June 2009

THE EXISTING AND POTENTIAL IMPACT OF USING GM INSECT RESISTANT (GM IR) MAIZE IN THE EUROPEAN UNION

Graham Brookes

PG Economics, UK

Table of contents

SUMMARY & CONCLUSIONS

This paper has reviewed data on the impacts linked to the use of GM insect resistant (GM IR) maize and explored the potential impacts of this technology if applied to all relevant maize growing regions in the EU. The key conclusions that can be drawn are:

- In maize growing regions affected by corn boring pests, the primary impact of the adoption of GM IR maize has been higher yields compared to conventional maize. Average yield benefits have often been +10% and sometimes higher, although impacts vary by region and year according to pest pressure;
- In 2007, users of GM IR maize have, on average, earned additional income levels of +€186/ha (range of +€25 to +€201/ha). Across all users of GM IR technology, the total increase in farm income directly attributable to the technology was +€20.6 million and cumulatively, since 1998, the total farm income gain has been +€55.7 million;
- In certain regions, GM IR maize has delivered important improvements in grain quality from significant reductions in the levels of mycotoxins found in the grain;
- Where maize growers have traditionally used insecticides to control corn boring pests, the switch to using GM IR technology has resulted in important reductions in insecticide use and its associated environmental impact (notably in Spain);
- Across the EU the potential adoption area for GM IR maize is in a range of 2.25 million ha to 4 million ha, depending on the annual levels of pest pressure. At these levels of adoption, the annual direct farm income benefit potential (at 2007 prices) falls within a range of €160 million and €247 million;
- Spain is the only EU member state where GM IR maize adoption levels are currently delivering farm income gains at or near full potential levels, and across the EU only between 8% and 12% of the total potential benefit is being realised;
- The countries currently foregoing the largest economic gains from GM IR maize technology are Italy, France and Germany, followed by Austria and Romania;
- Annual savings of between 0.41 million kg and 0.7 million kg of insecticide active ingredient could be realised if GM IR maize technology was used on its full potential area. At present, only between 14% and 25% of the total potential environmental benefit from reduced insecticide use is being realised;
- The countries currently foregoing the largest environmental benefits that might reasonably be realised from the use of GM IR maize are Italy, France and Germany. This contrasts with Spain, where the potential environmental benefits associated with reduced insecticide use (targeted at corn boring pests) have mostly been achieved.

1. INTRODUCTION

This paper reviews published data on the impacts linked to the use of genetically modified insect resistant (GM IR) maize in the European Union (EU) since the trait was first approved for planting in 1998. It also examines the potential (additional) impact of using this technology across all relevant maize growing regions in the EU.

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.

GM IR maize was planted for the first time in 1998 in Spain and in 2008 the area planted to GM IR maize in Spain was 79,269 ha. Small amounts of GM IR 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, France, Portugal and the Czech Republic also reported GM IR maize plantings, albeit on limited areas. By 2008, the number of countries in which GM IR maize was planted had increased to include Poland, Slovakia and Romania, although no plantings were allowed in 2008 in France (due to the imposition of a national ban) and Germany has introduced a ban for 2009. In total, the area planted to GM IR maize in the EU was just under 108,000 ha in 2008, equivalent to approximately 0.75% of total EU27 maize plantings (including forage maize area). The global GM crop area in 2008 was 125 million ha, of which the area planted to GM IR maize (targeting corn boring pests) was about 24 million ha.

2. AREAS SUFFERING DAMAGE FROM CORN BORING PESTS

2.1 Spain

The 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) although the incidence and impact of infestation varies significantly by region and year, is 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). Brookes (2003) classified the maize growing regions of Spain into 3 regions according to historic annual pest pressure levels (high, medium and low pest pressure regions) and drawing on these classifications, it is evident that the highest concentrations of GM IR maize plantings are found in regions which have traditionally experienced medium to high pest pressure levels[1] such as Aragon and Catalunya.

---

[1] 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

2.2 France

Annually, between 1 and 2 million hectares of maize are affected by ECB and MSB 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. 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.

2.3 Germany

Estimates of the area of the German maize crop annually affected by ECB fall between 0.3 and 0.5 million ha ((Degenhart et al, Deutscher Bundestag, 2006, Kleffmann market research data 2006). The largest ECB problems are found in Bavaria and Baden-Wurtenberg.

2.4 Czech Republic

ECB is the main pest of maize in the Czech Republic and 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) estimated high infestations of ECB in an area of about 80,000 to 90,000 ha, particularly in Moravia although the area subject to levels of damage that are economically significant is probably in the range of 40,000 ha and 60,000 ha.

2.5 Portugal

The potential market for GM IR 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 (source: Monsanto Company, 2007). The main high infestation regions are Alentejo and Ribatejo, with some presence also in Porto.

2.6 Poland

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, the Plant Protection Institute (Beres) estimates that annually since 2003, between 93 and 98% of maize crops in South East Poland experience problems with ECB.

2.7 Slovakia

ECB is estimated to cause economic levels of damage to about one third of the country's maize crop, ie, 50,000 ha (Brookes, 2007).

2.8 Romania

Industry sources estimate that the ECB annually causes economic levels of damage to between 0.5 million ha and 0.9 million ha in Romania. The areas most prone to ECB damage are in the West, North West, and South (Danube river provinces).

