Plant Biotechnology: Potential Impact for Improving Pest Management in European Agriculture

A Summary of Nine Case Studies
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This summary is the second release of information from a research project that, upon completion, will include 15 case studies for Europe. The June 2003 release included three case studies. The remaining 6 case studies will be released in June 2004 with the full report. The final report will include:

- Maize-Insect Resistant*
- Sugarbeet-Herbicide Tolerant*
- Potato-Fungal Resistant*
- Tomato-Virus Resistant
- Stone Fruit-Virus Resistant
- Wheat-Fungal Resistant
- Cotton-Insect Resistant
- Cotton-Herbicide Tolerant
- Oilseed Rape-Herbicide Tolerant
- Rice-Insect Resistant
- Rice-Herbicide Tolerant
- Maize-Herbicide Tolerant
- Wheat-Herbicide Tolerant
- Potato-Insect Resistant
- Citrus-Virus Resistant

*included in the June 2003 Report

Conversions

2.47 Acres = 1 Hectare

2.2 Pounds = 1 Kilogram

Introduction

Crop biotechnology has been widely discussed for the past decade. While the United States has planted millions of acres with genetically modified crops, in Europe, only Spain has any commercial biotech acres. The European Union and European countries are considering a variety of biotechnology regulations while a moratorium on approval of new biotech crops maintains the status quo. Questions remain about the potential impacts on agricultural production if biotech crops were to be commercialized in Europe. Although a number of researchers have released studies of the potential impact of certain biotech crops in individual countries, no single study has used a consistent methodology to estimate multi-crop biotech adoption in multiple European countries.

In 2002, the National Center for Food and Agricultural Policy (NCFAP) released a study that estimated the current and potential impacts of biotechnology in the United States by examining 40 case studies to project economic impacts for 47 states. The study focused on biotech crops that would improve pest management for weeds, insects and plant diseases. During the research, NCFAP noted that many of the same crop pests were present in Europe and that European researchers were testing biotech crops for managing the pests. NCFAP received funds from Monsanto, Syngenta, EuropaBio and BIO to estimate the potential impacts of biotech crops on European agriculture. NCFAP's proven methodology and strong ties to European researchers made it an ideal organization to conduct the first comprehensive study of how biotechnology could impact European agriculture.

In June 2003, NCFAP released the first three case studies to estimate the potential impact of biotechnology in Europe. These initial case studies are included herein as well as an additional six case studies that NCFAP researchers have recently completed.

Methodology

The same methodology that NCFAP researchers used in its U.S. study is employed in the European study. Case studies have been selected based on information that successful transformation of a crop has occurred and for which there are at least preliminary results for pest management purposes under European conditions. For each case study, NCFAP reviewed scientific literature, internet web sites and data from university and government research facilities. NCFAP interviewed European researchers who are testing biotech varieties, and they provided summaries of their research. NCFAP quantified the current use of pesticides, crop losses and costs of managing each pest problem in several countries by crop. Researchers estimated the acreage on which the biotech crop would be planted based on comparison of growers' costs.

Economic impacts were analyzed in three categories: estimated changes in yield, changes in production value and changes in production costs, which were used to calculate changes in net income. Pesticide use changes were also calculated. Written case study analyses were sent to outside reviewers for comment. The reviewers' comments were incorporated into the case study reports.

Key Findings

The widespread adoption of plant biotechnology in maize, oilseed rape, wheat, rice, tomatoes, potatoes, sugarbeets and stone fruit in Europe would result in significant yield increases, savings for growers and pesticide use reductions. All together, the nine biotech crops would increase yields by 8.5 billion kilograms per year, increase grower net income by €1.6 billion per year and reduce pesticide use by 14.4 million kilograms per year, compared with existing practices that would be replaced. Of these six new case studies, the biotech tomato offers the greatest yield and grower income increase while herbicide tolerant maize would result in the largest pesticide use reduction.

