nearly ubiquitous in Egyptian tomato fields. To control the virus, farmers spray for the whitefly with a wide variety of insecticides. Even after extensive and frequent spraying, average losses remain between 7 and 15 percent.

A farmer who switches to GE tomato will benefit in two ways. First, he will spend much less time and money on pesticide applications, which cost between 700 and 1,755 LE per feddan. Second, he can expect much lower levels of infection by TYCLV and hence less losses; as a result he will harvest 7-15 percent more tomatoes.

Overall, we calculate that by switching to GE tomatoes, the farmer will increase his net return by between 1,000 and 2,400 LE per feddan, even after paying a price premium for the GE seed (estimated at 25% above regular price).

Over the past three years, an average of 458,000 feddan have been planted in tomatoes annually. In the appended calculations, we examine a scenario where 50% of all land planted in tomato is seeded with the new GE variety. Under this scenario:

- Expenditures on pest control decrease by $54 million annually.
- Production increases by 404,000 tons, worth approximately $36 million annually.
- Farmer income increases by $82 million annually, or roughly $820 million over ten years.

Environmental Benefits

Under the first 50% adoption scenario mentioned above, pesticide applications on tomatoes are reduced by the equivalent of:

- 8 million feddan sprays, equivalent to:
- 730 thousand liters of pesticide annually.

Export and marketing concerns

Over 95% of Egyptian production of tomatoes is for the domestic market. Before the GE tomatoes will be approved for planting, they will need to undergo a food safety assessment and receive approval from the National Biosafety Committee. No problems are anticipated, as transgenic virus-resistant vegetables have been assessed and judged safe in other countries. The reaction of Egyptian consumers to GE tomatoes cannot be predicted at this time. On one hand, consumers may be wary about a novel food. On the other hand, they may be attracted to the higher quality produce, unblemished by viral damage.

Regarding tomato exports, careful assessment will need to be made of the acceptability of GE tomatoes in specific markets. Where non-GE tomatoes are required, traders will need to source their product carefully, probably through contracts with growers to produce non-GE

Introduction to the Tomatoes Calculations

Our analysis compare the cost and the benefit of using GE tomatoes with two different alternative pest control methods commonly used by Egyptian tomato grower.

Under case 1 the farmer is using a Cybermetherin pesticide (Fastac) in combination with mineral elements called ViroX. The farmer sprays twice daily for fifty days in summer. The dosage per spray is low but total costs are high. In the winter spraying is once every other day. This is common in Nubarea.

Under case 2, the tomato farmer use a less intensive spraying schedule, employing the pesticide known as Trebion and Sombosh, this costs to control the white fly are similar in summer and winter.

Tomatoes Calculations

SUMMER / NILI PLANTING

Case 1:
One Feddan of tomatoes: GE tomatoes compared with tomatoes sprayed by using a mixture of Fastac and ViroX

	Non GE		GE		Difference	
TYLCV pesticide costs:	1755	LE	0	LE	-1755	LE
Extra cost of GE seed:	0		200		200	LE
Yield:	13	MT	15	MT	1.95	MT
Value of yield:	6062	LE	6971	LE	909	LE

Total financial gain for farmer per feddan		**2464**	LE
Assumptions:	Yield increase:	15%	
	Price of product:	466	LE/MT

Case 2:
One Feddan of tomatoes: GE tomatoes compared with tomatoes sprayed by using a mixture of Trebion & Sombosh

	Non GE		GE		Difference	
TYLCV pesticide costs:	700	LE	0	LE	-700	LE
Extra cost of GE seed:	0		200		200	LE
Yield:	13	MT	15	MT	1.95	MT
Value of yield:	6062	LE	6971	LE	909	LE

Total financial gain for farmer per feddan		**1409**	LE
Assumptions:	Yield increase:	15%	
	Price of product:	466	LE/MT

WINTER PLANTING

Case 1:
One Feddan of tomatoes: GE tomatoes compared with tomatoes sprayed by using a mixture of Fastac and ViroX

	Non GE		GE		Difference	
TYLCV pesticide costs:	1008	LE	0	LE	-1008	LE
Extra cost of GE seed:	0		200		200	LE
Yield:	8	MT	19	MT	1.44	MT
Value of yield:	6282	LE	6785	LE	503	LE
Total financial gain for farmer per feddan			**1310**	LE		
Assumptions:	Yield increase:		8%			
	Price of product:		349	LE/MT		

