The benefits of adopting genetically modified, insect resistant (Bt) maize in the European Union (EU): first results from 1998-2006 plantings

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EXECUTIVE SUMMARY

This paper reviews data on the impacts linked to the use of genetically modified (Bt) maize resistant to two important insect pests – the European corn borer (ECB) and the Mediterranean stem borer (MSB) in the European Union (EU) since this crop was first approved for planting in 1998. A summary of the findings is presented in Table 1, followed by country-specific analysis.

Key finds are as follows:

- In 2006, approximately 65,000 ha of Bt maize were planted in seven EU member states;
- In maize growing regions affected by ECB and MSB, the primary impact of the adoption of Bt maize has been higher yields compared to conventional non-genetically modified (GM) maize. Average yield benefits have often been +10% and sometimes higher;
- In 2006, users of Bt maize have, on average, earned additional income levels of between €65 and €141/ha. This is equal to an improvement in profitability of +12 to +21%;
- In certain regions, Bt maize has delivered important improvements in grain quality through significant reductions in the levels of mycotoxins found in the grain.

Table 1: Agronomic and economic benefits of adopting Bt maize resistant to European corn borer (ECB) in the EU (1998 - 2006)

	Spain	France	Germany	Czech Republic	Portugal	Poland	Slovakia
Bt maize area (2006, ha)	53,667	5,200	950	1,290	1,240	30	30
Area of high ECB infestation (ha)	80,000	300,000 to 750,000	300,000 to 500,000	31,000 to 37,000	15,000	Not available	50,000
Average yield of Bt vs. conv. Maize (%)[1]	+1 to +15	+5 to +24	+14 to +15	+9 to +10	+12%	Average not available	Average not available
Average Bt maize seed premium (2006, €/ha)[1]	35	40 to 45	39 to 42	31 to 38	35	45	35
Average conv. maize gross margin (2006-2007, €/ha) [2]	1146	559	683	444	515	178	361
Average impact on profitability (€/ha)	+141 (+12%) in high infestation regions	+98 to +120 (+16 to +21%)	+83 to +93 (+12% to +14%)	+65 (+15%)	+112 (+22%)	Average not available	Average not available
Impact on grain quality (reduction in mycotoxin levels)	Significant reduction	Significant reduction	Significant reduction	Significant reduction	No studies	Significant reduction	No studies

Conv.: conventional; [1] Average across various regions, infestation levels and studies; [2] Variable costs largely from Brookes (2007a) European Arable Crop Profit Margins 2006-07, 5th edition, prices based on averages for the years 2004-2006.

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[1] Seed planting density varies across countries and therefore may contribute to differences in the Bt seed premium cited for each country

1. INTRODUCTION

This paper reviews published and company-produced data on the impacts linked to the use of genetically modified (GM) insect resistant (Bt) maize in the European Union (EU) since the trait was first approved for planting in 1998.

Worldwide, GM crops were grown commercially for the first time on significant surfaces (1.66 million ha) in 1996. Since then, planted surfaces have increased rapidly, reaching 102 million hectares in 2006 (James, 2006). Today, the main countries growing GM crops are the US, Argentina and Brazil (respectively 54.6, 18 and 11.5 million ha in 2006). Other important planting countries include Canada, India and China.

In the global context, GM crop surfaces in the EU are small (Table 2). Currently, only two crop/trait combinations are authorized for planting across the EU: maize tolerant to the herbicide glufosinate ammonium (transformation event T25) and 'Bt' maize expressing a gene from a common soil bacterium (*Bacillus thuringiensis*) that confers resistance to certain Lepidopteran pests (transformation events MON 810 and Bt 176). Only Bt 176 and MON 810 - resistant to the Lepidopteran pests *Ostrinia nubilalis* (European corn borer or ECB) and *Sesamia nonagroides* (Mediteranean stem borer or MSB) - have been planted in Europe to date. Currently, only varieties of the event MON 810 are available for cultivation: 41 varieties in Spain (from which 25 are included in the EU Common Variety Catalogue), 6 in France, 5 in Germany and 36 have been registered on the EU Common Variety Catalogue (status of December 2006).

Bt maize was planted for the first time in 1998 in Spain. Under a voluntary agreement between companies and the government, only small areas, approximately 20 - 25,000 ha or 5 % of the total Spanish maize area, were grown from 1998 to 2002. This increased after the end of the agreement in 2003, reaching an estimated 58,000 ha in 2006. Small amounts of Bt maize were also planted in France in 1998, in Portugal in 1999 and in Germany every year since 2000. Renewed activity was seen in 2005 as, in addition to Spain and Germany, France, Portugal and the Czech Republic also report Bt maize growings, albeit on limited surfaces. In total, the area planted to Bt maize in the EU was just below 65,000 ha in 2006, equivalent to approximately 0.6% of total EU25 maize plantings (including forage maize area).

Table 2: Bt maize plantings in the EU, 1998 - 2006 (ha)

	1998	1999	2000	2001	2002	2003	2004	2005	2006
Spain	22,467	25,071	26,061	11,598	21,004	32,244	58,219	53,225	53,667
Germany	100-200	100-200	100-200	100-200	100-200	100-200	100-200	250	950
France	1,800-3,000	0	0	0	0	0	0	500	5,200
Portugal	0	1,300	0	0	0	0	0	780	1,250
Czech Republic	0	0	0	0	0	0	0	270	1,290
Poland	0	0	0	0	0	0	0	0	30
Slovakia	0	0	0	0	0	0	0	0	30
Total	**24,367-25,667**	**25,171-25,271**	**26,161-26,261**	**11,698-11,798**	**21,104-21,204**	**32,344-32,444**	**58,419-58,519**	**55,025**	**64,650**

Sources: Ministerio de Agricultura, Pesca y Alimentación (MAPYA, Spain, 2006), James (2005 and 2006), Association Generale des Producteurs de Mais (AGPM) France, Brookes and Barfoot (2005 & 2007), Monsanto Company estimates (2007), GMO-compass website (2007), TransGen website (2007); TSF Online website (2007).

2. SPAIN

2.1 Background and data sources

- Commercial plantings in Spain since 1998; over 50,000 ha planted to Bt maize annually since 2004;
- The agronomic and economic analyses for Spain were conducted based on published study results and data from Syngenta and Monsanto Company field trials:
  - Alcalde (1999): Field trial data from 1997 in six regions of Spain (Albacete, Girona, Huesca, Lleida, Madrid and Zaragosa);
  - Brookes (2003), based on data collection from about 550 farms in medium to high ECB infestation areas in the North-West of Spain;
  - Demont et al. (2004), an econometric analysis that drew on publicly available impact data (eg, Brookes, 2003);
  - Gomez-Barbero and Rodriguez-Cerezo (2006 a and b), based on interviews conducted in 2002 to 2004 (random, stratified sample survey of 400 farmers, including 218 Bt maize users, across the three main Bt maize growing regions of Aragon, Catalonia and Castilla La Mancha). The full analysis from this latter study will be published in 2007;
  - Brookes and Barfoot (2007). The 10 year review of the global economic and environmental impact of GM crops (including Bt maize in Spain);

- Monsanto Company (2007): strip trials conducted in 19 locations (one field per location) in 2003-2006 in the provinces of Gerona (2 trials), Lleida (3 trials), Huesca (5 trials), Zaragoza (4 trials), Teruel (1 trial) and Navarra (4 trials). These trials were repeated all the years. In 2006, strip trials were performed in 12 locations: Gerona (1 trial), Lleida (3 trials), Huesca (3 trials), Zaragoza (4 trials) and Teruel (1 trial). The average infestation levels across the 12 trials conducted in 2006 was of 1.4 larvae/stalk (140 larvae in 100 analysed stalks).

