The farm level impact of using GM agronomic traits in Polish arable crops

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March 2005

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Executive summary and conclusions

This paper examines the potential commercial farm level impact of using genetically modified (GM) arable crops in Poland. It focuses on three crops important to Poland (oilseed rape, sugar beet and maize) and the two most widely introduced GM traits (herbicide tolerance and insect resistance (Bt))[1].

The results are based on a combination of desk research/analysis of Polish agronomic, economic, scientific and trials data. Feedback to informal questionnaires was also obtained from specialists in the input supply sector and the research community in Poland.

Production and profitability base
The agricultural sector is important to the Polish economy. It accounted for 7% of total gross domestic product and employed 2.6 million people (18% of total employment) in 2003.

Within the sector, the area planted to oilseed rape, sugar beet and maize accounted for 8.1% of the total utilised agricultural area in 2003. The production level value of the three crops was approximately €857 million in 2003 (equal to 7.2% of gross agricultural output).

Compared to average performance of mainstream producers in countries such as Germany and France, yields, levels of profitability[2] and variable costs of production are lower in Poland (see section 2).

EU accession and the future production base
From EU accession to 2011/12, when full transition to the EU's Common Agricultural Policy (CAP) is completed, the key points of relevance for crop performance and profitability are likely to be:

- Levels of support for agriculture will be higher than existed prior to accession. The receipt of direct aids will provide additional income and should lead to higher investment in agriculture, both in terms of fixed assets (eg, machinery, crop storage) and more efficient use of variable inputs (eg, new varieties and pesticides). As a result, levels of technical performance should improve and an element of 'closing the productivity gap' with longer standing EU member states should occur over a number of years;
- Polish agriculture will operate in a highly competitive market. In order to remain as competitive as possible in this market, many producers are likely to increasingly explore all forms of new technology that can assist them (eg, through yield enhancement, cost reductions), especially as accession is likely to raise the real costs of land and labour inputs;
- There will be accelerated structural change (consolidation of holdings, increase in the average size of farms).

With regard to the three crops evaluated in the present study, our <u>qualitative assessments</u> for plantings in five years time are increases of 20% and 30% respectively for oilseed rape and maize, and for a decrease of about 10% for sugar beet (relative to 2003 plantings: see section 2.3 for further details).

Impact of using GM technology at the farm level
Drawing on a review of literature on the impact of relevant commercially grown GM crops and trials, both in Poland and other parts of Europe, Table 1 summarises the likely impact of using GM

[1] The important arable crops of wheat and potatoes are not examined in this paper because GM traits in these crops are unlikely to become available to Polish farmers for at least 7-10 years whereas GM traits in oilseed rape, sugar beet and maize could become available within 3-5 years
[2] Even after taking into account the provision of the full rate of direct payments available to EU 15 arable farmers

herbicide tolerant oilseed rape, sugar beet and maize, and insect resistant maize in Poland. The reader should note that all analysis relates to application by commercial farms in Poland and does not cover small-scale subsistence farms. All analysis also assumes that the GM technology is made available in leading varieties adapted to Polish agronomic conditions and Polish farmers are able to make choices about whether to plant GM crops according to technical and agronomic performance criteria and market requirements. As such, this assumes that co-existence conditions for the planting of GM crops in Poland are practical and proportionate.

The key points to note are as follows[3]:

- Significant yield gains are likely from using herbicide tolerant oilseed rape and sugar beet. These arise from improved weed control and reduced phyto-toxic effects of herbicides that can 'knock-back' plant growth. Also, in some cases (eg, Invigor herbicide tolerant oilseed rape), the trait provides additional hybrid vigour. Yield gains may also arise from using Bt maize, although this extent will depend upon the level of pest infestation, which varies by locality and year;
- Additional revenues may arise for users of herbicide tolerant oilseed rape via reduced levels of harvest losses and higher oil content;
- The impact on the costs of production for each crop varies. Users of GM oilseed rape are likely to experience reduced levels of costs even after paying for the new technology. In sugar beet, there is likely to be little change to net average costs of production, and for maize growers some users may find that average variable costs decrease whilst for others costs increase;
- Substantial increases in average gross margin profitability are likely to arise for users of GM herbicide tolerant oilseed rape (+€60/ha to +€135/ha), sugar beet (+€184/ha to +€362/ha) and maize[4] (+€35/ha to +€78/ha). The impact of using Bt maize will vary according to the level of pest infestation, with some farms showing net gains in profitability (of up to +€22/ha) whilst others could make small net losses (farmers with low levels of infestation in a particular year);
- The technology offers benefits to farms of all sizes. Small farms have been some of the most enthusiastic adopters of GM traits due to their simplicity and very low capital costs. This is important in the Polish context where the average size of commercial farm is small by comparison with farms in many others parts of the EU;
- The technology offers additional intangible benefits such as increased management flexibility and simplicity;
- Finding outlets for GM derived crops is likely to be fairly straightforward, especially in the feed sector. Whilst markets currently exist in which there are non GM requirements, these account for a minority of uses and are found mostly in the human food sector. Price differentials between GM and non GM 'equivalent' crops have to date been either very small (eg, 1% to 3% in favour of non GM in the case of soybeans and meal sold into Europe), non existent or, in some cases, in favour of the GM 'equivalent' (when harvest losses are taken into consideration; eg, for some oilseed rape in Canada). New (non food) outlets, especially in the bio-fuels sector are also likely to develop in the next few years, providing increased opportunities for supplying GM oilseed rape and sugar beet.

Overall, the analysis of possible impact at the commercial farm level shows that important benefits are likely to be derived from using the technology, if it is made available in leading varieties adapted to Polish agronomic conditions. It is, however important to note that as weed and pest infestation levels and farm performance vary by farm and year, so will the impact of using GM technology. Some farmers may not derive benefits from using the technology and therefore the application of GM technology is unlikely to be attractive to all farmers. The analysis of impact on

[3] For details of all assumptions used, refer to section 3
[4] Glyphosate tolerant

farm performance does, however suggest that <u>most</u> farmers stand to benefit financially from using the traits examined.

Table 1: Summary of likely commercial farm level impact of using GM technology (per hectare)

	Herbicide tolerant oilseed rape	Herbicide tolerant sugar beet	Herbicide tolerant maize	Insect resistant (grain) maize
Yield	+15% to +20% with Roundup Ready (RR), +25% to +30% with Invigor	+15% to +30%	No expected impact: possibly small improvement	+3% to +6%
Variable costs of production	+8% to +11% with RR, +16% to +28% with Invigor	No change to -5%	Grain maize: -7% to -9% with RR, +2% to +9%; forage maize: -7% to -14% with RR, zero to +8% with Liberty Link (LL)	+7% to +11%
Gross margin profitability	+55% to +82% with RR; +39% to +88% with Invigor	+32% to +62%	+23% to +51% with RR; -31% to +15% with LL	-6% to +14%
Other impacts	Improved quality: reduced impurity levels (both traits) and higher oil content (Invigor). Increased management flexibility, scope for using low/no tillage	Increased management flexibility and better weed control	Increased management flexibility and better weed control	Increased management flexibility, reduced production risk, lower levels of mycotoxins

Sources: Baseline herbicide usage data (AMIS Global), conventional farm income data (Polish Advisory Services (GODR))

Notes:

1. GM traits analysed: Oilseed rape - Roundup Ready (RR) tolerant to the herbicide glyphosate and Invigor (tolerant to the herbicide glufosinate ammonium and having additional hybrid vigour); RR sugar beet, RR and Liberty Link (LL: tolerant to glufosinate ammonium) maize
2. Gross margin profitability for maize = for grain maize

National level impact

The potential impact of using these GM traits at the national level[5] is estimated to be:

- On production: between a +10% and +19% increase in crop output for oilseed rape (of particular value for export and/or as a raw material for bio-fuels). A similar level of increase in production could arise for sugar beet, although as production is heavily influenced by EU production quotas, the adoption of the technology would facilitate reductions in the area devoted to sugar beet and/or additional volumes of beet being available for export without subsidy or for use in non food sectors like bio-ethanol. Production levels of maize would remain unaltered (or possibly increase by just over 1%);
- Based on our estimates of adoption (see section 4.1), the impact on the annual added value for Polish production of the three crops would be between +€55 million and +€116 million. This is equal to an annual increase in gross agricultural output of between +0.46% and +1%;
- In terms of additional farm (gross margin) income there would be an increase of between €67 million and €123 million.

Given that these increases relate to four single pieces of new technology, the impacts are enormous when compared to the small, incremental nature of benefits usually associated with the application of new technology in agriculture.