Case 2:
One Feddan of tomatoes: GE tomatoes compared with tomatoes sprayed by using a mixture of Trebion & Sombosh

	Non GE		GE		Difference	
TYLCV pesticide costs:	700	LE	0	LE	-700	LE
Extra cost of GE seed:	0		200		200	LE
Yield:	8	MT	19	MT	1.44	MT
Value of yield:	6282	LE	6785	LE	503	LE
Total financial gain for farmer per feddan			**1003**	LE		
Assumptions:	Yield increase:		8%			
	Price of product:		349	LE/MT		

Area planted in Summer:	293,224 fd			
Areas converting to GE seeds:	146,612	50%		
Area under case 1 adopting:	50%	73,306	fd	
Financial gain under case 1:	180,649,735	LE	39,271,682	US $
Area under case 2:	50%	73,306	fd	
Financial gain under case 2:	103,311,905	LE	22,361,884	US $

Area planted in Winter:	164,858 fd					
Areas converting to GE seeds:	82,429	50%				
Area under case 1 adopting:	50%	41,214.50	fd			
Financial gain under case 1:	58,084,584	LE	12,627,083	US $		
Area under case 2:	50%	41,215	fd			
Financial gain under case 2:	41,320,009	LE	8,943,725	US $		
Total for all seasons:						
Financial gain for farmers:	379,275,117	LE	82,094,181	US $	820,941,812	US $/10 yrs
Reduction in pest control costs:	-250,339,989	LE	-54,186,145	US $	-541,861,448	US $/10 yrs
Increase in production	404,591 MT		35,700,353	US $	357,003,533	US $/10 yrs
Reduction in pesticide use	8,819,045	Sprays	730,699	Ltrs		

Notes

- Price of GE seed is assumed to be 25% higher than a good non GE hybrid variety, i.e., 25,000 LE/Kg or 1000 LE/Fd compared to 800 LE/Fd
- Price of 349 Le/t winter, 466 LE/t Summer/Nili according to the Agricultural Statistics Book, Economical Affairs Sector, MALR

Potential Benefits of Introducing Genetically Engineered Maize

First generation technology

AGERI, Pioneer Hi-bred seed company, and Syngenta seed company are all developing genetically-Engineered (GE) varieties of maize for Egypt. These varieties incorporate a gene from the bacteria *Bacillus thuringiensis* (*Bt*) that imparts resistance to the insect pests known as corn borers (the European Corn Borer [*Ostrinia nubilalis*] and the Pink Borer [*Sesamia cretica*] and *Chilo agamemnon*). Pioneer hopes to complete its registration of such a variety this year and commence commercialization in 2003.

Borers typically affect maize during its early stages of growth when they can penetrate the plant, retarding development or causing "dead heart" which effectively kills the plant. Borers, particularly *Sesamia cretica*, are a serious problem during the early planting season for maize in Egypt (April 15 - May 15). On untreated fields, we estimate borers reduce yields by 25%. Borers are much less problematic during the recommended planting season for maize (May 15 – June 15). During this season we estimate average losses of 5% on untreated fields. In the late season (June 15 – August 30) borers again become a serious problem, resulting in average losses of 15% on untreated fields.

Most farmers, of course, do not leave their fields untreated, at least in the early and late seasons when borers are common. They apply pesticides such as Lannate (Methomyl), Selecron (Profenfos), or Sevin (Carbaryl), at an average cost of LE 57 per treatment.[5] We estimate that a properly treated field will suffer only 3% losses in the early season, 1% losses in the recommended season, and 2.5% losses in the late season. Improperly treated fields (only one spray, not at the exact proper time or plant location) will have higher losses (estimated at 2.5-12.5%, depending on the season).

Thus, a farmer who adopts *Bt* maize can save in three ways. First, he can save money by eliminating the need to spray for borers. Second, he can increase his production by eliminating losses from borers. Third, the quality of his harvested grain can increase because damage from borers and fungal pathogens is greatly reduced.

During the early season, a farmer planting *Bt* maize can expect to save LE 57 to LE 114/feddan in pest control costs compared to those who spray once or twice. He can also expect to harvest from 3% to 13% more grain, compared to those who spray, and 25% more compared to those who do not spray at all. Overall, his net income should increase by LE 176 – 594 per feddan, after subtracting out money spent on *Bt* seed.

[5] Based on: 900 GE bottle of Lannate (130 LE); one feddan requires 300 GE (43.3 LE); hire of motor sprayer (7.5 LE/fd); hire two men to operate (6 LE/fd). Total cost 56.8 LE/fd.