2.2 European corn borer infestation areas

- ECB is the main insect pest that attacks maize crops in Spain, although the MSB is also of economic importance in many areas. The Spanish maize crop may be subject to two generations of ECB; in the North- East, three generations sometimes occur;
- The incidence and impact of ECB infestation varies significantly by region and year, influenced by local climatic conditions, use of insecticides and planting times (eg, early planted crops are usually better able to withstand attacks relative to later plantings);
- The maize growing regions of Spain were classified in Brookes (2003) based on unpublished information from Syngenta, Monsanto Company and Pioneer into 3 regions according to historic annual pest pressure levels (high, medium and low pest pressure regions). Drawing on these classifications, it is evident that the highest concentrations of Bt maize plantings in 2006 were found in regions which have traditionally experienced medium to high pest pressure levels[2] such as Aragon and Catalunya (Table 3). Overall, about 25% of the maize planted in Spain was estimated to be in regions classified as suffering high ECB pest pressure and a further 40% were in regions classified as suffering medium ECB pest pressure (Brookes, 2003);
- Recent estimates from Monsanto Company[3] suggest that the total potential Bt market (targeted at the ECB) may be about 80,000 ha, largely based on high infestation regions Catalonia (Gerona and Lleida), Aragon, Andalucía (Cadiz, Sevilla and Cordoba) and Extremadura (Albacete).

[2] Readers should note that this classification is a simplification of experience as areas of relatively low pest pressure and experience can be found within regions of traditionally high pest pressure and vice versa

[3] Personal communication, 2006

Table 3: Main regions growing Bt maize in Spain (2006)

Region	Area planted to Bt maize (ha)	% of total Bt maize crop
Aragon	23,734	44
Catalunya	20,365	38
Castilla la Mancha	4,176	8
Navarra	2,821	5
Extremadura	2,071	4
Others (Andalusia, La Rioja, Madrid)	500	1
Total	**53,667**	100

Source: MAPYA (2006)

2.3 Pest impact on yield

The occurrence of ECB and its impact on yield varies by region, year, local climatic conditions, use of insecticide and planting times:

- Alcalde (1999) showed an average yield loss of 6%, with maximum losses of up to 25%. In regions of high infestation, ECB was estimated in 1998 to 2002 to cause a yield loss of 10 to 40% (annual average of 15%) in the absence of any insecticide treatment and 5 to 20% (annual average of 10%) even if insecticides were used (Brookes, 2003);
- Monsanto Company strip trials from 2003 to 2005 showed a strong correlation between the % of maize stems attacked by ECB and yield losses (Table 4). Based on an average yield of 10 tonnes/ha, the trials indicate a yield loss in the range of 5 to 18%, depending on pest pressure.

Table 4: ECB damage and yield loss in Spain estimated from strip trials (2003 – 2005)

	Yield loss					
	2003		2004		2005	
% of stems attacked	**tonnes/ha**	**%**	**tonnes/ha**	**%**	**tonnes/ha**	**%**
20	0.86	9	0.496	5	0.474	5

30	1.067	11	0.564	6	0.983	10
40	0.996	10	0.953	10	1.118	11
50	1.562	16	1.343	13	1.684	17
60	1.653	17	1.753	18	1.423	14
Range		**9 to 17**		**5 to 18**		**5 to 17**

Source: Monsanto Company; Note: % yield loss estimated based on an average yield for maize of 10 tonnes/ha

2.4 Conventional treatment

Spanish maize farmers have historically either had no active policy/methods for the control of ECB or used insecticides (Brookes, 2003).

Treatment with insecticides

- Two insecticides, chlorpyrifos and synthetic pyrethroids, of which chlorpyrifos is the most widely used (83 to 88% of the total treated area in the period 1999 to 2001 (Table 5);
- Used mostly by farmers in high infestation regions (eg, Huesca) at the rate of one or two insecticide treatments per season;
- Insecticide application conducted either via addition to irrigation water (chlorpyrifos only) or via aerial spraying;
- Cost of treatments (in the Huesca region: 2002): 18 to €24/treated hectare via irrigation and 36 to €42/treated hectare by aerial spraying.

Table 5: Insecticide use in Spain for treating European corn borer (1999 - 2001)

Type of insecticide	Annual average 1999-2001: treated area (ha)	Annual average 1999-2001: active ingredient used (kg)
Chlorpyrifos	49,000 - 86,000	35,000 - 56,400
Synthetic pyrethroids	10,000 - 12,000	120 - 140
Total	**59,000 to 98,000**	**35,120 to 56,540**

Sources: Kleffmann market research

Insecticide use in Spain has traditionally been limited because:

- Many farmers perceive that insecticides have limited effectiveness: they may control European corn borer larvae on the surface of maize plants at the time of spraying but are less effective against larvae that have bored into stalks. Also, egg-laying can occur over a three week period and most insecticides are only effective for 7 to 10 days;

- Insecticides may kill certain beneficial insects/organisms that are natural predators of other maize pests (eg, spider mites or lacewings);
- The cost per treatment is widely considered to be high relative to perceived effectiveness;
- ECB pest pressure varies and hence in some years damage may be limited;
- Some farmers probably do not appreciate the level of damage to yields inflicted by the ECB. Some Bt maize users indicated that it was only after using Bt maize that they realized fully what adverse impact the ECB caused (Brookes, 2003).

2.5 Bt maize uses

To date, almost all the Bt maize grown in Spain was for grain and was sold to the animal feed sector.

2.6 Cost of technology

In 2006, the seed premium for the MON 810 maize was reported to be about €35/ha (Monsanto Company, 2007). The seed premium for using the Bt 176 trait, now no longer available, was reported back in 2002 to be between 18 and €30/ha (Brookes, 2003).

2.7 Yield impact of Bt maize seed

As ECB damage varies by location, year, climatic factors, timing of planting, whether insecticides are used or not and the timing of application, the positive impact on yields of planting Bt maize also varies. Data obtained in Spain between 1998 and 2005 is summarised below and in Table 6:

- Brookes (2003) found that in regions with traditionally high levels of infestation, an average 10% yield improvement (ie, 1 tonne/hectare on a base yield of 10 tonnes/ha) was delivered where insecticide treatments had previously been used (eg, Sarinena locality in the Huesca region) although the positive yield impact range was +5 to +20% (over the four years 1998-2001 relative to crops that had previously been treated with insecticides). Where the comparison over the same period in this region of high infestation levels was with conventional crops that had not been treated with insecticides, the average yield improvement from using Bt maize seed was +15% (ie, 1.5 tonne/hectare on a base yield of 10 tonnes/ha) and the range of positive yield benefits was +10 to +40%;
- The level of yield improvement is more moderate in regions or years of low pest infestation. Thus, Brookes (2003) found an example where the average yield gain from using Bt maize seed over the 1998-2001 period was an average of 1% (about 0.15 tonnes/ha: on one farm in the Barbastro locality of the Huesca region – a

locality of low to medium average corn borer infestation, within a broader region where average infestation levels tend to be fairly high);

- Yield improvements compared to conventional controls in the range of 3 to 13% (average 6%) were measured in trial plots across the regions of Albacete, Girona, Huesca, Lleida, Madrid and Zaragosa in 1997 (Alcalde, 1999);
- Monsanto Company field trials between 2003 and 2005 identified a positive average yield increase of 1.33 tonnes/ha (+10% on average base conventional yield of 13 tonnes/ha; relating to the use of Bt maize MON 810). These findings were across a number of sites with different levels of pest infestation;
- Gomez-Barbero and Rodriguez-Cerezo (2006 a and b) identified that Bt users perceive the yield benefits to be in a range of +1 to +14%. The sample of current non-users of Bt maize seed also perceive that their yields would increase if they adopted the technology (in a range of +2 to +10%). The survey's actual findings identified an average yield gain of 5% over the 2002 to 2004 period with clear regional variations. Yield gains were highest in Aragon and Catalonia but very limited in Castilla La Mancha (reflecting differences in the frequency and intensity of pest attack).