[5] Based on assumed adoption levels of 65% for herbicide tolerant oilseed rape and sugar beet, 35% for herbicide tolerant maize and 10% for insect resistant maize

Environmental impact

The adoption of GM technology in these three crops is forecast to deliver significant environmental benefits (Table 2). The volume of herbicides applied would fall by between a third and a half. In terms of the toxicity, the switch to using glyphosate and/or glufosinate tolerant crops would result in a net reduction in the toxicity level of products applied to the crops. Using a measure of mammalian toxicity, the total level of doses applied would fall by between 38% and 67% (see section 4.3).

Table 2: Summary of environmental impact of using GM herbicide tolerant crops in Poland

	Baseline 2003	Estimated usage with application of GM technology	% change in usage
Volume of herbicides used (kgs)	4,204,940	1,917,255 to 2,740,755	-35 to -54
LD50 number of doses (millions)	1,685	560 to 1,049	-38 to -67

Sources: Baseline herbicide usage data (AMIS Global)

Notes:

1. Assumed penetration rates for GM crops: oilseed rape and sugar beet 65%, maize 35% (see section 4.1)
2. LD 50 dose rates relates to a measure of mammalian toxicity (see section 4.3 for details)
3. Insect resistant maize is not examined: current use if insecticides on Polish maize crops being negligible

In addition, a potential move to low tillage cultivation will reduce soil disruption, erosion and the release of carbon dioxide from ploughing and hence make a positive contribution to reducing the impact of global warming.

Concluding comments

The data presented in this paper shows that the application and use of the GM agronomic traits of herbicide tolerance to oilseed rape, sugar beet and maize, and insect (Bt) resistance in maize offers Polish agriculture clear farm level benefits. The availability of this technology in leading varieties adapted to Polish conditions, over the next few years, could therefore prove valuable at a time when the sector is adapting to the increasingly open and competitive environment of the EU 25 market.

Polish arable farmers that adopt the technology have the potential to gain more from adoption than their EU 15 counterparts because they are starting from a lower average level of technical efficiency (eg, in terms of average levels of weed control). Therefore they will potentially derive greater productivity (notably yield) gains. As such, the technology offers scope for accelerating the process of ‘productivity catch up’ post EU accession, enabling Polish producers to compete more effectively, and earlier than they might otherwise have been capable of, if they did not use GM technology.

1 Introduction

Currently, no commercial genetically modified (GM) crops are planted in Poland, although some field trials have been conducted for herbicide tolerant oilseed rape and sugar beet. In the next few years, some GM traits may become available to Polish arable farmers, if products are brought through for regulatory approval, the approvals are received and seed companies develop varieties containing these products suitable for Poland. The traits most likely to become available first are herbicide tolerant oilseed rape, sugar beet and maize and insect resistant (Bt) maize.

This paper examines the potential farm level impact of planting these GM crops in Poland. Readers should note that GM traits in other arable crops of importance to Poland, such as wheat and potatoes are not examined because GM traits in these crops are unlikely to become available to Polish farmers for at least 7-10 years, whilst GM traits in oilseed rape, sugar beet and maize may become available in 3-5 years.

The results are based on a combination of desk research/analysis of Polish agronomic, economic, scientific and trials data. Feedback to informal questionnaires was also obtained from specialists in the input supply sector and the research community in Poland. The research took place in the summer of 2004.

The paper[6] is structured, after this introduction, as follows:

- Section 2: briefly places the crop production base of the three crops in context and examines the likely future direction of production for each crop;
- Section 3: the impact of GM technology at the farm level including an overview of existing research, impact on yield, costs of production, crop quality and profitability;
- Section 4: national level impact of adoption: on production, value and farm level profitability. The impact on the environment is also examined.

2 Production base of relevant arable crops

2.1 General

The agricultural sector is important to the Polish economy. In 2003 the utilised agricultural area (UAA) in Poland was 16.2 million hectares, equal to about 52% of the total land area in the country[7]. Within this about 78% is classified as arable land, with the balance mostly pastureland (the three crops examined in detail in this paper (oilseed rape, sugar beet and maize) accounted for 10.4% of the arable land area in 2003).

Of the total population of 38.2 million, 14.6 million live in rural areas and some 2.6 million people worked in the agricultural sector in 2002 (equal to 18% of total employment). This represents the highest share of total employment accounted for by agriculture across the EU 25 and compares with an average of 4.3% across the EU 15.