2.9 Other countries (currently countries where corn boring pests are problematic but GM IR maize technology is not permitted for use)

- *Italy:* corn boring pests cause major problems to the Italian maize crop every year, especially in the Po valley. Industry sources estimate that about 80% of the total Italian maize crop annually experience economic losses from corn boring pests;
- *Hungary*: corn boring pests are not a major problem in Hungary. Whilst the area suffering economic levels of damage varies by region and year, the area affected annually tends to be between 5% and 10% of the total crop area.
- *Greece*: up to about 100,000 ha of maize (in years of high infestation) in Greece can experience economic losses due to corn boring pests, although the annual area typically experiencing losses tends to fall within a range of 12,000 ha to 60,000 ha;
- *Austria*: industry sources estimate that between about 50% and 70% of the Austrian maize crop annually suffers economic levels of damage from corn boring pests;
- *Bulgaria*: between about 10% and 15% of the Bulgarian maize crop is perceived to suffer economic losses from corn boring pests (based on industry estimates).

Overall, across the EU 27, the estimated area that annually suffers from economic levels of damage from corn boring pests is within a range of about 2.25 million hectares and 4 million hectares, with the lower end of the range probably representative of the area experiencing economic losses in a year of below average (low) pest problems and the higher end of the range representative of the area suffering economic losses in years of above average (high) infestation levels.

3. CONVENTIONAL TREATMENT

European maize farmers generally have one of three approaches to dealing with corn boring pest problems. One is having no active policy of treatment (ie, they take no crop protective action). The approach of having no active policy for treatment tends to be a fairly common one (both in Europe and worldwide) because corn boring pest pressure varies and hence in some years damage may be limited. Crop protection strategies (usually based on insecticide treatment: see below) have also tended to be 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;
- Egg-laying can occur over a three week period and most insecticides are only effective for 7 to 10 days;
- Some farmers probably do not appreciate the level of damage to yields inflicted by the ECB and MCB. This is highlighted in surveys of farmers using GM IR technology), where some GM IR maize users have indicated that it was only after using this technology that they realized fully what adverse impact the ECB/MCB caused (see for example, Brookes, 2003).

The other two approaches involve some from of crop protection strategy that either uses insecticides or biological control methods (consisting of the release of the parasitic wasp *Trichogramma):*

- In Spain, maize farmers have historically either had no active policy/methods for the control of ECB or used insecticides (Brookes, 2003). Insecticide treatments have been used mostly by farmers in high infestation regions (eg, Huesca) at the rate of one or two insecticide treatments per season;
- In France, where farmers decide to treat against ECB and/or MCB, they use insecticides or biological control methods. In recent years, the area treated with insecticides or *Trichogramma* has been between about 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);
- German maize farmers similarly have one of no active policy for ECB control, or used insecticides, or work with biological control methods (*Trichogramma).* Unpublished Kleffmann farmer survey data has identified that nearly two-thirds of farmers with ECB infestation did nothing to control the problem in 2006 and

less than 20% of farmers used either insecticides or *Trichogramma*. The rest indicated they used crop rotation or ploughing as the only control method;

- In the Czech Republic, the area subject to regular conventional insecticide treatments or treated with trichogramma is about 40,000 hectares (based on Daems et al., 2006 and Monsanto Company estimates (2007));
- In Poland. the use of insecticides or trichogramma for ECB control has been negligible mainly because ECB pest pressure varies, there has been limited history of ECB damage, some farmers probably do not appreciate the level of damage to yields inflicted by the pest, the cost of treatments is perceived to be high (64 to €77/ha *Trichogramma*, €26/ha insecticides (Monsanto Company, 2007) and there is a perception of limited effectiveness (insecticides 62% to 89% efficacy, *Trichogramma* 57% to 59% efficacy (Berés and Lisowicz, 2005);
- Similarly in Portugal and Slovakia, very little insecticide use is reported to be have been used for ECB control. This reflects the same reasons outlined above for other countries (eg, ECB pest pressure varies, perception of limited effectiveness of insecticides);
- In Romania, only limited use of insecticides has traditionally been made, with 10,000 ha to 33,000 ha receiving sprays in years of high infestation only;
- In Italy, the annual maize area typically treated with insecticides for corn boring pests is estimated to be within a range of 50,000 ha and 175,000 ha (source: industry estimates);
- Use of insecticides in other maize growing countries is perceived to be very limited (for the reasons cited above).

4. YIELD IMPACT OF GM IR MAIZE SEED

As ECB and MCB 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. Table 1 summarises the findings of analysis on the impact of GM IR maize on maize yields in the EU countries where it has been used. Additional information is provided in Appendix 1.

Table 1: Yield impacts from using GM IR maize in the EU

Country	Average yield of GM IR maize relative to conventional % difference	Range of yield impacts (where identified)	Comments

Spain	+6.3% 1998-2003 +10% 2004 onwards	+1% to +30%	Bottom of range is low infestation locality in a year of low pest pressure and top of range is high infestation locality in year of high pest pressure
France	+10%	+5% to +24%	Bottom of range is low pest pressure year and top of range is high pest pressure year
Germany	+4%	+4% to +5%	No additional data available for low and high pest pressure years
Czech Republic	+10%	+5% to +20%	Range of impacts recorded in different regions with differing levels of pest pressure; low end of range = low pest pressure, high end of range = high pest pressure
Portugal	+12.5%	+8% to +17%	Range of impacts recorded in different regions with differing levels of pest pressure; low end of range = low pest pressure, high end of range = high pest pressure
Poland	+12.3%	+2% to +26%	Range of trial results in 2005 with top of range based on 2006 trials in year/region of high infestation
Slovakia	+12.5%	+10% to +14%	Range of commercial plot monitoring in 2006
Romania	+7.1%	No data available	Range of commercial plot monitoring in 2007

In comparison, the average positive yield impacts from using GM IR (targeting corn boring pests) in other parts of the world have been within a range of +5% (US and Canada) to +24% (the Philippines).