Table 1: Potential Impact by Crop

Crop	Trait	Adoption (000 Hectares)	Pesticide Use (000 Kilograms)	Yield (Million Kilograms)	Income (€ Million)
Maize	Herbicide Tolerant	1,571	-1,702	0	+24
Oilseed Rape	Herbicide Tolerant	668	-118	+125	+43
Wheat	Herbicide Tolerant	2,759	-1,474	0	+90
Rice	Herbicide Tolerant	132	-1,252	0	+14
Tomato	Virus Resistant	125	-60	+443	+305
Stone Fruit	Virus Resistant	22	0	+168	+78
Maize	Insect Resistant	1,599	-53	+1,899	+249
Sugarbeet	Herbicide Tolerant	1,688	-2,208	+5,050	+390
Potato	Fungal Resistant	1,164	-7,513	+858	+417
Total		**9,728**	**-14,380**	**+8,543**	**+1,610**

Table 2: Potential Impact by Country

Country	Adoption (000 Hectares)	Pesticide Use (000 Kilograms)	Yield (Million Kilograms)	Income (€ million)
Austria	24	-110	+16	+8
Belgium	160	-751	+351	+60
Denmark	98	-386	+181	+29
Finland	30	-144	+15	+8
France	3,358	-3,208	+2,632	+332
Germany	1,867	-2,923	+1,792	+278
Greece	29	-97	+40	+29
Ireland	14	-108	+9	+5
Italy	1,924	-1,942	+1,665	+474
Netherlands	272	-1,362	+490	+114
Portugal	17	-123	+6	+5
Spain	1,127	-1,189	+730	+127
Sweden	32	-154	+18	+12
United Kingdom	776	-1,883	+598	+129
Total	**9,728**	**-14,380**	**+8,543**	**+1,610**

Case Study: Herbicide Tolerant Oilseed Rape

A rapid increase in production of winter oilseed rape in northern Europe occurred in the 1970s. It was heavily supported to develop vegetable oil production in Europe. However, oilseed rape, called canola in the United States and Canada, is a slow-growing crop. Consequently, it is very sensitive to weed competition, and herbicides are the most widely used method of weed control. More than 90% of oilseed rape acreage in the E.U. is treated with herbicides. The average cost of weed control, the largest grower expense, for rapeseed is between €60 and €120/ha and can be as high as €150/ha in some difficult situations.

Two varieties of biotech herbicide-tolerant canola, glufosinate- and glyphosate-tolerant, were commercialized in Canada in 1996 and in the United States in 1999. Approximately 65% of U.S. canola acreage is planted with biotech varieties, and 55% of Canadian canola acres are biotech. In Canada, the biotech canola increased yield by 10% with an increase in profit of $12/A. In the United States, canola growers are saving $13/A as a result of lower weed control costs with an average yield increase of 6%.

Transgenic oilseed rape has been evaluated in U.K. grower fields since 1998. A three-year set of Farm Scale Evaluations (FSEs) was conducted in the U.K. to compare genetically modified herbicide tolerant (GMHT) crops with conventional varieties. They determined that glufosinate treatments were more effective in controlling weeds in the GMHT plots than were the herbicides used with the conventional varieties. A participant in Scottish trials estimated that the GMHT oilseed rape was £84/ha cheaper to grow than conventional varieties. Recent U.K. farm level field trials conducted in 2002 have shown yield gains of 14% for GMHT winter oilseed rape and 22% for spring oilseed rape. In 2001, the yield gain was estimated to be about 9%.

A French report from CETIOM concluded that a decrease of about 30% in herbicide costs is possible with the herbicide tolerant varieties. A recent study projected likely adoption of herbicide tolerant rapeseed varieties on 25% of the E.U.'s acres due to an economic advantage resulting from better weed control with higher yields and/or lower costs of weed control. The substitution of two glufosinate applications for the current herbicides used in rapeseed would lower herbicide use by 12%. The cost of a glufosinate-tolerant program would be a 25% reduction from current costs. It is assumed that the glufosinate-treated rapeseed would yield approximately 6% more due to better weed control.

Table 3: Potential Impact of Herbicide Tolerant Oilseed Rape

Country	Projected Adoption (000 Hectares)	Pesticide Use (000 Kilograms)	Yield (Million Kilograms)	Net Grower Income (€ Million)
France	271	-98	+44	+16.8
Germany	284	-18	+63	+20.8
United Kingdom	113	-2	+18	+4.8
Total	**668**	**-118**	**+125**	**+42.4**

Case Study: Herbicide Tolerant Maize

European Union maize production is grown on 4.5 million hectares and is valued at €5.3 billion/year. The maize growing areas in Europe are fertile, rain fed, and warm with large weed seed bank build up. As a result, 50-500 weed seedlings/m^2 emerge to compete with the crop. Maize is sown at a low seed rate (approx 8-10 plants/m^2), and young maize plants are especially intolerant of weed competition.