Table 6: Impact of Bt maize on yield in Spain (1998 – 2005)

Regions	Base maize yield	Yield of Bt compared to conventional maize		Comments	Reference
	tonnes/ha	tonnes/ha	%		
Huesca (Sarinena)	10	+ 1	+10 (+2 to + 20)	High infestation region; insecticides previously used	Brookes, 2003
		+2	+15 (+10 to +40)	No insecticides previously used	Brookes, 2003
Several regions	-	-	+6	Trial plots across a number of regions in 1997	Alcalde, 1999
Huesca (Barbastro)	-	+ 0.2	+1	One farmer, low average infestation; no insecticides previously used	Brookes, 2003
15 locations (Catalonia, Aragon and Navarra)	13	+ 1	+10	Field trials; conventional crop included treated and not treated (with insecticides) plots	Monsanto Company, 2003 – 2005
Aragon, Catalunya and Castilla	-		Perceived: +1 to +14; Measured	Survey of 400 farms, incl. 218 Bt maize users; may include some conventional crops	Gomez-Barbero and Rodriguez-Cerejo, 2006 a

La Mancha			average: +5	treated with insecticides	and b
Range	**10 to 13**	**0.2 to 1**	**1 to 40**	**-**	**-**

2.8 Farm cost and profit impacts

There are a number of studies/analyses on the impact of using Bt maize in Spain at the farm or national level. The reader should note that the cost and profit impacts are closely linked to infestation levels and their associated impact on yield.

a) Brookes (2003)

In the Sarinena locality in the Huesca region (locality of high infestation levels): gross margin increases of between +67 and +€330/ha (ie, +6 to +35%), with an average of €147/ha (+13%) were identified. The cost of using the Bt maize (technology fee) was more than recovered via the savings on insecticide costs. The main benefit however, came from yield gains, which more than offsets additional cost of the technology.

In one low infestation locality (one farmer in the Barbastro locality of the Huesca region), the net result of using Bt maize has been 'break even' in term of cost and revenue changes (ie, no net change over four years)[4].

b) Monsanto Company trials, 2003-2005

A summary of the estimated impact on farm margins using three years (2003 to 2005) of trial data from Monsanto Company for yield impact and average profitability performance data is shown in Table 7. The conventional crop was not treated with insecticides. This estimates the average farm income benefit to be +€141/ha, a 12% increase in gross margin profitability compared to growing conventional maize.

Table 7: Impact on gross margin of using Bt maize, based on field trials 2003 – 2005 (€/ha)

	Conventional maize	**Bt maize**	**Bt vs. conventional maize**
Revenue			
Price (€/tonne)	127	127	0
Yield (tonnes/ha)	10.61	11.72	+1.11

[4] This farmer indicated that year one was one of average ECB attack and the impact of Bt maize use was positive, year two was one of low infestation and hence the impact of Bt maize use was negative, year three was one of high ECB attack and the impact of Bt maize use was positive and year 4 was one of no ECB attack for which Bt maize impact was negative.

Sales revenue	1,347	1,488	+141
Variable costs			
Seed	166	201	+35
Insecticide	35	0	-35
Total	201	201	0
Gross margin	**1,146**	**1,287**	**+141 (+12%)**

Source: Monsanto Company trial data 2003 - 2005; Notes: 1) baseline price, conventional average yield and seed cost is averaged for the three years (Brookes, 2002 - 2004): European arable crop profit margins, 2nd to 4th editions); 2) insecticide cost and seed premium (€35/ha) – Monsanto Company personal communication

c) Gomez-Barbero and Rodriguez-Cerezo (2006 a and b)

This survey-based analysis covering the 2002 to 2004 period identified an average gross margin benefit from using Bt maize compared to conventional maize of €85/ha per growing season. The gross margin impacts ranged between +€7/ha in Castilla La Mancha and +€125/ha in Aragon.

d) Brookes and Barfoot (2007)

Table 8 summarises the farm and national level income impacts from 1998 to 2005 using analysis from Brookes (2003) as the baseline impact data:

- The net annual average saving on cost of production (from lower insecticide use) was between 34 and €42/ha and the net increase in gross margin between +86 and +€108/ha;
- At the national level, these yield gains and cost savings have resulted in farm income being boosted, in 2005 by €4.4 million. Cumulatively, since 1998, the increase in farm income (in nominal terms) has been €25.4 million;
- Relative to national maize production, the yield increases derived from Bt maize were equivalent to a 0.69% increase in national grain maize production (2005). The value of the additional income generated from Bt maize was also equivalent to an annual increase in production of 0.87%.

Table 8: Farm level income impact of using Bt maize in Spain, compared to using conventional maize, 1998-2005

Year	Cost savings (€/ha)	Net cost savings inclusive of cost of technology (€/ha)	Net increase in gross margin (€/ha)	Impact on farm income at a national level (€ millions)
1998	33.6	3.33	85.5	2.1

Year	Cost savings (€/ha)	Net cost savings inclusive of cost of technology (€/ha)	Net increase in gross margin (€/ha)	Impact on farm income at a national level (€ millions)
1999	42.0	12.0	95.9	2.4
2000	42.1	14.0	97.2	2.4
2001	42.1	23.5	106.9	2.7
2002	42.1	23.6	106.9	2.7
2003	42.1	23.5	107.8	3.5
2004	41.4	23.2	90.1	5.2
2005	42.1	23.6	97.7	4.4
Range	**34 to 42**	**3 to 24**	**86 to 108**	**2.1 to 5.2 (Total: 25.4)**

Source: Brookes and Barfoot (2007)

e) Demont and Tollens (2003 and 2004)

This work estimated that for the four year period of 1998 to 2001 the total benefit distributed between farmers using the technology and the supply chain upstream of farmers (seed supplying sector and technology providers) was €11.2 million. This was split as follows: €8.4 million (75%) to farmers and €2.8 million (25%) to the supply industry.

This analysis was updated in 2004 to cover the six year period 1998 to 2003 and estimated the total welfare gain to have been €15.5 million, of which farmers derived €10.4 million benefit (66% of the total) and the upstream supply industry €5.1 million (33% of the total).