5. ECONOMIC IMPACT OF USING GM IR TECHNOLOGY IN THE EU (TO 2007)

The main impact on farm profitability of growing GM IR maize has been via increased yields (Table 1), with average yield impacts across the countries where GM IR maize has been used being within a range of about +4% to +12%. Clearly the level of yield enhancement varies by region and year, with the additional yield effects being lower than average in years of low pest pressure and higher than average in years of high pest pressure.

In relation to costs of production, impacts vary. In countries such as Spain, France and Germany where use of insecticides targeted against corn boring pests have traditionally been commonplace, savings of between €40/ha and €50/ha have arisen, giving a net reduction in costs of production (after deducting the seed premia paid for the technology) of about €7/ha to €10/ha. In all other countries, net costs of production have increased as a result of the seed premia being greater than any savings from reduced insecticide use (in most of the other countries, insecticide use is not commonplace and hence no costs have been assumed in the analysis: see Table 2).

The net impact of GM IR maize technology has been to deliver improvements to farm profitability. In 2007, the average increase in farm profitability from use of GM IR technology was €186/ha, within a range of +€25/ha (Romania) and €201/ha in Spain (Table 2). At the national level, these yield gains and cost savings have resulted in farm income being boosted, in 2007, by €20.6 million and cumulatively, the increase in farm income (in nominal terms) has been €55.7 million. The largest share of these farm income gains have, not surprisingly, gone to Spanish farmers who have been using GM IR technology since 1998 compared to the more recent use in other countries. Across all years of adoption, the average farm income benefit has been €131/ha.

The level of farm income benefit earned by EU maize growers in 2007 represented 1.3% of the total direct farm income gain from using GM IR (targeting corn boring pests) globally ($1.53 billion).

Table 2: Farm level income impact of using GM IR maize in EU countries

	Year first planted GM IR maize	Area GM IR maize 2007 (ha)	Average yield impact (%)	Cost of technol-ogy 2007 (€ha)	Net increase in gross margin 2007 (€/ha)	Impact on farm income at a national level 2007 ('000 €)	Cumulative Impact on farm income at a national level year of first use to

							2007 ('000 €)
Spain	1998	75,148	+10	35	+201.27	+15,125	+49,339
France	2005	22,135	+10	40	+186.72	+4,133	+4,806
Germany	2005	2,685	+4	40	+85.99	+231	+294
Portugal	2005	4,263	+12.5	35	+105.51	+450	+557
Czech Republic	2005	5,000	+10	35	+107.20	+536	+614
Slovakia	2005	948	+12.3	35	+75.03	+71	+72
Poland	2006	327	+12.5	35	+90.40	+30	+31
Romania	2007	360	+7.1	32	+25.40	+9	+9
Total		**110,866**			**+185.67**	**+20,585**	**+55,722**

Source and notes:

1. Impact data based on Brookes (2008) and updated. In Spain yield impact +6.3% 1998-2004 and 10% used thereafter (originally Bt 176, latterly Mon 810). Cost of technology in Spain based on €18.5/ha to 2004 and €35/ha from 2005
2. Cost savings from reductions in insecticide use only applicable in Spain (average saving €42/ha), France and Germany (average saving €50/ha) and the Czech Republic (average saving €18/ha)

The analysis presented above is based on estimates of average impact in all years. Recognising that pest pressure varies by region and year, additional sensitivity analysis was conducted (see Appendix 2 for details) for two levels of impact assumption; one in which all yield effects in all years were assumed to be 'lower than average' (levels of impact that largely reflected yield impacts in years of low pest pressure) and one in which all yield effects in all years were assumed to be 'higher than average' (levels of impact that largely reflected yield impacts in years of high pest pressure). The results of this analysis suggest a range of positive cumulative direct farm income gains of +€35.2 million to +€94.4 million. This range is within 63% to 169% of the main (average) estimates of farm income presented above.

Examining the cost farmers pay for accessing GM technology, Table 3 shows that the total cost over all years of use was equal to 18% of the total technology gains (inclusive of farm income gains plus cost of the technology payable to the seed supply chain[2]). In

---

[2] The cost of the technology accrues to the seed supply chain including sellers of seed to farmers, seed multipliers, plant breeders, distributors and the GM technology providers

other words, 82% of the total direct economic gain from GM IR technology went to farmers. This compares with the global average farmer share of total benefits from using this technology of 74% (ie, EU farmers are obtaining a higher than average share of total benefits).

Table 3: Cost of accessing GM IR technology ('000 €) relative to the total farm income benefits 1998-2007 in the EU

Cost of technology	Farm income gain	Total benefit of technology to farmers and seed supply chain
12,577	55,722	68,299

6. OTHER IMPACTS OF GM IR TECHNOLOGY

6.1 Environmental impact (use of insecticides)

The adoption of GM IR maize by some farmers in the EU has resulted in environmental benefits, most notably where the technology has replaced the application of insecticides as a measure for control of corn boring pests. Whilst the use of insecticides for control of corn boring pests has traditionally been limited (for reasons see section 3), some savings, in terms of both the amount of insecticide active ingredient applied and the associated environmental impact, have arisen. In particular:

- *Spain:* Based on insecticide usage data from 1999-2001 (early years of (limited) GM IR maize adoption when insecticides were 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%. Further analysis by Brookes & Barfoot (2009 forthcoming) estimated that the adoption of GM IR maize has also resulted in a net decrease in the field Environmental Impact Quotient (EIQ/ha load)[3][4]. Since 1998 the cumulative saving (relative to the level of use if the total crop had been non GM) was 364,000 kg of insecticide