During the recommended season, savings will be less, because borers are less of a problem. During the late season, savings are again significant, and the benefits of *Bt* maize are evident.

In appended calculations, we examine a scenario where 50% of all land planted in maize (for grain not for fodder) employs the new *Bt* maize technology (750,000 feddan). Under this scenario:

- Expenditures on pesticides decrease by $6.6 million annually.
- Production increases by 117,000 tons, worth approximately $16 million annually.
- Farmer income increases by $6.2 million in the early season, $8.7 million in the recommended season, and $4.8 million in the late season.
- The total increase in farmer income is $20 million annually, or roughly $200 million over ten years.

Bt maize will offer an additional benefit to farmers – it will allow them to farm their land more intensively. Instead of waiting for the "safe" recommended planting time for maize, farmers can plant earlier or later without fear of borers. After harvesting potatoes in March, for example, they can plant maize immediately in April instead of waiting around until mid-May. It is difficult to put a value on this benefit, but it is surely of economic importance to farmers.

Environmental Benefits

Under the 50% adoption scenario mentioned above, pesticide applications on maize are reduced by the equivalent of:

- 540,000 feddans sprayed, equivalent to:
- 162,000 kilograms of pesticide annually.

This reduction will mean less pesticide run-off into waterways, where it can negatively effect human, fish, and other wildlife health. The reduction will almost certainly mean a reduction in illnesses suffered by farmers who apply pesticides and a reduction in children's exposure to pesticides in fields or in homes where they are often stored. Many Egyptian farmers apply pesticides in unsafe ways (e.g., without protective clothing). They can cease all spraying for borers if they use *Bt* maize.

A word should also be added regarding beneficial insects. These insects are common in Egyptian fields and can help control pest insects by eating them. Spraying a pesticide like Lannate kills both target borers and beneficial insects. *Bt* maize has no undesirable effects on beneficial insects. It leaves them to do their natural work in controlling secondary pests.

Second generation technology

Research is currently being conducted internationally and at AGERI to add additional traits to maize through genetic modification. These traits include vitamin enhancement (folates), improved oil content, drought resistance, and resistance to other classes of insect pests. When these products are ready to be marketed, they will offer significant new economic and health benefits for Egypt.

Export concerns

Because Egypt does not export maize (it is a massive importer), we do not expect the introduction of GE maize to pose trade problems. Concerns may arise, however, if GE maize is integrated into processed foods for export. These processors may need to source non-GE maize (domestically or internationally), if their product market requires its use

Introduction to the Maize Calculations

Our analysis of the potential benefits of adoption of *Bt* maize assumes that farmers growing maize of traditional varieties principally for green fodder purposes will not benefit or be interested in converting to *Bt* maize. We estimate that 25% of the 2 million feddan planted annually in maize falls into this category. Thus, only 1.5 million feddan may potentially benefit from the introduction of *Bt* maize.

Our calculations look at a scenario where 50% of these 1.5 million feddan convert to *Bt* maize. What would be the effects of such a conversion?

Certainly pesticide use would decline, reducing the cost of production. Yields would also increase, as losses due to pests are reduced. The *Bt* gene provides better protection than sprayed pesticides. Grain quality would also be expected to increase by 1-3%, as borers and the fungal pathogens that accompany them will not damage the grain.

Estimating the magnitude of these effects requires us to look at different cases and different seasons. Our analysis of the potential benefits of adoption of *Bt* maize recognizes that the degree to which a farmer benefits from the new technology depends on his current farming practice. A farmer who plants non-*Bt* maize in the early season and does not spray for borers suffers significant crop losses. If he adopts *Bt* maize he will benefit significantly. A farmer who plants non-*Bt* maize during the "recommended" season (and sprays it) suffers very little crop loss. If he switches to *Bt* maize, his benefit will be minimal.

To calculate overall benefits, we established three "cases" during each of the three planting seasons (a total of 9 cases). These are as follows:

Case 1: One feddan of non-*Bt* maize, sprayed twice for borers, coverts to *Bt* maize. Such a conversion results in significant savings in pesticide costs but little additional yield.

Case 2: One feddan of non-*Bt* maize, sprayed once for borers in a typical but sub-optimal way, coverts to *Bt* maize. Such a conversion results in some savings in pesticides and some additional yield.

Case 3: One feddan of non-*Bt* maize, not sprayed at all, converts to *Bt* maize. Such a conversion results in no pesticide savings but significant increases in yield.