2.9 Environmental impact (use of insecticides)

a) Brookes (2003)

Based on usage data for the main insecticides chlorpyrifos and synthetic pyrethroids from 1999-2001 (used almost exclusively to control ECB attacks in regions with high infestation levels), Brookes (2003) estimated that the usage savings would potentially amount to a net reduction in the area sprayed of 59,000 to 98,000 hectares and a reduction in active ingredient usage of 35,000 to 56,000 kg. Relative to total insecticide usage on maize in Spain (including soil insecticides) this represents a reduction in the total area sprayed of 27 to 45% and a reduction in active ingredient use of 26 to 35%. Clearly if these insecticides are used by some farmers to control other target pests (eg, *Heliothis* and cut worms), the impact on (reduced) insecticide use will have been lower.

b) Brookes and Barfoot (2007)

Based on data for the years 1999 to 2001, the adoption of Bt maize has resulted in a net decrease in both the volume of insecticide used and the field Environmental Impact Quotient (EIQ/ha load)[5]. More specifically:

- The volume of insecticide active ingredient (ai) use[6] was 48% lower than the level would probably have been if the crop had been all non GM in 2005 (-42,000 kg). Since 1998 the cumulative saving (relative to the level of use if all of the crop had been non GM) was 239,000 kg of insecticide ai (a 34% decrease);
- The field EIQ/ha load has fallen by 30% since 1999 (-10.4 million units). In 2005, the field EIQ load was about 43% lower than its conventional equivalent.

2.10 Mycotoxins

Farmers perceive the quality of Bt maize to be superior to that of conventional maize due to the less frequent presence of fungi potentially producing mycotoxins. This is supported by evidence from several studies, including:

[5] The average volume of insecticide ai used is 0.96 kg/ha and the average field EIQ is 42/ha

[6] Insecticides that target corn boring pests

- Bakan et al. (2002) who examined *Fusarium* infection levels in Bt versus non Bt maize trial plots at five locations (three in France and two in Spain). The results indicate that Bt maize had up to ten times less fumonisin content than the non Bt maize varieties;

- Serra et al. (2006)[7] found that the percentage of maize plants attacked by fungi were significantly lower in Bt maize (1.2%) compared to conventional maize (2.5%). Also fumonisins were observed in only 17% of Bt plants compared to 100% of the conventional maize plants analysed.

2.11 Intangible impacts

The adoption of Bt maize may also non-monetary benefits, for example:

- Production risk management: Bt maize could be seen as an insurance against ECB, taking away the worry of significant ECB damage occurring;
- Convenience benefit: devote less time to crop walking and/or applying insecticides;
- A small net saving in energy use: mainly from less use of aerial spraying;
- Reduced exposure to insecticides for farmers and farm workers;

Easier harvesting (eg, fewer problems from fallen crops: ECB damaged crops are easily flattened by late summer winds).

3. FRANCE

3.1 Background and data sources

- First commercial plantings in 1998 (between 1,800 and 3,000 ha planted), then no commercial crops again until 2005. Plantings in 2006 were equivalent to 5,200 ha (Association Générale des Producteurs de Maïs (AGPM)/Arvalis, 2006);

- The agronomic and economic analysis for France are based on:

  - AGPM/Arvalis (2006) and Poeydemenge (2006) describing 15 trials carried out in 2005 and 2006 by AGPM/Arvalis, known as the Programme d'Accompagnement de Cultures issues des Biotechnologies (PACB). The AGPM/Arvalis research was conducted in 12 departments located in the principal maize growing regions of Aquitaine, Midi-Pyrenees, Poitou-Charentes, Pays de la Loire, Champagne Ardennes, Rhone-Alpes and Centre.

  - Grenouillet (2006) describing Monsanto Company trials conducted between 1997 and 2003. The tests were conducted in areas that regularly suffer infestation problems from ECB and MSB (South-West, Mid-West and the Centre of France). Field trials in 1998 and 1998 consisted in small plots (4

[7] Based on research conducted at two sites; one in Girona (coastal area) and one in Lleida over the two years 2004 and 2005

rows by 12 m) replicated 4 times. After 1999, the trials consisted single replicated plots of 8 rows by 20 m each;

- Monsanto Company (2007): commercial plantings research in 2006 which covered 60 fields on commercial farms in the main maize growing regions in the South-West of France, eg, Midi Pyrenées and Aquitaine. These farms grew 650 ha of Bt maize (ie, 13% of total 2006 Bt maize plantings).

3.2 European corn borer infestation areas

Annually, between 1 and 2 million hectares of maize are affected by European corn borer and Mediterranean stem borer in France, of which approximately 0.3 to 0.75 million ha experience economic levels of losses from these pests. These areas tend to be concentrated in the South-West, including areas within the principal maize growing regions of Midi Pyrénées, Aquitaine and Poitou-Charentes where 1-2 generations of ECB, and 2-3 generations of MSB occur. ECB (one generation) also causes problems for maize growers further north, including the other primary maize growing region of Alsace.

3.3 Pest impact on yield

As in all regions with ECB/MCB problems, the impact varies by location, year, climatic factors, time of planting and use of insecticides, according to the level of infestation. In high infestation regions, yield losses are assumed to be similar to those reported in Spain (15% or more).

3.4 Conventional treatment

Where they decide to treat against ECB and/or MCB, French farmers use insecticides (including lambda-cyhalothrin, cypermethrin, cyfluthrin and carbofuron) or biological control methods, consisting in the release of the parasitic wasp *Trichogramma*.

- From 2003 to 2005, the area treated with insecticides or *Trichogramma* was between 0.2 and 0.7 million ha (source: unpublished Kleffmann market research data). This is equivalent to between 6 and 23% of the total French maize crop (inclusive of fodder maize plantings);
- Poeydemenge (2006) report that insecticides have an efficacy level of 75%. AGPM/Arvalis (2006) put the efficacy of insecticide treatment (one spray) at an average of 35% (range: 25 to 58%).

3.5 Bt maize uses

All of the Bt maize grown in 2006 was used in the animal feed sector, with some maize also exported to feed compounders in Spain.

3.6 Cost of technology

The cost of the technology is €40 to €45/ha (Poeydemenge, 2006; AGPM/Arvalis, 2006; Monsanto Company, 2007).

3.7 Yield impact of Bt maize seed

Data obtained in France on the yield impact of using Bt maize is summarised below. The efficacy against ECB of this technology is reported to range between 95 and 99% (Labatte et al., 1996; Grenouillet, 2006).

- Poeydemenge (2006) identified an average yield improvement in 2005 of 0.7 tonnes/ha on a base yield of 10 tonnes/ha (+7%) relative to crops treated with insecticides;
- AGPM/Arvalis trials identified a yield gain of 0.55 tonnes/ha (+6%) in 2006 where there had been low levels of pest infestation and 1.15 tonnes/ha (+13%) where medium to high levels of pest infestation had occurred. The average yield gain was 0.92 tonnes/ha (+11%);
- Grenouillet (2006) cites average yield gains within a range of +5 to +17%. In high infestation regions, the gains were in a range of +5 to +25% in six of the seven years analysed;
- The Monsanto Company field trials in 2006 found an average 12% increase in yield (on a base conventional maize yield of 11.13 tonnes/ha). When analysed according to pest pressure, the yield benefits of using Bt maize seed was +2, +10 and +15% respectively for low, medium and high infestation zones.

3.8 Farm cost and profit impacts

There are a number of studies/analyses of the impact of using Bt maize in France on farm profits, including:

a) AGPM/Arvalis (2006)

Assuming insecticide costs of €50/ha/treatment and a seed premium for Bt maize of €40/ha, the technology delivered an increase in average gross margin profitability of +€98/ha (+18%) in 2005 and +€120/ha (+35%) in 2006 (Table 9).