---

[3] This universal indicator, developed by Kovach et al (1992) and updated annually, effectively integrates the various environmental impacts of individual pesticides into a single 'field value per hectare'. This provides a more balanced assessment of the impact of GM crops on the environment as it draws on all of the key toxicity and environmental exposure data related to individual products, as applicable to impacts on farm workers, consumers and ecology, and provides a consistent and comprehensive measure of environmental impact

[4] An average volume of insecticide active ingredient used of 0.96 kg/ha, with an average field EIQ of 41.77/ha

ai (a 41% decrease) and the field EIQ/ha load had fallen by 37% since 1999 (-15.8 million units). In 2007, the amount of insecticide active ingredient and the field EIQ load were respectively 73% (-72,140 kg of active ingredient) lower than their conventional equivalent;

- *Other countries:* As indicated in section 3, insecticides for the control of corn boring pests are commonly applied to some maize growing areas in France, Germany and the Czech Republic. On the assumptions that the limited areas planted to GM IR maize in these countries would otherwise have used insecticides as the primary corn boring control mechanism, and the insecticide use savings per hectare (from use of GM IR technology) identified in Spain were equally applicable in these countries[5], this suggests that the GM IR plantings in these three countries have resulted in an additional reduction in the amount of insecticide active ingredient applied to maize crops of 28,630 kgs and a saving of 1.24 million EIQ/ha load units.

The estimated insecticide usage savings associated with use of GM IR maize in the EU, in 2007, was equivalent to about 5% of the total global insecticide savings from use of this technology (about 1.9 million kg).

6.2 Other environmental impacts

There is growing evidence that the use of GM IR maize technology, by reducing the amount of insecticides applied to maize crops, has resulted in a reduction in the level of adverse side effects from insecticide use on non target organisms and resulted in higher levels of beneficial insect population (see for example Carpenter J et al (2002) and Sanvido O et al (2006).

It is also of note that extensive reviews of the environmental impact of use of GM IR maize technology has found no evidence to date of any adverse environmental impact. For example, in the review undertaken by Sanvido et al (2006) the report concluded that *'The data available so far provides no scientific evidence that the commercial cultivation of GM crops has caused environmental harm'.* Similarly, all scientific evidence so far submitted to the European Food Safety Authority related to the environmental impact of GM IR maize, has provided no grounds for withdrawing its approval for planting in the EU.

6.3 Grain quality

There have been a number of studies in maize growing countries of the EU examining the presence of fungi that potentially produce mycotoxins, in GM IR versus conventional

---

[5] The average insecticide saving identified in Spain were for active ingredient use -0.96 kg/ha and for the associated reduction in the environmental impact, as measured by the EIQ indicator - 41.77 EIQ load units/ha

maize. These studies (see appendix 3) show that in certain regions, GM IR maize has delivered important and consistent improvements in grain quality through significant reductions in the levels of mycotoxins found in the grain. This is not surprising given that the ECB and MCB pests damage maize crops making them susceptible to fungal damage and the development/build up of mycotoxins in the grain. As with the impact of the technology on yield and income, the positive impact on grain quality has varied by region and year according to the level of pest attack and extent to which this has caused fungal damage and mycotoxin development in crops.

6.4 Intangible impacts

The adoption of GM IR maize has also delivered a number of non-monetary benefits, including:

- Improved production risk management: GM IR maize has been seen as an insurance against ECB/MCB by many farmers, taking away the worry of significant ECB/MCB damage occurring;
- A convenience benefit: farmers using GM IR maize tend to devote less time to crop walking and/or applying insecticides, with many citing this as an important benefit;
- 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/MCB damaged crops are easily flattened by late summer winds).

7. POTENTIAL BENEFITS CURRENTLY BEING FOREGONE

7.1 Economic benefits foregone

It is evident from section 2 (Areas suffering damage from corn boring pests), that a significant annual area of maize grown in the EU 27 could potentially benefit from the use of GM IR technology, if the technology was available to all EU maize farmers without legal restriction and farmers perceived that they were able to grow these crops without interference and sell the grain without problems. This potential adoption area is probably within the range of 2.25 million ha and 4 million ha, depending on the annual levels of pest pressure.

Drawing on the evidence presented in section 5, for yield and economic impacts associated with GM IR technology use, and extrapolating these impacts across this range of potential adoption areas, Table 4 and Figure 1 summarise the farm income benefits that might reasonably be derived from wider adoption of this GM IR technology in the EU maize sector (for details of the benefit assumptions applied to the EU member states where corn boring pests are problematic but currently do not use GM IR maize technology, see Table 5). Key points to note are:

- the annual direct farm income benefit potential falls within a range of €166 million and €325 million, although the likely adoption levels are more likely to fall within the range of €166 million to 247 million;
- Spain is the only member states where GM IR maize adoption levels are currently delivering farm income gains at or near the likely benefit 'potential', although Portugal may be getting close to this level, if the lowest estimate of susceptible area is taken as the baseline for potential adoption;
- GM IR adoption levels in 2007 in the Czech Republic were delivering farm income gains equal to about 8% to 13% of the total 'potential' (assuming only high and medium susceptible areas represent the maximum potential area);
- In 2007, in France, the farm income benefits derived from GM IR maize technology were delivering between about 5% and 11% of the total 'potential' (assuming only high and medium susceptible areas represent the maximum potential area). With the ban on plantings introduced in 2008, these gains have been removed from French maize growers;
- In the other GM IR maize using member states, the farm income gains so far derived are very small (under 5%) relative to the potential available, reflecting the current small areas planted to GM IR maize traits;
- Across all EU member states with maize areas susceptible to economic levels of damage from corn boring pests, the 2007 level of farm income benefits derived from using GM IR technology is only between 8% and 12% of total potential benefits (assuming only high and medium susceptible areas represent the maximum potential area);
- The member states currently foregoing the largest economic gains from using GM IR technology are Italy, France and Germany, followed by Austria and Romania. Of these countries, only Romania allows its maize farmers to use GM IR technology (but only since 2007 when it joined the EU).