The structure of agricultural production is highly fragmented. There are over 18.5 million agricultural holdings over 1 hectare in size, with the average size of holding being only 7.4 hectares. Fifty nine per cent of farms are under 5 hectares in size (these farms account for 36% of the UAA), with only 9.9% of holdings over 15 hectares (accounting for 44.1% of the UAA).

[6] The authors acknowledge funding for the research came from Monsanto Europe SA. The contents of the paper are, however the independent and objective views of the authors and have not been influenced by Monsanto – this was a condition of undertaking the work

[7] The average share of total land area as UAA across the EU 15 is about 40%

The gross output of agriculture in 2003 was 56,264 million Pln (€11,971 million[8]). This was equal to about 7% of total gross domestic product (GDP) in the country. Within this, the output from crop production was 29,701 million Pln (€6,319 million). This is about 4% of total GDP.

2.2 Oilseed rape, sugar beet and maize in Poland

Within the Polish agricultural sector, the area planted to oilseed rape, sugar beet and maize accounted for 8.1% of the total utilised agricultural area in 2003 (Table 3). The production level value of the three crops was approximately €857 million in 2003 (equal to 7.2% of gross agricultural output).

Compared to average performance of mainstream producers in countries such as Germany and France, yields, levels of profitability[9] and variable costs of production are lower in Poland.

Table 3: Summary of key features for oilseed rape, sugar beet and maize in Poland

	Oilseed rape	Sugar beet	Maize
Area (2003: hectares)	426,000	286,000	600,000
Average yield (tonnes/ha)	2.3	35	5.67
Typical gross margin (€/tonne)	154	580	154
Typical base gross margin (€/tonne)	259	809	407
Typical base gross margin in Germany (€/tonne)	439	2,131	545
Average expenditure on crop protection (€/tonne)	85	79	69
Average expenditure on herbicides for weed control (€/tonne)	39	59	66
Value of production (€ million)	216	320	321

Sources: Various: see appendix 1

Notes:

1. Maize area and value of production includes forage maize. All other performance indicators are for grain maize only
2. Performance indicators are for the average performing (in terms of profitability) farm
3. Base gross margin = Revenue from sales less variable costs of seed, fertiliser and crop protection only
4. Base gross margins in Germany do not include any area-based payment

2.3 The future direction of production

2.3.1 General factors affecting farm profitability and the choice of production systems

There are several key factors that influence farm-level profitability for a particular cropping system:

- Short term profit factors (eg, crop yield, output prices, input costs);
- Dynamic factors (short to medium term): these include impacts on subsequent crop yields due to current fertiliser use, weed control, tillage method, crop disease incidence;
- Sustainability factors (eg, pesticide resistance, soil degradation);
- Risk factors (eg, yield and price variability, system flexibility, farmer attitude to risk);

[8] The € to Pln exchange rate used throughout this paper is €1 = 4.7 Pln; a typical rate of exchange in 2003

[9] Even after taking into account the provision of the full rate of direct payments available to EU 15 arable farmers

- Whole farm factors (eg, machinery capacity, finance availability and cost, labour, farmer objectives, knowledge and experience).

How these factors impinge on individual farmers ultimately determines the way in which farms and farming systems are used. Not surprisingly, due to variation in the above five factors, the economic performance of farms can vary widely, both between and within regions. This means that when attempting to examine the potential impact of a new piece of technology (ie, GM cost reducing technology) there is likely to be significant variation in the impact at a local level. This is clearly shown in relation to the identified impact of commercially grown GM crops in North America and Spain.

Also, it is important to recognise that when considering different possible rates of application of farming inputs to a crop, there may be a reasonably wide range of input levels either side of the 'economic optimum' that delivers profit levels that are only marginally different from that attained at the optimum. In other words, there can be a reasonable margin for error, and scope for flexibility in choosing input levels, without substantially reducing profits.

2.3.2 EU accession and the future production base

Looking forward several years when GM agronomic traits in the three crops may become commercially available, it is important to consider how the baseline of production for these crops would look compared to 2004/05. This covers an important period for Polish agriculture as full transition of the EU's Common Agricultural Policy (CAP) will take place in the period to 2011/2012. This is examined in detail in Appendix 2.