Table 9: Impact of using Bt maize on farm profitability in France relative to a conventional crop treated with insecticides, 2005-2006 (€/ha)

	2005			2006		
	Conventional maize	Bt maize	Bt vs. conv. maize	Conventional maize	Bt maize	Bt vs. conv. maize
Revenue						

Price (€/tonne)	120	120	0	120	120	0
Yield (tonnes/ha)	10	11	+1	9	10	+1
Sales revenue	1,248	1,336	+88	1,032	1,142	+110
Variable costs						
Seed	150	190	+40	150	190	+40
Fertiliser	139	139	0	139	139	0
Crop protection	100	50	-50	100	50	-50
Irrigation	300	300	0	300	300	0
Total	689	679	-10	689	679	-10
Gross margin	**559**	**657**	**+98 (+18%)**	**343**	**463**	**+120 (+35%)**

Note: analysis based on Poeydemenge (2006) and AGPM/Arvalis (2006) applied to average variable costs for maize in Brookes (2007a) European arable crop profit margins 2006-07 and average harvest prices at the farm level for the average of 2004-2006; Conv.: conventional.

b) Monsanto Company (2007)

Assuming no insecticide costs and a seed premium for Bt maize of €40/ha, the technology delivers an increase in average gross margin profitability of +€114/ha (+ 16%) compared to a conventional crop treated with insecticide (Table 10).

Table 10: Average impact of using Bt maize on farm profitability in France relative to a conventional crop treated with insecticides (€/ha)

	Conventional maize	Bt maize	Bt vs. conventional maize
Price (€/tonne)	120	120	0
Yield (tonnes/ha)	11	12	+1
Sales revenue	1,336	1,490	+154
Variable costs			
Seed	150	190	0

Fertiliser	139	139	0
Crop protection	50	50	0
Other variable costs (irrigation)	300	300	0
Total	639	679	+40
Gross margin	**697**	**811**	**+114 (+16%)**

Note: analysis based on Monsanto Company (2007) applied to average variable costs for maize in Brookes (2007a) European arable crop profit margins 2006-07and average harvest prices at the farm level for the years 2004-2006

3.9 Environmental impact (use of insecticides)

Gianessi et al. (2004) estimated that a reduction in insecticide use of 5,500 kg of active ingredient would be possible, assuming adoption of Bt maize on an area of 275,000 ha.

Drawing on unpublished Kleffmann market research data of the French maize crop was treated with insecticides targeted at ECB and *Sesamia* in 2006, if this area adopted Bt maize and no longer sprayed, the savings in insecticide spraying would be 251,000 ha no longer sprayed.

3.10 Mycotoxins

- Poeydemenge (2006) reports findings from the 2005 trials comparing fumonisin levels in maize from conventional and Bt maize. For both Fumonisin types B1 and B2, there was a reduction of 90% or more in the levels in Bt crops relative to the conventional alternative (baseline levels in the conventional crops were about 3,900 parts per billion (ppb) for Fumonisin B1 and about 1,200 ppb for Fumonisin B2;
- AGPM/Arvalis (2006) reports findings from the 2006 PACB trials as follows: for both Fumonisin types B1 and B2, there was a 33% reduction in the levels in Bt maize relative to the conventional alternative where low levels of pest infestation were experienced (baseline conventional levels for these fumonisins were 1,000 ppb). For maize in locations with medium to high levels of pest infestation, the reduction in Fumonisin B1 and B2 levels was 58% (baseline levels in the conventional crops were 3,100 ppb);
- Bakan et al. (2002) examined *Fusarium* infestation levels in Bt versus non Bt maize trial plots in five locations (three in France and two in Spain). This research found that the fungal biomass was 4 to 18 times lower in Bt maize and that Bt maize had up to ten times (0.1 to 8.85 ppm) less Fumonisin B1 content than the non-Bt maize varieties;

- Grenouillet (2006) found significant reductions in the levels of Fumonisin B1, Deoxynivalenol (DON) and Zearalenone in Bt Yieldgard maize compared to conventional maize in the Monsanto Company trials conducted between 1998 and 2003. When compared to the recently introduced EU maximum limits for Fumonisin B1 in human foods of 2 ppm (Regulation (EC) No. 856/2005), 17 of the conventional samples from the trials would have failed this threshold and in 15 of these cases the Yieldgard equivalent would have been below (ie, passed) the threshold.

3.11 Intangible impacts

The intangible benefits observed in France are potentially the same as have occurred in other adopting countries (see section 2.11), including greater management flexibility and improved production risk management.

4. GERMANY

4.1 Background and data sources

- Between 1998 and 2004, there were only limited pre-commercial plantings (up to 5 tonnes of seed per variety) as no appropriate Bt maize varieties were listed on the German variety catalogue. As of 2005, one variety was approved in Germany and plantings increased to 250 ha, then reached 950 ha in 2006, as five varieties were approved;
- The agronomic and economic impact analyses for Germany are mainly based on:
    - Degenhardt et al. (2003), based on trial plots in two regions of Germany followed between 1998 and 2002. The trial plots were 0.5 ha in size at four locations in the Rhine Valley (lower infestation) and Oderbruch region (higher infestation) and were undertaken by the main technology providing companies (Monsanto Company and Pioneer Hi-Bred). The efficacy of Bt maize was tested in comparison to untreated control maize, insecticide treatment or biological control methods using the parasitic wasp *Trichogramma*;
    - Gianessi et al. (2004), estimates based on discussions with farm advisers and scientists.

4.2 European corn borer infestation areas

- In 2003, about 300,000 ha of the German maize crop were estimated to be affected by ECB, equivalent to 18% of the 2005 total maize crop. The States affected included North Rhine Westphalia, Thuringia, Saxony, Saxony-Anhalt and Brandenburg. Only the northern most states were perceived to be largely ECB-free (Degenhart et al., 2003).

- Estimates of the level of pest infestation in 2005 (Deutscher Bundestag, 2006) put the area affected at about 387,000 ha.
- A more recent unpublished farmer survey conducted by Kleffmann in 2006 with 1,924 arable farmers, found that 26% had experienced ECB infestations in the previous two years. At the national level, this equated to about 500,000 ha of maize with ECB problems. The largest ECB problems were found in Bavaria and Baden-Wurtenberg.

4.3 Pest impact on yield

No published information for pesticide impact on yield was identified for Germany. As for other countries, the impact of ECB on maize yield varies by location and year according to infestation levels.

4.4 Conventional treatment

German maize farmers have historically had either no active policy for ECB control, used insecticides or worked with biological control methods (*Trichogramma).* In 2003, the area treated with insecticides targeted at the ECB was estimated to be about 40,000 ha (Gianessi et al., 2004). A more recent unpublished Kleffmann farmer survey identified that nearly two-thirds of farmers with ECB infestation did nothing to control the problem in 2006. Less than 20% of farmers used either insecticides or *Trichogramma*, the rest indicated they used crop rotation or ploughing as the main control method.

Gianessi et al. (2004) reported that *Trichogramma* treatment was used on 7,000-10,000 ha per year, mainly on seed crops.

4.5 Bt maize/uses

To date, all the Bt maize planted in Germany has been used for animal feed on-farm or sold to the animal feed compounding sector.

4.6 Cost of technology

The seed premium payable by farmers in 2006 was €23/unit of seed, equivalent to between €39 and €42/ha, depending on seed planting density.