Table 4: Potential annual direct economic farm level benefit from using current GM IR maize technology (targeted at corn boring pests)

Country	Susceptible area to corn boring pests: high only ('000 ha)	Susceptible area to corn boring pests: high & medium ('000 ha)	Susceptible area to corn boring pests: high, medium & low ('000 ha)	Direct benefit assump-tions (€/ha)	Potential economic gain applied to high susceptible area only ('000 €)	Potential economic gain applied to high/medium susceptible area only ('000 €)	Potential economic gain applied to high/med/low susceptible area only ('000 €)

Spain	75	90	136	130.25	9,769	11,722	17,714
France	200	450	700	173.73	34,746	78,178	121,611
Portugal	5	15	20	88.5	442	1,327	1,770
Germany	300	400	500	75.8	22,740	30,320	37,900
Italy	870	1,009	1,083	75.74	65,927	76,402	82,057
Greece	12	40	60	136.36	1,636	5,454	8,182
Austria	130.0	163.9	197.8	63.98	8,317	10,486	12,655
Poland	9.7	16.1	22.6	87.07	844	1,406	1,969
Czech Republic	40	60	90	93.56	3,742	5,614	8,420
Slovakia	50	76.6	90	73.59	3,679	5,637	6,623
Hungary	59.7	89.5	119.4	23.80	1,421	2,131	2,842
Bulgaria	17	34	68	6.34	107.80	215.60	431.10
Romania	500	711	900	25.4	12,700	18,059	22,860
Total	**2,268.4**	**3,155.1**	**3,968.8**		**166,070.8**	**246,951.6**	**325,034.1**

Sources: Based on Brookes (2008), Brookes & Barfoot (2009 forthcoming) and industry sources

Notes:

1. Susceptible areas classification: high = areas with consistent high levels of infestation most years, high/medium = high infestation regions plus areas with medium average levels of infestation (high infestation in some years, low in others); high/medium/low = all areas that periodically suffer economic losses from corn boring pests (ie, includes regions that in some years have little infestation but in others have higher levels of infestation)
2. Direct benefit assumptions. For countries using the technology, the direct benefit is based on the average benefit identified over the years of adoption (1998-2007 for Spain and from 2005 in most other countries). For current non adopting countries, based on Table 5

Table 5: Direct economic benefit assumptions applied to maize crops in EU member states currently not using GM IR technology

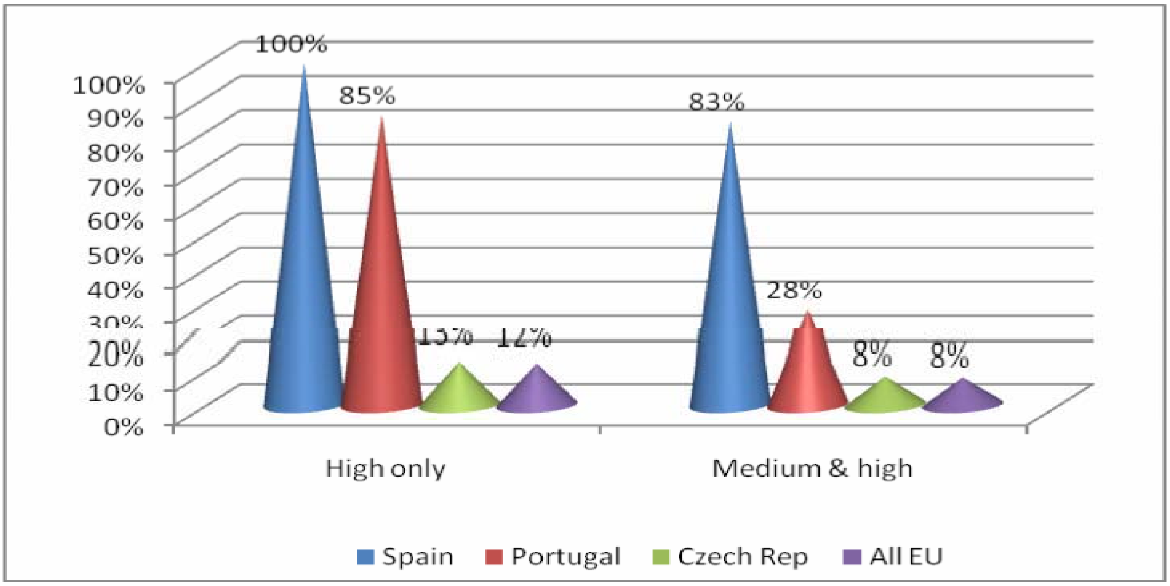
Country	Assumed cost of technology €/ha	Base yield (t/ha)	Price of maize (€/tonne)	Yield benefit assumption (% increase)	Additional revenue from yield gain (€/ha)	Net gain/ha (€/ha)
Austria	35	10.1	98	+10	98.98	63.98

Bulgaria	32	5.0	108	+7.1	38.34	6.34
Greece	35	9.52	180	+10	171.36	136.36
Italy	40	9.41	123	+10	115.74	75.74
Hungary	35	6.0	98	+10	58.80	23.80