Herbicides are used on 98% of European maize acreage. Without weed control, European maize yield losses would be 34% but are just 4% since herbicides are used. Atrazine was a mainstay in European maize production due to its excellent crop safety, low cost, residual action and broad spectrum of activity on weeds. However, by 2003, seven E.U. countries had banned the use of atrazine in maize. French corn growers estimated that the ban of atrazine would result in the substitution of other herbicides at an increased cost of €23/ha or €69 million total. Following a 2003 review, the E.U. decided not to reregister atrazine, so it will no longer be permitted for use in any E.U. country.

Two herbicide-tolerant maize systems have been developed, glufosinate and glyphosate. In the U.S., herbicide tolerant varieties were planted on 15% of total maize acres in 2003. Growers have saved approximately $10/A (€4.05/ha) in herbicide costs as a result of adopting the herbicide tolerant varieties. Atrazine is still permitted in the U.S. and remains the most widely used herbicide due to its low cost and broad-spectrum effectiveness. Experiments carried out since 1995 in U.K. have shown that glufosinate can achieve high levels of control of both grass and broad-leaved weeds in glufosinate-tolerant forage maize. Glyphosate tolerant maize has been experimented with in the Czech Republic and Germany.

It has been estimated that herbicide tolerant biotech maize would likely be planted on 40% of E.U. acreage due to limited effectiveness of conventional herbicides and/or the greater expense of the conventional herbicides in comparison to GM alternatives. The substitution of two applications of glufosinate for the current herbicides used in maize would lower herbicide use by 55%. The cost of a glufosinate-tolerant program represents an average reduction of €15/ha or 12% from current costs. Glufosinate tolerant maize already has E.U. marketing approval.

Table 4: Potential Impact of Herbicide Tolerant Maize

Country	Projected Adoption (000 Hectares)	Pesticide Use (000 Kilograms)	Yield (Million Kilograms)	Net Grower Income (€ Million)
France	766	-689	0	+11.5
Germany	159	-134	0	+2.4
Italy	444	-710	0	+6.6
Spain	202	-169	0	+3.0
Total	**1,571**	**-1,702**	**0**	**+23.5**

Case Study: Herbicide Tolerant Rice

Italy, Greece, Spain and Portugal account for 97% of the E.U.'s rice production, and weeds are the most important pest problem that affects rice production. Prior to the use of herbicides, hundreds of women known as *le mondine* arrived from all parts of Italy to delicately root out the weeds while leaving the young rice in place.

Weed control is critical in rice production as infestations cause both yield and quality impacts. Uncontrolled weeds would reduce European rice yields by 55-60%. Chemical control is the most commonly used and reliable method for controlling weeds in European rice. Traditionally, weed control in European rice has been achieved by using two herbicide applications. Repeated use of the same herbicides in rice fields has led to the development of herbicide-resistant weeds in Europe. Typically, rice growers spend €200 to €220 per hectare when herbicide-resistant weeds are a problem.

Combinations of herbicides have been recommended and are being used as tools to enhance the control of resistant weeds. Weed control represented 5% of the total rice production cost in Greece fifteen years ago compared to 10% now (€70-90/ha higher). At present, farmers are successfully managing herbicide-resistant populations with chemical solutions such as pre-sowing applications and increased post-emergence treatments.

Two types of transgenic herbicide-tolerant rice are in development: glufosinate tolerant and glyphosate tolerant. Research in the U.S. suggested that single or sequential applications of glufosinate provided excellent weed control. In the U.S., herbicide tolerant rice would lower weed control costs by $16/A. Both the herbicides provided control superior to conventional herbicides even under severe pressure. Herbicide tolerant rice has not been field tested in Europe.

Herbicide-tolerant rice would be economically advantageous for planting on 35% of E.U. rice acreage due to improved weed control and/or lower costs. The substitution of two applications of glyphosate for the current herbicides used in rice would lower herbicide use by 83%. In Greece, Spain, and Portugal the substitution of two applications of glyphosate would lower weed control costs by 50%, while in Italy, the reduction in costs would be 58%. Since no experiments have been conducted in Europe with the herbicide tolerant biotech rice, it is assumed that yields would be unchanged.