4.7 Yield impact of Bt maize seed

Findings from Degenhardt et al. (2003) identified the following impact of Bt maize on yield:

- The average number of larvae per plant on Bt maize was zero in the Rhine Valley and 0.02 in the Oderbruch region. Bt maize therefore resulted in practically complete pest control;
- The yields increase of Bt maize crops relative to untreated maize were 14 and 15% in the Rhine Valley and the Oderbruch region, respectively;

- The yield increase compared to insecticide-treated plots and *Trichogramma* were in the range of +3 to +4% and 8 to 11%, respectively for both regions.

4.8 Farm cost and profit impacts

a) Degenhardt et al. (2003)

The impact on costs of production and profitability of Bt maize in the Rhine Valley and the Oderbruch region was estimated to be +83 and +€93/ha relative to untreated maize; +38 and €66/ha compared to crops treated with insecticides and +136 and +€150/ha compared to maize treated with *Trichogramma.* In terms of the average gross margin for conventional maize in 2006/07, the gains from using Bt maize (relative to an untreated crop) are equal to +12 to +14%.

b) Gianessi et al. (2004)

Gianessi et al. (2004) cite gains of €61/ha compared to crops treated with insecticide and €154/ha compared to crops treated with *Trichogramma*.

Table 11: Average impact of using Bt maize on farm profitability in Germany (€/ha)

	Bt vs. untreated conv. maize	**Bt vs. conv. maize treated with insecticides**	**Bt vs. conv. maize treated with *Trichogramma***
Degenhardt et al. (2003)[1]	+83 to +93	+38 to +66	+136 to +150
Gianessi et al. (2004)	-	+61	+154

Conv. : conventional; [1] Values for the Rhine Valley and the Oderbruch region

4.9 Environmental impact (use of insecticides)

Gianessi et al. (2004) estimated a reduction in insecticide use of 800 kg of active ingredient assuming that an area of 40,000 ha planted Bt maize and was therefore no longer treated with insecticides.

4.10 Mycotoxins

- Magg et al. (2003) examined moniliformin (MON) concentrations in early maturing Bt maize hybrids, their isogenic counterparts, commercial cultivars and experimental hybrids and any correlation between resistance to the ECB and MON concentrations. This research was conducted at five locations in Germany. It found that MON concentrations were significantly lower (and grain yields higher) in Bt maize hybrids relative to their isogenic counterparts, commercial cultivars and experimental hybrids. Correlations between concentrations of MON and other *Fusarium* mycotoxins were however not significant. The work concluded that the use of Bt maize hybrids reduces the contamination of maize grains with MON in Central Europe;

- Papst et al. (2005) investigated the association between concentrations of mycotoxins and European corn borer resistance. The study made comparisons between early maturing Bt hybrids, their isogenic counterparts and commercial hybrids. The field experiments were conducted at three locations in the main maize growing regions of Germany (See low in the east and Freising and Heilbron in the south). It found that the Bt maize hybrids (protected against ECB attack) had significantly lower levels of Deoxynivalenol (DON) and fumonisin (FUM) concentrations than their isogenic counterparts and commercial hybrids. The study concluded that the use of Bt maize cultivars may represent a short term solution to minimising toxin levels in maize kernels.

4.11 Intangible impacts

As in other countries, potentially the same impacts of greater management flexibility and improved production risk management.

5. CZECH REPUBLIC

5.1 Background and data sources

- First commercial plantings in 2005. Bt maize area planted in 2006 was 1,290 ha;
- The agronomic and economic analyses for the Czech Republic were conducted based on the following data:
  - Daems et al. (2006): economic analysis based on publicly available data;
  - Monsanto Company (2007): strip trials conducted in 2005 at seven locations and mini-strip trials at four locations in Bohemia/Moravia (unpublished results);
  - Abel (2006): press reporting of discussions with farmers. The report presents information from one farm near Brno (4,150 ha farm growing 20 ha of Bt maize).

5.2 European corn borer infestation areas

- ECB is the main pest of maize in the Czech Republic. The highest infestation regions can be found in the southern part of the country, although medium levels of infestation occur in parts of the North and the Centre. One, sometimes two generations of ECB are common;
- The State Phytosanitary Service (SRS), Prague (2006) estimates high infestations of ECB in an area of about 80,000 to 90,000 ha, particularly in Moravia;
- Approximately 30 to 35% of the total grain maize crop area[8] (equivalent to 31,000 to 37,000 ha) is subject to levels of damage that are economically significant

[8] Total maize plantings in 2005 were 316,000 ha comprising 105,000 ha grain maize and 211,000 ha of silage maize

(based on the area of the crop subject to regular conventional treatments in Daems et al., 2006);

- Monsanto Company (2007) estimate that the total area 'treated' for ECB is about 40,300 ha, inclusive of the Bt maize planted area.

5.3 Pest impact on yield

In its extensive review of several literature sources and trials data from 1959 to 2006, Daems et al. (2006) finds yield losses due to ECB ranging between 8 and 25% depending on the year and the location. Abel et al. (2006) cites a 10% yield loss for one farmer, even after insecticide application.

5.4 Conventional treatment

As in other countries affected by ECB, farmers in the Czech Republic either do not control the pest, apply insecticides or use biological control methods consisting in use of the parasitic wasp *Trichogramma*.

- Data from the Central Institute for Supervising and Testing in Agriculture (UKZUZ) Brno, and the SRS, put the area treated for ECB with insecticides at just over 14,000 ha in 2003;
- More recent estimates by Monsanto Company (2007) suggest that the area sprayed in 2006 was about 33,000 ha. In addition, *Trichogramma* was used on 6000 ha and Bt maize on 1,300 ha;
- The main insecticides used are deltamethrin, alpha-cypermethrin, lambda-cyhalotrin, teflubenzuron and methoxyfenozide. Crops are typically treated once, although some farmers occasionally have two applications (sometimes aerial spraying);
- Daems et al. (2006) cite efficacy of conventional treatments at 40 to 60% for insecticides and 15 to 70% for biological control using *Trichogramma*.

5.5 Bt maize uses

The Bt maize in 2006 was used mostly for animal feed, with 60% harvested for the grain (fed to livestock), and the balance harvested for silage and fed on-farm to livestock. There was also a limited amount used for bioethanol.

5.6 Cost of technology

According to Daems et al. (2006), the seed premium ranges from €31 to €38/ha. Monsanto Company (2007) cites a seed premium of €35/ha.

5.7 Yield impact of using Bt maize seed

Available data on the yield impact of using Bt maize is summarised below:

- Monsanto Company trials undertaken in 2005 showed a +9 to +10% yield increase across 11 trials undertaken in Bohemia/Moravia. The base yield was 11.64 tonnes/ha;
- Daems et al. (2006), in reviewing the impact of ECB on yield which put the range of positive yield impact between +5 and +20;
- Abel (2006) cited a yield benefit of +10% for the one Bt maize grower in Brno.

5.8 Farm cost and profit impact

Abel (2006) cites an increase in gross margin profitability of 10% (+€44/ha) based on insecticide costs of 18 to €36/ha, spray application costs of 8.4 to €16.8/ha and a seed premium for Bt maize seed of €35/ha. Table 12 applies this impact analysis to an adjusted average maize gross margin for the country. This suggests that Bt maize would deliver, to an average maize grower with ECB infestation problems, additional gross margin income of €65.4/ha (+15%).