Notes:

1. Cost of technology: based on costs in other countries in 2007 (higher cost in Italy applied to reflect higher charges in countries where insecticide use is commonly applied (notably France))
2. Base yields: average of 2006-2008 values; adjusted upwards in Bulgaria to reflect average yields of commercial farmers (excluding subsistence growers)
3. Yield benefit assumptions: based on average benefits in neighbouring countries using the technology
4. Price of maize is the average 2008 farm level harvest price
5. Analysis assumes no savings from reduced use of insecticides. Given the use of insecticides on some current maize areas (notably in Italy, see section 3) targeting corn boring pests, this understates the likely total benefit by about €9 million to €11 million

Figure 1: 2007 direct income gains from using GM IR maize as % of potential: selected EU countries



Note: High only = assumes maximum direct income gain potential based on only regular high infestation areas uses GM IR technology. Medium & high assumes maximum direct income gain potential based on high and medium infestation areas use GM IR technology

7.2 Environmental benefits foregone

Drawing on the evidence presented in section 3 (conventional treatment for corn boring pests) and section 6.1 (environmental impacts associated with use of GM IR maize), and extrapolating these impacts to the range of potential adoption areas, Table 6 summarises the environmental benefits associated with reduced insecticide use that might reasonably be derived from wider adoption of this GM IR technology in the EU maize sector. This suggests that:

- Annual savings of between about 0.41 million kg and 0.7 million kg of insecticide active ingredient could be realised;
- In 2007, only between 14% and 25% of the total annual savings in insecticide active ingredient use and associated environmental impact were realised;
- Most of the potential annual environmental benefits associated with reduced insecticide use have possibly been achieved in Spain. In the Czech Republic, up to about a quarter of the potential savings may have been realised;
- Limited environmental benefits from reduced insecticide use were possibly being achieved in France (7%-11% of potential) and Germany (2%-3% of potential) in 2007. However, with the introduction of the ban on planting of GM IR maize from 2008 in France and 2009 in Germany, these environmental benefits are now no longer being achieved;
- The countries currently foregoing the largest environmental benefits that might reasonably be realised from use of GM IR maize are Italy, France and Germany. This contrasts with Spain, where the potential environmental benefits associated with reduced insecticide use (targeted at corn boring pests) have mostly been achieved.

Table 6: Potential annual EU environmental benefit associated with using less insecticides (for controlling corn boring pests) if GM IR maize technology used

Country	Area typically treated annually with insecticides for corn boring pests ('000 ha)	Potential saving in active ingredient usage ('000 kg)	Potential saving in associated environmental impact ('000 EIQ load units)	Estimated % of potential achieved in 2007
Spain	75-98	72 to 94.1	3,133 to 4,093	77-100
France	200-300	192 to 288	8,354 to 12,531	7-11 (Note zero from 2008)
Germany	80-120	76.8 to 115.2	3,342 to 5,012	2-3 (Note: zero from 2009)
Italy	50-175	48 to 168	2,088 to 7,310	Zero

Czech Republic	20-40	19.2 to 38.4	835 to 1,671	13-25
Others	1-5	1 to 4.8	42 to 209	0
Total	**426-738**	**409 to 708.5**	**17,794 to 30,826**	**14-25**

Notes:

1. Area treated with insecticides: for Spain based on usage in early years of GM IR maize adoption, before widespread use of the technology. For other countries based on a combination of unpublished market research data (source: Kleffmann) and industry estimates
2. Potential (and actual) savings in terms of insecticide active ingredient use and associated environmental load based 0.96 kg/ha and an EIQ load/ha of 41.77/ha – based on Spanish data (Brookes 2003)

APPENDIX 1: RESEARCH INTO THE YIELD IMPACT OF GM IR MAIZE

Spain

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 La Mancha	-		Perceived: +1 to +14; Measured average: +5	Survey of 400 farms, incl. 218 Bt maize users; may include some conventional crops treated with insecticides	Gomez-Barbero and Rodriguez-Cerejo, 2006 a and b
Range	**10 to 13**	**0.2 to 1**	**1 to 40**	**-**	**-**

France

- 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.

Germany

Findings from Degenhardt et al. (2003) shows that yield increases for 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 these regions.

Czech Republic

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 put the range of positive yield impact between +5 and +20% and Abel (2006) cited a yield benefit of +10% for the one Bt maize grower in Brno.

Portugal

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) identified a range of positive yield impact of +8% to +17%. Analysis by Skevos, Fevereiro and Wesseler (2009) on 12 farms in the Odemera region of South West Portugal in 2007 found an average positive yield impact of about +13.5%, within a range of +2.8% and +25%.

Poland

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).

Slovakia

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

APPENDIX 2: DETAILS OF METHODOLOGY AS APPLIED TO 2007 FARM INCOME CALCULATIONS

Country	Area of trait ('000 ha)	Yield assumption % change	Base yield (tonnes/ha)	Farm level price (€/tonne)	Cost of technology (€/ha)	Impact on costs, net of cost of technology (€/ha)	Change in farm income (€ha)	Change in farm income at national level ('000 €)
Spain	75.1	+10	9.34	208	-35	+7	+201.27	+15,125,188
France	22.1	+10	9.4	188	-40	+10	+186.72	+4,133,047
Germany	2.7	+4	9.09	209	-40	+10	+85.99	+230,890
Portugal	4.3	+12.5	5.51	204	-35	-35	+105.51	+449,768
Czech Republic	5	+10	5.75	216	-35	-35	+107.20	+536,000
Slovakia	0.9	+12.3	4.28	209	-35	-35	+75.03	+71,125
Poland	0.3	+12.5	5.28	190	-35	-35	+90.40	+29,561
Romania	0.3	+7.1	3.5	231	-32	-32	+25.40	+9,145