Table 5: Potential Impact of Herbicide Tolerant Rice

Country	Projected Adoption (000 Hectares)	Pesticide Use (000 Kilograms)	Yield (Million Kilograms)	Net Grower Income (€ Million)
Greece	7	-88	0	+0.6
Italy	76	-502	0	+8.8
Portugal	9	-120	0	+0.7
Spain	40	-542	0	+3.4
Total	**132**	**-1,252**	**0**	**+13.5**

Case Study: Herbicide Tolerant Wheat

The contribution of the European Union's wheat to world total is 8% of area and 16% of production. Per hectare wheat yields are highest and have been increasing in the E.U. compared to other important wheat producing countries in the world. Modern wheat production in Europe relies on effective herbicides, which allow farmers in Europe to grow wheat only on land most suited for its production. Europe accounts for 35% of the worldwide sales of herbicides in wheat production. Without control, weeds would lower wheat yields by 20-25% in Europe; with current herbicide use, the loss of wheat yields to weeds is estimated at 8%. It is estimated that 98% of the E.U.'s wheat hectares are treated with herbicides and that 97 trillion weed seedlings are killed annually.

Eight grass weeds have developed resistance to various herbicides used in wheat production in Europe. Research has focused on combinations of herbicides applied at different rates or timings for control of resistant populations. The additional cost of herbicide use, plowing and yield loss resulting from the management of resistance can be as high as ₤143/ha.

In 1994, U.S. field trials began with wheat cultivars that have been transformed through the insertion of a gene from a soil microorganism. This transformation makes it possible to spray wheat with glyphosate herbicide without crop injury. A frequently mentioned benefit of herbicide tolerant wheat is that growers will be able to control a broad spectrum of weeds with a single active ingredient in comparison to the 2-3 active ingredient applications, which are common at this time. The potential impact in the U.S. of adopting glyphosate tolerant wheat is an increase in grower income of $12/A. No field trial work is currently conducted on herbicide tolerant wheat in the E.U.

A recent study estimated that herbicide tolerant wheat would likely be planted on 20% of the E.U.'s hectares due to economic benefits of improved weed control with higher yields and/or lower weed control costs. The substitution of two glyphosate applications would lower herbicide use by 32%. The cost of a glyphosate tolerant program represents an average reduction of 47% from current costs. It is assumed that wheat yields would be unaffected with a substitution of glyphosate for the current herbicides used in European wheat.

Table 6: Potential Impact of Herbicide Tolerant Wheat

Country	Projected Adoption (000 Hectares)	Pesticide Use (000 Kilograms)	Yield (Million Kilograms)	Net Grower Income (€ Million)
France	954	-801	0	+28.6
Germany	579	+12	0	+24.4
Italy	458	-151	0	+2.0
Spain	441	-145	0	+19.8
United Kingdom	327	-389	0	+14.8
Total	**2,759**	**-1,474**	**0**	**+89.6**

Case Study: Virus Resistant Stone Fruit

The disease referred to as Sharka, a virus, was first reported in 1915 in Bulgarian plums. During World War II, Sharka was discovered in Hungary and quickly spread to Austria and Germany. It continued its spread during the 1970s into France and Italy and reached the orchards of Spain and Portugal by 1984. The disease cut Greek apricot acreage by almost 50% and has eliminated production in some parts of Italy. Almost 100,000 trees were destroyed in France between 1973 and 1990 in an effort to prevent the disease's spread, and in Germany, delayed removal of infected trees has led to 90% infection rate in some orchards. In Spain, over a half million trees were removed over a 15-year period.

Sharka produces symptoms such as leaf discoloration, and rings or spots on fruit. Symptoms include premature fruit drop, deformed fruit, and discoloration of the skin and flesh. The virus so seriously affects the fruit of diseased trees that the fruit becomes unsuitable for direct consumption or industrial processing (dried, jams or brandied). Infected trees cannot be cured and must be removed to retard disease spread. Sharka's 1999 appearance in the United States led to an eradication program in Pennsylvania.

Attempts to develop Sharka resistant stone fruit trees using modern biotechnology methods have been successful in the United States, Austria and France. The Institute of Applied Microbiology in Austria first reported successful transformation for Sharka resistance in stone fruits in 1992. After more than ten years of preparation, the young trees are currently kept in a contained greenhouse system. A collaborative effort between researchers in France and the U.S. led to the development of genetically modified resistant plum plants reported in 1997. The transgenic plums remained virus-free for an entire three-year experiment. Transgenic plum plants are currently being field-tested in Poland, Romania, and Spain to determine the long-term expression of resistance under varied climatic conditions, infection pressure and virus strains. These European field tests have confirmed that the line is highly resistant to Sharka.