Table 12: Estimated impact of using Bt maize in the Czech Republic (€/ha)

	Conventional maize	Bt maize	Bt vs. conventional maize
Revenue			
Price (€/tonne)	103	103	0
Yield (tonnes/ha)	7.2	7.92	+10%
Sales revenue	742	816	+74
Variable costs			
Seed	52	87	+35
Fertilizer	59	59	0
Crop protection[1]	55	37	-18
Other variable costs	132	124	-8
Total	298	307	+9
Gross margin	**444**	**509**	**+65 (+15%)**

Note: Based on data from Abel (2006), Monsanto Company 2005 trial data, adjusted variable costs for 2006-07 (Brookes (2007a) and prices are average for the years 2004-06; [1] One spray at €18/ha.

5.9 Environmental impact (use of insecticides)

Where Bt maize technology is replacing the use of insecticides, this is clearly reducing the level of insecticide use and its associated impact on the environment. Given that about 33,000 ha of maize in the Czech Republic used insecticides targeted at the ECB in 2006 (and assuming that the area planted to Bt maize replaced previously sprayed crops), then the potential for reducing the spray area annually with insecticides is 34,000 ha.

5.10 Mycotoxins

Findings from the Monsanto Company trials of 2005 showed significant reductions in the levels of mycotoxins (DON, FUM) in the kernels of a Bt maize variety relative to its conventional equivalent. Parts per million levels for FUM fell from about 600 ppb to about 50 ppb and DON levels fell from about 100 ppb to about 10 ppb.

5.11 Intangible impacts

Potentially the same as have occurred in other adopting countries; greater management flexibility and improved production risk. Less need for crop walking/scouting and forecasting pest attacks and hence no need to spray twice (from the air) was an important reason for adopted given by the Bt maize grower interviewed by Abel (2006).

6. PORTUGAL

6.1 Background and data sources

- Thirteen hundred hectares of Bt maize planted in 1999, then no further commercial crops grown until 2005. The areas of Bt maize planted in 2005 and 2006 were 500 and 1,240 ha, respectively;
- The agronomic and economic analyses for Portugal as mainly based on unpublished field trial data from Monsanto Company, eg, five sites in Ribatejo and Alentejo in 2005 (Monsanto Company, 2007)[9].

6.2 European corn borer infestation areas

The potential market for Bt maize in Portugal (targeted at the ECB, where there are relatively high levels of annual infestation) is 15,000 ha, equal to about 10% of the grain maize area, or 6% of the total maize (including forage maize) in Portugal (Monsanto Company, 2007). The main high infestation regions are Alentejo and Ribatejo, with some presence also in Porto.

[9] These trials were continued in 2006; provisional results are available.

6.3 Pest impact on yield

No studies of country-specific impact identified. A positive impact similar to that experienced in Spain is likely.

6.4 Conventional treatment

No information available on the extent to which insecticides are used to combat ECB infestations on Portuguese maize. Likely to be similar to Spain (limited use).

6.5 Bt maize uses

To date, all of the commercial crops have been used in the animal feed sector (either sold to feed compounders or used on-farm as feed).

6.6 Cost of technology

The typical seed premium paid for the technology in 2006 was €35/ha.

6.7 Yield impact of using Bt maize seed

The Monsanto Company trials conducted in 2005 identified an average yield improvement of 1.19 tonnes/ha (+12%) relative to untreated crops. Provisional results from the 2006 trials (for five fields[10]) identified a range of positive yield impact of +8% to +17%.

6.8 Farm cost and profit impact

Data from the Monsanto Company 2005 field trials, assuming no insecticide costs and a seed premium of €35/ha, indicates an increase in average gross margin profitability of +€112/ha (+22%) for Bt maize users compared to untreated conventional maize (Table 13).

Table 13: Impact of using Bt maize on farm profitability in Portugal, 2006 (€/ha)

	Conventional maize	Bt maize	Bt vs. conventional maize
Revenue			
Price (€/tonne)	133	133	0
Yield (tones/ha)	8.8	9.9	+1.1
Sales revenue	1,170	1,317	+147
Variable costs			
Seed	164	199	+35
Fertiliser	211	211	0

Crop protection	71	71	0
Irrigation	209	209	0
Total	655	690	+35
Gross margin	**515**	**627**	**+112 (+22%)**

Note: The average yield used for the gross margin analysis is the country average for irrigated crops – this is lower than the average conventional crop yield in the trials undertaken by Monsanto Company. Variable costs are for 2006-07 (source: Brookes (2007a) and prices are the average for 2004-06

6.9 Environmental impact (use of insecticides)

This is likely to be small if only limited amounts of insecticide are currently being used.

6.10 Mycotoxins

No data available.

6.11 Intangible impacts

Potentially the same as have occurred in other adopting countries; greater management flexibility and improved production risk management.

7. POLAND

7.1 Background and data sources

- No commercial crops planted to date – very small 'pre-commercial test' plantings in 2006 (30 ha).
- The agronomic and economic analyses are based on:
  - Brookes and Aniol (2005): ex-ante analysis of the benefits potentially incurred by adopting Bt maize in Poland;
  - Monsanto Company (2007): field trials in 2006 at two locations on South East Poland.

7.2 European corn borer infestation areas

A few years ago, ECB presence in Poland was largely limited to some regions in the South and South-East of the country. However, its prevalence has increased and almost all regions of Poland are reported to currently experience some level of infestation. Whilst levels of infestation vary by year and region, approximately 25% of the maize crop in 2003 was estimated to have been infested with ECB, with the greatest levels of infestation (80 to 100% of maize crops in some localities) found in the southern most regions, south of Wroclaw, south of Rzeszów. The year 2004 was reported to be of low levels of infestation relative to 2002 and 2003 (Brookes and Aniol, 2005). More recent data from the Plant Protection Institute (Beres, in press) estimates that annually since

2003, between 93 and 98% of maize crops in South East Poland experience problems with ECB attacks. Particularly during that period the caterpillars of ECB attacked as many as 98.6% of plants in 2003, 92.0% in 2004 and 93.2% in 2005. The numbers of caterpillars feeding per plant was 4.7, 2.9 and 3.0 accordingly. This data shows increasing importance and economic value of this pest in Poland. Customary economic level of damages is set as 15% of ECB infestation in grain production and 30%-40% in silage production (Lisowicz, 2001 and 2003).

There is usually only one generation of ECB in Poland, which attacks relatively late (at the pollen production phase), when the crop is established.

7.3 Pest impact on yield

No specific data available is available in the public domain.

7.4 Conventional treatment

From 1998 to 2003, market research data[11] shows no insecticide use in some years and very low levels of use in other years. Use of *Trichogramma* for ECB control was also negligible.

Overall, the lack of insecticide and *Trichogramma* use on Polish maize crops, despite the increasing incidence of ECB infestation reflects the following reasons (Brookes and Aniol, 2005):

- ECB pest pressure varies and hence in some years damage may be limited;
- Some farmers probably do not appreciate the level of damage to yields inflicted by the ECB. Whilst this is commonplace in all countries where ECB is a 'problem pest', it may be of greater importance in Poland, given that maize is a relatively new crop for many farmers, ECB is a fairly new pest in many regions and there is limited knowledge about control measures available;
- There is a lack of suitable equipment for spraying the crop, especially when the crop is established. There is usually only one generation of ECB in Poland, which attacks relatively late (at the pollen production phase), when the crop is established;
- The small average size of fields limits the scope for use of specialist spraying equipment or aerial spraying;
- The cost of treatments is perceived to be high (64 to €77/ha *Trichogramma*, €26/ha insecticides (Monsanto Company, 2007);
- Perception of limited effectiveness (insecticides 62 to 89% efficacy, *Trichogramma* 57 to 59% efficacy (Berés and Lisowicz, 2005).