Drawing on the analysis of Appendix 2, the key points of relevance for crop performance and profitability are likely to be:

- Levels of support for agriculture will be higher than existed prior to accession. The receipt of direct aids will provide additional income and should lead to higher investment in agriculture, both in terms of fixed assets (eg, machinery, crop storage) and more efficient use of variable inputs (eg, new varieties and pesticides). As a result, levels of technical performance should improve and an element of 'closing the productivity gap' with longer standing EU member states should occur over a number of years;
- Polish agriculture will operate in a highly competitive market. In order to remain as competitive as possible in this market, many producers are likely to increasingly explore all forms of new technology that can assist them (eg, through yield enhancement, cost reductions), especially as accession is likely to raise the real costs of land and labour inputs;
- There will be accelerated structural change (consolidation of holdings, increase in the average size of farms).

With regard to the three crops evaluated in the present study, our <u>qualitative assessments</u> for plantings in five years time are increases of 20% and 30% respectively for oilseed rape and maize, and for a decrease of about 10% for sugar beet (relative to 2003 plantings: see Appendix 2 for further details).

3 Impact of using GM technology in Polish arable crops

This section examines the possible impact of using GM technology in the Polish arable cropping sector. The research concentrates on the three main arable crops for which GM traits could be developed for Polish growers and are likely to approved and commercialised for use in the European Union over the next few years[10]. These traits are:

- Herbicide tolerant and novel hybrid (higher yielding) oilseed rape;
- Herbicide tolerant sugar beet;
- Herbicide tolerant maize;
- Insect resistant (Bt) maize.

These are examined further in the sub-sections below. The readers should note that all analysis presented relates to commercial farms in Poland and excludes small-scale subsistence farms[11]. All analysis also assumes that Polish farmers are able to make choices about whether to plant GM crops according to technical and agronomic performance criteria and market requirements. As such, this assumes that co-existence conditions for the planting of GM crops in Poland are practical and proportionate.

3.1 GM herbicide tolerant and hybrid vigour oilseed rape

3.1.1 Evidence of impact

a) Commercial experience

Most of the empirical evidence relating to impact has focused on glyphosate tolerant spring oilseed rape (the most widely grown GM oilseed rape in North America). Impact on yield varies according to local conditions. On the evidence available (the most comprehensive study of actual commercial impact is in Canada[12]), there have been, on average, positive yield and profitability gains. The rate of adoption has been substantial with two-thirds of the Canadian canola area and 84% of the US canola area being GM varieties in 2003. In global terms, 16% of the total oilseed rape area were planted to GM varieties in 2003[13].

b) Pre-commercialisation: relevant trials in Europe

In the European context of winter oilseed rape, there is limited data available (the GM crop is not grown commercially):

- Estimates of the possible impact of glyphosate tolerant oilseed rape in France in 1998 (Messean) identified a yield improvement of 15%;
- Farm level trials conducted in 2001 and 2002 of glufosinate tolerant oilseed rape (also containing improved GM hybrid vigour) have shown yield gains of 9%-14% for winter oilseed rape and 22% for spring oilseed rape (Bayer CropScience 2003) relative to current commonly planted varieties;
- estimates of possible impact in Australia are +10% to +15% relative to open pollinated varieties (Zand & Beckie 2002)[14];
- In Poland unpublished trials results from 1998 to 2000 of glyphosate tolerant oilseed rape identified yield gains of 15% to 20%.

Impact on costs of production and profitability of herbicide tolerant oilseed rape (in the absence of GM derived hybrid vigour[15]) in North America has shown positive and negative effects, although

[10] As indicated in the introduction, the important Polish crops of wheat and potatoes are not examined because GM traits in these crops are unlikely to become available to Polish farmers for 7-10 years
[11] Whilst accounting for a majority of farms in Poland, subsistence farms account for only a small share of total crop production
[12] Canola Council 2001
[13] Source: James 2003
[14] The forecast average yield impact across the Australian oilseed rape crop inclusive of use of both glyphosate and glufosinate tolerant varieties is +8% (Nelson 2003)

on balance the net impact on profitability has probably been positive. For some farmers costs of production have increased post adoption, mainly because of the cost of the technology, although yield improvements have tended to outweigh the cost increases to produce a net positive return. There are inevitably instances of some farmers who have made greater levels of savings or profitability improvements and others who have experienced more limited benefits (and possibly net negative impacts). Where farmers have experienced low levels of positive returns these are often farms for which the level of weed problems have tended to be limited.