It is assumed that Sharka resistant stone fruit trees would prevent estimated losses as follows: Austria/Germany (4%), Italy/Greece/Spain (3%), Portugal/France (1%). These estimates include current losses from less productive trees and losses due to tree removal.

Table 7: Potential Impact of Virus Resistant Stone Fruit

Country	Projected Adoption (000 Hectares)	Pesticide Use (000 Kilograms)	Yield (Million Kilograms)	Net Grower Income (€ Million)
Austria	.4	0	+2.3	+1.5
France	2.8	0	+8.9	+8.8
Germany	3.5	0	+17.9	+12.5
Greece	2.9	0	+30.5	+20.3
Italy	6.0	0	+60.7	+24.6
Portugal	.5	0	+0.9	+0.8
Spain	5.7	0	+46.6	+8.6
Total	**21.8**	**0**	**+167.8**	**+77.1**

Case Study: Virus Resistant Tomato

Tomato yellow leaf curl virus (TYLCV) first appeared in European tomatoes in 1988 and is spread by whiteflies. Symptoms include severe stunting, marked reduction in leaf size, flower abscission, and significant yield reduction. In certain regions, it has caused 100% yield losses and forced netting use in greenhouses in many countries. Portuguese production has declined 48% since 1995, and in 2000, losses of 15 to 60 per cent were reported in Greece.

Although insecticides are widely used in European tomato production to kill whiteflies, complete eradication or exclusion of whiteflies is impossible. Approximately 1 per cent of tomato production is lost in Greece, Italy, Portugal and Spain. The virus appeared in the United States in 1989 and reduced Florida tomato production by 20 per cent. As in Europe, widespread insecticide use has been employed to minimize losses. University of Florida researchers have transformed tomatoes to have resistance to TYLCV. Italian researchers have also transformed tomato plants by inserting a gene of the TYLCV. The biotech tomato plants are resistant to TYLCV. It is estimated that the virus resistant variety would be planted on 53 per cent of the production area in Spain, Italy, Greece and Portugal and would substitute for use of insecticides and netting while preventing the one per cent yield loss associated with the disease.

The Campania region accounts for six per cent of Italy's total tomato production. The predominant tomato grown for processing in Campania is the San Marzano variety that has been awarded the protected origin label "Pomodoro San Marzano Dell'Agro Sarnese Nocerino". Tomato production in Campania has declined significantly in the last decade due to epidemics of cucumber mosaic virus, and there is concern that production will disappear from the region.

In 1992, the Italian Plant Pathology Research Institute began a project to produce biotech tomatoes with resistance to CMV. Seven years of field tests showed that the biotech tomatoes were unaffected by CMV and have all the agronomic characteristics of the San Marzano tomato. Planting transgenic tomato varieties resistant to CMV could prevent the total loss of the production of San Marzano tomatoes in Campania.

Table 8: Potential Impact of Virus Resistant Tomato

Country	Projected Adoption (000 Hectares)	Pesticide Use (000 Kilograms)	Yield (Million Kilograms)	Net Grower Income (€ Million)
Greece	19	-9	+10	+8.0
Italy	66	-32	+408	+276.0
Portugal	7	-3	+5	+3.0
Spain	33	-16	+20	+18.0
Total	**125**	**-60**	**+443**	**+305.0**

Case Study: Insect Resistant Maize

Maize is the domesticated form of a wild grass originally from Mexico. Early explorers brought maize seeds to Spain, and, thereafter, the plant spread throughout Europe.

European farmers produce 40 billion kilograms of maize on 4.0 million hectares with a value of €5.3 billion/year. Four countries (Italy, France, Spain and Germany), account for 88 percent of European maize production. Among the insect pests that cause damage to maize, two species of corn borer are of particular importance in Europe: European corn borer and Mediterranean corn borer. The feeding of the borers results in reduced plant growth, reduced kernel size, and harvest losses due to broken plants. Secondary infections of fungi and bacteria are other risks associated with corn borer feeding. Research in France has shown that yield losses to corn borers can be as high as 15 percent while in Spain the losses can be as high as 30 percent. Corn borer control is extremely difficult. Once they enter the stalk, they cannot be controlled with insecticides. Currently, insecticide treatments are made to only 32 percent of the hectares in Europe where borers are a problem. As a result, it has been estimated that Europe loses five percent of its maize production annually to uncontrolled borers.