In all cases, we assume the cost of one pesticide application to be LE 57/feddan and the cost of *Bt* seed to be LE 48 extra per feddan.[6]

After calculating the potential benefits on a per feddan basis in each of these cases, in each of three seasons, we multiplied the results by the total number of feddans to which each case applies. For example, we estimated the number of feddans planted in the Early Season that fall into Case 1. We then multiplied this by the per-feddan benefit number. Finally, we total the estimated benefits over all nine cases.

[6]Compare one feddan planted with 8 kg of Bt hybrid seed at 14 le/g with one feddan planted with non-Bt hybrid seed at 8 le/kg. The difference is 48 le.

Maize Calculations

EARLY PLANTING

Case 1: One feddan of maize, sprayed twice, converts to Bt maize

	Non Bt Maize	Bt Maize	Difference	
Borer pesticide costs:	114 LE	0 LE	-114	LE
Extra cost of GE seed:	0	48	48	LE
Yield:	3.6 MT	3.7 MT	0.11	MT
Value of yield:	2730 LE	2840 LE	110	LE

Total financial gain for farmer per feddan **176** LE

Assumptions:			
	Yield increase:	3%	
	Grain quality increase:	1%	
	Price of grain:	102.12	LE/ardeb

Case 2: One feddan of maize, sprayed once sub-optimally, converts to Bt maize

	Non Bt Maize	Bt Maize	Difference
Borer pesticide costs:	57 LE	0 LE	-57 LE
Extra cost of GE seed:	0	48	48 LE
Yield:	3.3 MT	3.69 MT	0.41 MT
Value of yield:	2482 LE	2848 LE	366 LE

Total financial gain for farmer per feddan **375** LE

Assumptions:			
	Yield increase:	13%	
	Grain quality increase:	2%	
	Price of grain:	102.12	LE/ardeb

Case 3: One feddan of maize, not sprayed, converts to Bt maize

	Non Bt Maize	Bt Maize	Difference	
Borer pesticide costs:	0 LE	0 LE	0	LE
Extra cost of GE seed:	0	48	48	LE
Yield:	3.0 MT	3.7 MT	0.74	MT
Value of yield:	2234 LE	2876 LE	642	LE

Total financial gain for farmer per feddan **594** LE

Assumptions:			
	Yield increase:	25%	
	Grain quality increase:	3%	
	Price of grain:	102.12	LE/ardeb

Planting during the Early season:

Early plantings of maize:		200,000	fd		
Plantings for grain:		150,000	fd		
Area under case 1:		33%		50,000	fd
Area under case 1 adopting:	50%	25,000	fd		
Financial gain under case 1:		4,390,683	LE	950,364	US $
Area under case 2:		33%		50,000	fd
Area under case 2 adopting:	50%	25,000	fd		
Financial gain under case 2:		9,372,397	LE	2,028,657	US $
Area under case 3:		33%		50,000	fd
Area under case 3 adopting:	50%	25,000	fd		
Financial gain under case 3:		14,855,476	LE	3,215,471	US $

Total Financial Gains:	**28,618,556**	**LE**	**6,194,493**	**US $**

PLANTING DURING RECOMMENDED SEASON

Case 1: One feddan of maize, sprayed twice, converts to Bt maize

	Non Bt Maize	Bt Maize	Difference	
Borer pesticide costs:	114 LE	0 LE	-114	LE
Extra cost of GE seed:	0	48	48	LE
Yield:	3.44 MT	3.48 MT	0.03	MT
Value of yield:	2172 LE	2193 LE	22	LE

Total financial gain for farmer per feddan **87** LE

Assumptions:	Yield increase:	1%	
	Grain quality increase:	0%	
	Price of grain:	85.1	LE/ardeb

Case 2: One feddan of maize, sprayed once sub-optimally, converts to Bt maize

	Non Bt Maize	Bt Maize	Difference	
Borer pesticide costs:	57 LE	0 LE	-57	LE
Extra cost of GE seed:	0	48	48	LE
Yield:	3.3 MT	3.4 MT	0.08	MT
Value of yield:	2068 LE	2141 LE	73	LE

Total financial gain for farmer per feddan **82** LE

Assumptions:	Yield increase:	2.5%	
	Grain quality increase:	1%	
	Price of grain:	85.1	LE/ardeb