7.5 Bt maize uses

All Bt maize grown to date has been used for animal feed and ethanol production.

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[11] Sources: Kynetec and Kleffmann cited in Brookes and Aniol (2005)

7.6 Cost of technology

The seed premium in 2006 was equivalent to €45/ha (Monsanto Company, 2007).

7.7 Yield impact of using Bt maize

- Preliminary official variety registration trials conducted in 2005 and comparing three Bt maize varieties from different companies against their conventional equivalents identified a positive yield impact of Bt maize in the range of +2 to +23% (+0.2 to +2.7 tonnes/ha);
- Specific trials conducted by Monsanto Company in 2006 comparing two Bt maize varieties with their conventional equivalent varieties found a positive yield gain of 25 to 26% (+2.15 to +2.19 tonnes/ha).

7.8 Farm cost and profit impact

Applying the yield impacts from the Monsanto Company 2006 trials to current gross margins, Table 14 highlights the range of potential impact (that is dependent largely upon the level of ECB infestation). In regions of low ECB infestation (or years of lower than average infestation), the yield gains are small and may result in a net reduction in gross margin profitability. However, in high infestation regions/years, significant yield and income gains are likely to occur.

Table 14: Impact of using Bt maize on average Polish maize gross margins, 2006 (€/ha)

	Conventional maize	Bt maize	Bt vs. conventional maize
Revenue			
Price (€/tonne)	128	128	0
Yield (tonnes/ha)	5.75	5.84-7.19	0.09-1.44
Sales revenue	736	748-920	+12 - +184
Variable costs			
Seed	95	140	+45
Fertiliser	166	166	0
Crop protection	62	62	0
Other variable costs	235	235	0
Total	558	603	+45
Gross margin	**178**	**145 to 317**	**-33 to +139 (-18% to +78%)**

Source: Conventional cost data derived from the Polish Farm Advisory Service (WODR) and presented in Brookes (2007a), European arable crop profit margins, 2006-07; Notes: Price of grain maize based on average for 2004-06, Yield: range of impact based on +1.6% to +25%, Seed premium based on +€45/ha, Crop protection assumed to be unaltered (ie, no treatments for corn borer were being used on the conventional crop)

7.9 Environmental impact (use of insecticides)

This is likely to be limited because negligible amounts of insecticide are currently being used on maize in Poland. The increasing incidence of ECB in Polish maize crops does, however suggest that insecticide use specifically targeted at the ECB may develop in the next few years and hence this (possible future use of insecticides) could be displaced by Bt maize technology.

7.10 Mycotoxins

Tekiela and Gabarkiewicz (2006) studied and compared *Fusarium* occurrence and mycotoxin content in Bt versus conventional maize in 2005. The comparisons were made between four Bt and equivalent conventional maize varieties, at two locations in South-East Poland. In all cases, the levels of mycotoxins (Fumonisins B1, B2 and B3 and Deoxynivalenone) and were significantly lower in the Bt maize relative to the conventional maize (Table 15).

Table 15: Mycotoxin levels in Bt versus conventional maize (trial results) Poland, 2005

Parts per million	Bt maize	Conventional maize
Deoxynivalenol (DON)	Less than 50 to 155	148-1,141
Fumonisin (FUM) B1	0-25	121-409
Fumonisin (FUM) B2	0-8	44-103
Fumonisin (FUM) B3	0	6.7-13

Source: Tekiela and Gabarkiewics (2006)

8. SLOVAKIA

8.1 Background and data sources

- Commercial plantings first occurred in 2006 (30 ha);
- The main sources of agronomic and economic information are:
    - Brookes (2007b): economic analysis based on 2006 plantings;
    - Monsanto Company (2007): unpublished data from three commercial farm locations in Bajc, Lipove and Borovco in 2006 (total of 30 ha).

8.2 European corn borer infestation areas

- ECB is currently a problem for many farmers in Slovakia. It is estimated to cause economic levels of damage to about one third of the country's maize crop, eg, 50,000 ha (Brookes, 2007 b);

- Monsanto Company (personal communication) estimates that infestation problems are today at a higher level: 47% of the country's maize crop (found mostly in the South) suffers high infestation (where more than two-thirds of plants are infested and the average yield loss is 20%), 29% suffers medium infestation (a third to two-thirds of plants are infested with an average yield loss of 10%) and the balance of 24% suffers low infestation (average yield loss of 3%).

8.3 Pest impact on yield

There is a strong relationship between ECB infestation levels and yield losses. At a 10% infestation level (of plants) a 2% yield loss occurs, rising to in excess of 30% yield loss when 100% of plants are infested (Cagan, 2005).

8.4 Conventional treatment

Very little insecticide use is reported for ECB control in Slovakia (Brookes, 2007b). As in other countries this reflects a number of reasons such as:

- ECB pest pressure varies and hence in some years damage may be limited;
- Some farmers probably do not appreciate the level of damage to yields inflicted by the ECB;
- The cost of treatment is perceived to be high;
- Perception of limited effectiveness of insecticides.

8.5 Bt maize uses

Of the 2006 Bt maize crop, about 30% was used as feed on the farms where the crop was grown, a further 30% was sold the animal feed compounding industry and the balance of 40% was used in the production of bioethanol.

8.6 Cost of technology

The seed premium in 2006 was €35/ha.

8.7 Yield impact of using Bt maize seed

Findings from the 2006 commercial plantings identified a positive yield impact within a range of 10 – 14.7% (Monsanto Company, 2007).

8.8 Farm cost and profit impact

- The analysis presented in Brookes (2007b) which assumed no insecticide costs identified an increase in average gross margin profitability in the range of +32 to +€63/ha (+8.9 to +17.5%: Table 16);

Table 16: Impact of using Bt maize on farm profitability in Slovakia, 2006 (€/ha)

	Conventional maize	**Bt maize**	
Revenue			
Price (€/tonne)	96	96	0
Yield (tonnes/ha)	6.97	7.67 - 7.99	0.7-1.02
Sales revenue	669	736-767	67-98
Variable costs			
Seed	90	125	+35
Fertiliser	79	79	0
Crop protection	60	60	0
Other variable costs	79	79	0
Total	308	343	+35
Gross margin	**361**	**393 to 424**	**+€32 to +€63 (+8.9% to +17.5%)**

Source: Yield impact of +10% to +14.7% used by Brookes (2007a) based on findings of trials and commercial experience in the Czech Republic (see section 7) and commercial plantings in Slovakia. Variable costs for 2006-07 (Brookes 2007a) and prices are the average for 2004-06

- At the national level the annual positive impact on farm income is likely to be between +1.5 and +3 million euros (based on one third of the total maize adopting the technology – in other words one third of the crop suffering economic levels of ECB damage.

8.9 Environmental impact

The positive environmental impact of Bt maize is likely to be limited because negligible amounts of insecticide are currently used on maize in Slovakia. The increasing incidence of ECB however suggest that insecticide use specifically targeted at this pest may develop in the next few years and hence this (possible future use of insecticides) could be displaced by Bt maize technology.

8.10 Mycotoxins

No data is available yet in the public domain.

8.11 Intangible impacts

Potentially the same as have occurred in other adopting countries; greater management flexibility and improved production risk management.

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