Through genetic engineering, Bt maize, which kills the corn borers when they feed on the plant, has been created with a gene from a soil bacterium. Bt maize was approved for planting in Europe in the 1990s. Research in Europe has shown that borers cause nearly no yield reduction in the Bt maize plots. Bt maize yields have consistently been 15 percent higher than conventional corn treated with insecticides under European conditions. Research has also shown that Bt maize varieties are significantly lower in toxin contamination levels than conventional varieties.

Due to a voluntary agreement, Bt maize is currently only planted on 25,000 hectares in Spain. A recent study in Spain showed that Bt maize improved profitability by 13 percent. Table 9 estimates the potential impact of planting Bt maize in Europe on hectares that are highly infested with corn borers. Total adoption is projected at 1.6 million hectares (41 percent). Bt maize would substitute for 53,000 kilograms of insecticide use and maize production would increase by 1.9 billion kilograms due to improved borer control. Net grower income is projected to increase by €249 million due to the value of increased production minus the cost of the technology.

Table 9: Potential Impact of Insect Resistant Maize

Country	Projected Adoption (000 Hectares)	Pesticide Use (000 Kilograms)	Yield (Million Kilograms)	Net Grower Income (€ Million)
France	765	-6	+857	+101.0
Italy	554	-1	+607	+107.0
Spain	181	-45	+254	+28.0
Germany	99	-1	+181	+13.0
Total	**1,599**	**-53**	**+1,899**	**+249.0**

Case Study: Herbicide Tolerant Sugarbeet

Beet became a source of refined sugar in 1747 when a German scientist first extracted crystalline sugar from the root. Extensive sugarbeet planting began in mainland Europe during the Napoleonic Wars when the British Navy blockaded French ports, preventing sugarcane imports. By 1880, sugarbeets were the main source of European sugar. Sugarbeets are grown on 1.6 million hectares in Europe. European Union growers produce 115 billion kilograms of sugarbeets, which are processed into 15 billion kilograms of white sugar. The value of sugarbeets to European Union farmers is approximately €4.7 billion per year.

Weeds occur in all European sugarbeet fields at levels that would cause crop failure. In fact, competition from uncontrolled weeds can reduce root yields by 26 to 100 percent. Currently, no single herbicide controls all of the weeds found in Europe's sugarbeet fields. As a result, numerous herbicide applications are made every year to kill weeds. Typically, four to five applications of herbicides are made to the typical sugarbeet field at a total cost of €197 per hectare and a total use of 3.2 kilograms of chemical per hectare. Some of the herbicides that are applied to sugarbeet fields can harm the crop. It is estimated that sugarbeet production is lowered by five percent due to herbicide damage to the crop.

Sugarbeets have been genetically modified with a gene from a soil bacterium to be resistant to glyphosate, a broad-spectrum herbicide. Field research in each of the major European sugarbeet-growing countries indicates that two applications of glyphosate are highly effective in controlling weed infestations with no crop damage. The use rate of glyphosate would average 1.9 kilograms per hectare, and the cost of the biotech weed control program would average €86 per hectare.

Adoption of the biotech herbicide tolerant sugarbeet on 100% of the European Union's hectares would reduce herbicide use by 2.2 million kilograms while increasing production by five billion kilograms of beets due to reduced crop damage. Net grower income would be increased by €390 million. Table 10 displays the aggregate impact estimates for major sugarbeet-producing countries.

Table 10: Potential Impact of Herbicide Tolerant Sugarbeet

Country	Projected Adoption (000 Hectares)	Pesticide Use (000 Kilograms)	Yield (Million Kilograms)	Net Grower Income (€ Million)
United Kingdom	171	-222	+450	+41
France	437	-350	+1,600	+98
Germany	461	-921	+1,300	+116
Netherlands	110	-66	+350	+34
Belgium	98	-255	+300	+25
Italy	242	-218	+550	+35
Spain	109	-98	+350	+29
Denmark	60	-78	+150	+12
Total	**1,628**	**-2,208**	**+5,050**	**+390**

Case Study: Fungal Resistant Potato

Spanish explorers brought the potato to Europe from the Americas in the 16th century. The potato was not accepted as a food in Europe for many years because Europeans believed that potato was unnatural and poisonous. Today, European farmers produce 44 billion kilograms of potatoes on 1.16 million hectares with a value of €5 billion.