Notes:

1. Impact on costs net of cost of technology = cost savings from reductions in insecticide costs, labour use, fuel use etc from which the additional cost (premium) of the technology has been deducted. For example (above) Spain cost savings from reduced expenditure on insecticides etc = +€42/ha, from which cost of technology (-35€/ha) is deducted to leave an et impact of costs of +€7/ha

APPENDIX 3: SUMMARY OF FINDINGS INTO IMPACT OF GM IR MAIZE ON GRAIN QUALITY

In Spain, studies include 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 indicated that Bt maize had up to ten times less fumonisin content than the non Bt maize varieties. In addition, Serra et al. (2006)[6] 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.

In France, 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. The AGPM/Arvalis (2006) reports similar findings from 2006 trials. 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) and 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). Lastly, Grenouillet (2006) found significant reductions in the levels of Fumonisin B1, Deoxynivalenol (DON) and Zearalenone in Bt Yieldgard maize compared to conventional maize in 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.

In Germany, 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.

---

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

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.

In the Czech Republic, 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.

In Poland, 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 7).

Table 7: 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 Gabarkiewicz (2006)

APPENDIX 4: IMPACTS, ASSUMPTIONS, RATIONALE AND SOURCES

	Yield impact assumption used	Rationale	Yield references	Sensitivity analysis applied to yield assumptions	Costs references
Spain	+6.3% 1998-2004 +10% 2005 onwards	Impact based on authors own detailed, representative analysis for period 1998-2002 then updated to reflect improved technology based on industry analysis	Brookes (2003) identified an average of +6.3% using the Bt 176 trait mainly used in the period 1998-2004 (range +1% to +40% for the period 1998-2002. From 2005, 10% used based on Brookes (2008) which derived from industry (unpublished sources) commercial scale trials and monitoring of impact of the newer, dominant trait Mon 810 in the period 2003-2007. Gomez Barbero & Rodriguez-Corejo (2006) reported an average impact of +5% for Bt 176 used in 2002-2004	+5% to +15% all years	Based on Brookes (2003) the only source to break down these costs. The more recent cost of technology costs derive from industry sources (reflecting the use of Mon 810 technology). Industry sources also confirm value for insecticide cost savings as being representative
Other EU	France +10%, Germany +4%, Portugal +12.5%, Czech Republic +10%, Slovakia +12.3%, Poland +12.5%, Romania 7.1%	Impacts based on average of available impact data in each country	Based on Brookes (2008) which drew on a number of sources. For France 4 sources with average yield impacts of +5% to +17%, for Germany the sole source had average annual impacts of +3.5% and +9.5% over a two year period, for Czech Republic three studies identified average impacts in 2005 of an average of 10% and a range of +5% to +20%; for Portugal, commercial trial and plot monitoring reported +12% in 2005 and between +8% and +17% in 2006; in Slovakia based on trials for 2003-2007 and 2006/07 plantings with yield gains averaging between +10% and +14.7%; in Poland based on variety trial tests 2005 and commercial trials 2006 which had a range of +2% to +26%; Romania based on estimated impact by industry sources for the 2007 year	France and Czech Republic +5% to +15% all years, Germany +2% to +6% all years, Romania +5% to +10%, all other countries +10% to +15% all years	Data derived from the same source(s) referred to for yield

REFERENCES

Abel C (2006) Czech in time for GM crops, Farmers weekly (UK) 3 November 2006, 145 (18), 36-38.

AGPM/Arvalis (2006) Programme PACB 2006-Annexe 1: Mais OGM en plein champ: des résultats probants.

Alcade E (1999) Symposium de Sanidad Vegetal. Sevilla., FULL REF

Bereś P (In press) Effects of chemical control of the European corn borer (*Ostrinia nubilalis* Hbn). In South-Eastern Poland in 2003-2005. J. Plant Protection Res. (submitted for publication in 2006).

Bakan B, Melcion D, Richard-Molard D and Canagnier B (2002) Fungal growth and fusarium mycotoxin content in isogenic traditional maize and GM maize grown in France and Sapin, J Agric Food Chem, 50, 728-731.

Berés P and Lisowicz, F (2005) Effectiveness of *Thrichoramma* spp. in maize protection against European corn borer (*Ostrinia nubilalis* Hbn.) in ecological farms. Progress in Plant Protection/Postepy W Ochronie Roslin 45, 47-51.

Brookes G (2003) The farm level impact of using Bt maize in Spain, 7th ICABR conference on public goods and public policy for agricultural biotechnology, Ravello, Italy. Also on http://www.pgeconomics.co.uk (accessed April 2009).

Brookes G (2005a) The possible impact of using GM agronomic traits in Polish arable crops, 9th ICABR conference on public goods and public policy for agricultural biotechnology, Ravello, Italy, http://www.pgeconomics.co.uk (accessed April 2009).

Brookes G (2005b) Staying competitive in the global and European maize market. http://www.pgeconomics.co.uk (accessed April 2009).

Brookes G (2007) The potential role of GM cost reducing technology in helping the Slovak arable cropping sector remain competitive, PG Economics, Dorchester, UK, http://www.pgeconomics.co.uk (accessed April 2009).

Brookes G (2008) The impact of using GM insect resistant maize in Europe since 1998, International Journal of Biotechnology, vol 10, 2/3

Brookes G (2009) European arable crop profit margins, 2008-09 6th editions, GBC Ltd, Gloucester, UK.