Case 3: One feddan of maize, not sprayed, converts to Bt maize

	Non Bt Maize	Bt Maize	Difference	
Borer pesticide costs:	0 LE	0 LE	0	LE
Extra cost of GE seed:	0	48	48	LE
Yield:	3.1 MT	3.3 MT	0.16	MT
Value of yield:	1965 LE	2084 LE	119	LE

Total financial gain for farmer per feddan **71** LE

Assumptions:	Yield increase:	5%	
	Grain quality increase:	1%	
	Price of grain:	85.1	LE/ardeb

Planting during the Recommended season:

Plantings of maize		1,400,000	fd		
Plantings for grain:		1,050,000	fd		
Area under case 1:		10%	105,000	fd	
Area under case 1 adopting:	50%	52,500	fd		
Financial gain under case 1:		4,584,172	LE	992,245	US $
Area under case 2:		40%		420,000	fd
Area under case 2 adopting:	50%	210,000	fd		
Financial gain under case 2:		17,158,876	LE	3,714,042	US $
Area under case 3:		50%		525,000	fd
Area under case 3 adopting:	50%	262,500	fd		
Financial gain under case 3:		18,605,410	LE	4,027,145	US $

Total Financial Gains: **40,348,458 LE** **8,733,432 US $**

PLANTING DURING LATE SEASON

Case 1: One feddan of maize, sprayed twice, converts to Bt maize

	Non Bt Maize	Bt Maize	Difference	
Borer pesticide costs:	114 LE	0 LE	-114	LE
Extra cost of GE seed:	0	48	48	LE
Yield:	2.5 MT	2.6 MT	0.06	MT
Value of yield:	1595 LE	1652 LE	56	LE

Total financial gain for farmer per feddan **122** LE

Assumptions:			
	Yield increase:	2.5%	
	Grain quality increase:	1%	
	Price of grain:	85.1	LE/ardeb

Case 2: One feddan of maize, sprayed once sub-optimally, converts to Bt maize

	Non Bt Maize	Bt Maize	Difference	
Borer pesticide costs:	57 LE	0 LE	-57	LE
Extra cost of GE seed:	0	48	48	LE
Yield:	2.3 MT	2.4 MT	0.12	MT
Value of yield:	1450 LE	1553 LE	103	LE

Total financial gain for farmer per feddan **112** LE

Assumptions:			
	Yield increase:	5.0%	
	Grain quality increase:	2%	
	Price of grain:	85.1	LE/ardeb

Case 3: One feddan of maize, not sprayed, converts to Bt maize

	Non Bt Maize	Bt Maize	Difference	
Borer pesticide costs:	0 LE	0 LE	0	LE
Extra cost of GE seed:	0	48	48	LE
Yield:	2.2 MT	2.5 MT	0.33	MT
Value of yield:	1378 LE	1632 LE	254	LE

Total financial gain for farmer per feddan **206** LE

Assumptions:			
	Yield increase:	15.0%	
	Grain quality increase:	3%	
	Price of grain:	85.1	LE/ardeb

Planting during the Late season:

Plantings of maize:		400,000	fd		
Plantings for grain:		300,000	fd		
Area under case 1:		33%		100,000	fd
Area under case 1 adopting:	50%	50,000	fd		
Financial gain under case 1:	6,091,883	LE	1,318,589	US $	
Area under case 2:		33%		100,000	fd
Area under case 2 adopting:	50%	50,000	fd		
Financial gain under case 2:	5,588,775	LE	1,209,692	US $	
Area under case 3:		33%		100,000	fd
Area under case 3 adopting:	50%	50,000	fd		
Financial gain under case 3:	10,310,585	LE	2,231,728	US $	

Total Financial Gains:		**21,991,244**	**LE**	**4,760,009 US $**

Total for all seasons:

Financial gains for farmers:	90,958,257	LE	19,687,934	US $
Reduction in pesticide costs:	30,671,999	LE	6,638,961	US $
Increase in Production:	116,632	MT	13,048,974	US $
Reduction in pesticide use:	540,000	Sprays	162,000	kg.

Notes:

- Price of GE seed is estimated at 14 le/kg, which is 6 le more than non-GE hybrid seed. At 8 kg/fd this means 48 le/fd extra cost.
- According to "Agricultural Statistics" of the Economic Affairs Sector, MALR, during the past three years, the yield of non-GE maize averages 3.28 Mt/fd during Summer Season and 2.3 Mt/fd during Nili season. We take these figures as Case 2 yields
- Case 1 yields are adjusted upwards 5-10% and Case 3 yields are adjusted downwards 5-10%.