A fungus causes a disease of potatoes known as late blight. Infected potatoes emit a distinctive unpleasant odor due to decay of plant tissue. Late blight first appeared in Europe in 1845 and had devastating consequences, particularly in Ireland, where peasants were entirely dependent on potatoes for food. Approximately 40 percent of the Irish potato crop was destroyed in 1845 with 100% destruction in 1846 resulting 1.5 million deaths and the emigration of an equal number of Irish to America. Late blight continued to be a major problem until the 1880s when the first fungicide (copper) was discovered.

Potato growers in Europe spray synthetic chemical fungicides eight to fourteen times a year at a cost of €322 per hectare to kill the late blight fungus. Despite these sprays, the fungus destroys about two percent of the European potato crop.

Biotech researchers are focusing on a wild plant species related to potato that exhibits complete resistance to late blight. Genetic engineering techniques have been used to transfer the resistance gene into potato plants. Transformed potato plants have been unaffected by late blight.

Successful introduction of a biotech late blight resistant potato on 100% of European acreage would eliminate the need for 7.5 million kilograms of fungicides and increase production by 858 million kilograms. Grower net income would increase by €417 million. Table 11 displays these impact estimates for individual European countries.

Table 11: Potential Impact of Fungal Resistant Potato

Country	Projected Adoption (000 Hectares)	Pesticide Use (000 Kilograms)	Yield (Million Kilograms)	Net Grower Income (€ Million)
Austria	23	-110	+14	+6
Belgium	62	-496	+51	+35
Denmark	38	-308	+31	+17
Finland	30	-144	+15	+8
France	162	-1,264	+122	+66
Germany	282	-1,861	+230	+90
Ireland	14	-108	+9	+5
Italy	78	-328	+39	+13
Netherlands	162	-1,296	+140	+80
Spain	116	-174	+59	+17
Sweden	32	-154	+18	+12
United Kingdom	165	-1,270	+130	+68
Total	**1,164**	**-7,513**	**+858**	**+417**

Conclusions

Crop pests need to be controlled in order to maintain high yields. If inadequate pest control lowers crop yields, more land is required for crop production. Currently in Europe, regular, multiple herbicide applications control weeds in sugarbeets, wheat, rapeseed, maize and rice. While effective, these weed control sprays are expensive. Biotech herbicide tolerant crops would enable European growers to use fewer herbicide active ingredients at a lower cost to achieve equivalent (maize, wheat, rice) or better (sugarbeet, rapeseed) control with higher yields.

Weeds are a serious pest problem, but plant diseases and insects take their toll on production as well. European maize growers do not regularly use insecticides to control corn borers, and Europe loses five percent of its maize production to borers annually. The adoption of insect resistant maize varieties would prevent this loss. Plant viruses spread by insects have had a profound effect on tomato and stone fruit production in Europe. Apricots can no longer be grown in certain regions. The San Marzano tomato is disappearing from the Campania region in Italy due to virus problems. Biotech stone fruit and tomatoes have been developed at European institutions and have shown a high degree of resistance to the viruses in research trials. Use of biotech varieties could eliminate the losses and enable tomato growers to reduce their use of insecticides.

U.S. growers have planted herbicide tolerant rapeseed (canola) and maize as well as insect resistant maize. Due to marketing uncertainties, U.S. growers have not planted herbicide tolerant sugarbeets even though they have been approved and commercialized. The E.U. moratorium on approving new biotech crops has denied European growers access to the sugarbeet as well resulting in continued reliance on expensive weed control programs. The only biotech crop currently planted in the European Union is insect resistant maize in Spain, which has resulted in higher profitability among adopters.

For one hundred years, researchers have been searching for an effective way to control late blight of potatoes, the disease that caused the Irish Potato Famine causing the deaths of millions of people. Potatoes can be grown in Europe and the United States because growers make eight to 12 applications of fungicides to every acre each year. Researchers have developed a biotech potato that prevents the disease as a result of inserting one gene from another plant species. Thus, there is another choice to manage this pestilence.

This study clearly shows that the option of controlling pests with biotech crops has great potential in Europe. Most of the biotech cultivars have been tested in Europe and have performed well. Several of the biotech crops have been developed by European institutions and await approval.

Growers adopt new technology when it improves their financial conditions. U.S. growers are planting 80 million acres with biotech crops because improved pest control at lower cost has improved their bottom lines. European farmers face the same pests and could experience the same improved pest control and cost savings.

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