Brookes G and Barfoot P (2009) GM crops: global socio-economic and environmental impacts 1996-2007, PG Economics, forthcoming.

Cagan (2005) Data on relationship between ECB infestation and yield reductions in corn, unpublished, Agricultural University of Nitra, personal communication via Monsanto Company.

Carpenter J et al (2002) Comparative environmental impacts of biotechnology-derived and traditional soybeans, corn and cotton crops, CAST, Iowa, USA

Daems W, Demont M, Muska F, Sonkups J and Tollens E (2006) Potential impact of biotechnology in Eastern Europe: transgenic maize, sugar beet and oilseed rape in the Czech Republic, 10th ICABR conference on agricultural biotechnology, Ravello, Italy.

Degenhardt H, Horstmann F and Mulleder N (2003) Bt maize in Germany: experience with cultivation from 1998 to 2002, Mais 2/2003.

Délos M, Baubet F, Bombarde M, Guery B, Weissemberger, A, Declercq J (2006) Bilan phytosanitaire du maïs en 2005; Ravageurs en France; surtout ceux du sol. Phytoma 592, 42-44.

Demont M and Tollens E (2003) Impact of biotechnology in Europe: the first four years of Bt maize adoption in Spain, EUWAB-project, Dept of Agricultural and Environmental Economics, K U Leuven, Belgium. http://www.agr.kuleuven.ac.be/aee/clo/wp/demont2003h.pdf (accessed January 2007).

Demont M and Tollens E (2005) Potential impact of biotechnology in Eastern Europe: transgenic maize, sugar beet and oilseed rape in Hungary. Katholieke Universiteit Leuven. http://www.agr.kuleuven.ac.be/aee/clo/ep/demont2005a.pdf (accessed January 2007).

Deutscher Bundestag (2006) Drucksache 16/3059, October 2006.

Gianessi L, Sankala S and Reigner N (2004) Potential impact for improving pest management in European Agriculture: maize case study. http://www.ncfap.org (accessed January 2007).

GMO-compass website (2007) http://www.gmo-compass.org (accessed January 2007).

Gomez-Barbero and Rodriguez-Cereozo (2006a) The adoption of GM insect-resistant Bt maize in Spain: an empirical approach, 10th ICABR conference on agricultural biotechnology, Ravello, Italy, July 2006.

Gomez-Barbero and Rodriguez-Cereozo (2006b) Economic impact of dominant GM crops worldwide: a review, EUR 22574. JRC, Sevilla, Spain http://www.jrc.es/home/pages/detail.cfm?prs=1458 (accessed January 2007).

Grenouillet C (2006) Intérêt du maïs Bt Yieldgard pour limiter le risque de développement de fusarioses des épis et la présence de mycotoxines dans les grains, AFPP 8TH conférence sur les maladies des plantes, Tours, France, December 5-6, 2006.

James C (1996 - 2008) Global status of transgenic crops, various global review briefs from 1996 to 2008, ISAAA. http://www.isaaa.org (accessed April 2009).

Kovach, J., C. Petzoldt, J. Degni and J. Tette (1992). A method to measure the environmental impact of pesticides. New York's Food and Life Sciences Bulletin. NYS Agricul. Exp. Sta. Cornell University, Geneva, NY, 139. 8 pp. annually updated

Labatte J et al. (1996) Field evaluation of and modelling the impact of three control methods on the larval dynamics of Ostrinia nubilalis, Journal of Economic Entomology, 89, 852-62..

Lisowicz F (2001) The occurrence of economicaly important maize pests in South-Eastern Poland. J. Plant Protection Res. 41, 250-255.

Lisowicz F (2003) The occurrence and the effects of European corn borer (*Ostrinia nubilalis* Hbn.) control on corn crop in Przeworsk region in 2001-2002. J. Plant Protection Res. 43, 399-403.

Magg T, Bohn M, Klein D, Merditaj V and Melchinger A (2003) Concentration of moniliformin produced by Fusarium species in grains of transgenic Bt maize hybrids compared to their isogenic counterparts and commercial varieties under European corn borer pressure, Plant Breeding 122, 322-327.

Monsanto Company (2007) unpublished trial results from several years in Spain, Portugal, France, Czech Republic, Poland and Slovakia.

Papst C, Utz H, Melchinger A, Eder J, Magg T, Klein D and Bohn M (2005) Mycotoxins produced by Fusarium spp. In isogenic Bt vs. non-Bt maize hybrids under European corn borer pressure, American Journal of Agronomy 97, 219-224.

Poeydemenge C (2006) Les bénéfices du maïs Bt observés en France. Presentation to the SEPROMA General Assembly, 21 September 2006. Also, Poeydemenge C (2006) Bt maize benefits observed in France, presentation to 10th ICABR conference on agricultural biotechnology, Ravello, Italy, July 2006.

Sanvido O et al (2006) Ecological impacts of GM crops: experiences from 10 years of experimental field research and commercial cultivation, ART, Zurich

Serra J, Lopez A and Salva J (2006) Varietats de blat de moro geneticamente modificades (GM) amb resistencia al barrinadors. Productivitat I alters parameters agronomiques. Dossier Tecnic del DARP, Generalitat de Catalunya 10, 13-18.

Skevos T, Fevereiro P & Wesseler J (2009) Environmental regulations and agricultural production: the case of Bt corn production in Portugal, Wageningen University, Netherlands

Tekiela A and Gabarkiewicz R (2006) Fusarium spp. occurrence and mycotoxin content in grain of GM corn varieties, unpublished, Institute of Plant Protection, Rzeszow, and Monsanto Poland, Warsaw.