Impact on costs and profitability, in the Polish context, has not yet been fully undertaken and published. Trials results to date suggest that use of glyphosate tolerant oilseed rape should have financial advantages over a complete conventional herbicide programme. In Australia, the forecast impact (Nelson 2003) is for a 3% saving on total variable costs (assuming a technology cost of Aus $25/ha).

Other benefits are also possible, which may be considered by growers to be as important (if not more important) than increases in profitability. These include[16]:

- Increased management flexibility and convenience;
- Increased crop rotation flexibility;
- Lower labour, machinery, fuel and harvesting costs.

Possible negative impact issues associated with weed resistance build-up, out-crossing and herbicide resistant volunteers have been raised, but there is a lack of representative data and research to support these concerns and the reported incidence has been of a very limited nature. The current dominance of GM oilseed rape within total oilseed rape production in Canada and the USA, and the very limited citing of problems reported by farmers suggest that these issues are currently not significant to growers, are not deterring uptake of the technology, are manageable and incur marginal additional (if any) costs.

3.1.2 Technology cost and demand issues

The cost of the technology will impact on costs and profitability; the higher the cost, the lower the positive impact on returns and vice versa. Drawing on Canadian experience, the cost of the technology could be in the region of €30 to €40/ha[17]. The price of the technology in Poland will, however, not necessarily be the same as in North America (especially as the technology may well offer GM derived (higher yielding) hybrid vigour). Commercial factors will determine the pricing, including estimates of the possible farm level benefit and the nature of competition and pricing of alternative (non GM) seed. Some illustrations of possible benefits are presented in the sub-section 3.1.3 below.

Issues such as whether there is a market for GM oilseed rape and is there a price differential between GM and non GM oilseed rape will also have to be taken into consideration by Polish farmers when evaluating the technology. As a significant share of oilseed rape usage in the non food sectors (industrial and feed), there is likely to be a reasonable market for GM oilseed rape[18], even if it was to be excluded from markets that service direct human food consumption.

Price differentials between GM and non GM oilseed rape may also affect the assessments made by farmers considering adoption. It is, however important to recognise that farm level price differentials between GM and non GM crops in general have tended to be very low and not always

[15] Invigor oilseed rape varieties accounted for about 20% of GM oilseed rape plantings in 2002. This means that studies of impact in North America are largely examining the impact of glyphosate tolerant oilseed rape
[16] Quantification of some of these has been made in the Canola Council study for Canada
[17] It is interesting to note, in contrast that Nelson (2003) assumes a technology cost in Australia of about €14 to €15/ha
[18] See for example, Brookes G & Barfoot P (2004) Coexistence of GM and non GM arable crops: the non GM and organic context in the EU; PG Economics (2003) Consultancy support for the analysis of the impact of GM crops on UK farm profitability – both papers available on www.pgeconomics.co.uk

in favour of non GM supplies. The Canadian Canola Council study, for example found that GM growers were benefiting from harvest yield premia from having less seed rejected or downgraded because of impurities due to weed material. Trials of Invigor oilseed rape in the UK and Australia are also showing higher oil content in the GM crop, which delivers price premia to growers.

3.1.3 Possible impact in Poland

The two possible GM herbicide tolerant oilseed rape products that may become available to Polish farmers are:

- Invigor oilseed rape, which is tolerant to the herbicide glufosinate-ammonium;
- Roundup Ready oilseed rape, which is tolerant to the herbicide glyphosate.

Drawing on the review of commercial experience to date and trials in Europe (including Poland) and assuming that these traits are made available in leading varieties adapted to Polish agronomic conditions, the possible impact of using herbicide tolerant (and possibly GM hybrid) oilseed rape is examined below.

a) Possible reductions in production costs

Currently, the average performing commercial Polish grower spends about €70/ha on herbicides made with two spray runs (comprising €39/ha for weed control and the balance for dessication)[19]. If glyphosate is used and applied (as used in Polish trials) at 2 spray runs of 1.5 litres/run, the cost of treatment for weed control (excluding the cost of the spray runs which are estimated to the same pre and post use of the GM technology) would be between €7/ha and €10/ha depending on whether branded Roundup or a generic glyphosate is used. This is a saving of between €29/ha and €32/ha. For the below average performing grower, currently spending less on herbicides for weed control (an average of €13/ha), there would be only marginal savings in weed control costs, although more effective weed control and higher yields would be achieved. Conversely, for the above average performer, spending more on herbicides and possibly treating his/her current crop with 3 spray runs, their would be savings.

If Invigor oilseed rape is used, glufosinate is typically recommended for application at between 2-3 litres/ha at a cost of €16/litre[20]. Therefore two applications would cost €64-€96/ha. Inclusive of herbicides used for desiccation of the crop, total herbicide costs would be an average of €95-€127/ha. Based on these costs, average herbicide costs would increase by €25-€57/ha as a result of using glufosinate tolerant oilseed rape. Cost savings would therefore only accrue to a limited number of current growers with significantly above average expenditure on herbicides (where weeds are a major limiting factor on yield).

It is also important to recognise that the cost of the technology has to be taken into the cost considerations referred to above. Based on an assumed additional cost (seed premium) of €30-€40/ha (see section 3.1.2), this would result in the net increases in costs of using the technology for the average performing farmer to be:

- For glyphosate tolerant oilseed rape, the impact on the variable costs of seed and crop protection expenditure would be between +€29/ha to +€42/ha;
- For glufosinate tolerant oilseed rape, the impact would be between +€55/ha to -€97/ha.
- Using these assumptions for the volumes of herbicide used, current prices of the herbicides and the assumed price of the technology, this suggests that production cost savings would only arise for a minority of growers using glyphosate tolerant oilseed rape (eg, above average performers who have an average crop protection expenditure of €108/ha and choose to use glyphosate tolerant oilseed rape). For most growers (and all

[19] These figures are representative of average performers (ie, the median performer). In terms of the mean level of expenditure on herbicides, herbicide use survey data suggests a lower mean value of €44/ha

[20] 2004 price based on 75 Pln/litre

growers considering the use of Invigor oilseed rape) interest in take-up of the technology will be driven by other factors such as yield (see below).

b) Possible yield increases
The literature review identified scope for yield benefits coming from:

- *More efficient weed control.* In Poland trials of glyphosate tolerant oilseed rape have shown that yield gains of 15%-20% are likely, suggesting that weed control in conventional oilseed rape production is poor. Trials of Invigor oilseed rape in countries like the UK, where weed control is considered to be good and yield gains of 9% to 15% were identified, suggest that if applied in Poland, the net yield gains could be 25% to 30%. Clearly, the scope for delivering yield enhancements in Poland will vary by region, soil types, the extent to which there may be particularly bad weed infestations;
- *A reduction in "knock-back".* Currently herbicide treatments may damage crop productivity by between 1% and 5% of yield through, for example leaf scorching or later emergence of crops because of the impact of residual herbicides in the soil.

In the Polish context, the impact on revenues of a yield gain of +15% to +30% would be equal to an increase of roughly €76/ha to +€152/ha (based on an average pre-adoption yield of 2.3 tonnes/ha and a price of €220/tonne).

c) Improved quality of oilseed
Producer gains could materialise from two main sources:

- *Reduced losses at harvest.* Growers experience varying degrees of pod shatter and subsequent crop losses. A combination of a cleaner crop without weeds and a more uniform crop[21] may result in higher harvestable yield. Drawing on the Canola Council work (2001) farmers have seen 1.27% less of their harvested yield being subject to discounts by crushers. Based on 2003 oilseed rape prices in Poland (€220/tonne) this is equivalent to €2.8/tonne and, would at the higher yields obtained from the GM technology, be equal to a €7.4 to €8.37/ha gain in income;
- *Higher oil content.* Evidence from both Australia (Nelson 2003) and the UK (farm level trials: Bayer CropScience 2003) has found that Invigor oilseed rape is delivering a 1.5%-2% increase in oil content. As farmers are usually paid premia/penalties by crushers according to the oil content of seed around the baseline of 40%, this increase in oil content may offer another form of revenue enhancement. For example, relative to a base oil content of 40% and assuming a base price of €220/tonne, a 1.5% increase in oil content is worth an additional €3.3 to €4.4/tonne.

d) Increased management flexibility
The majority (60%) of the herbicide used on oilseed rape in Poland is pre-emergent. This is considered to be more risky than post emergent spraying, is very weather dependent and usually needs to be carried out at harvest time or soon after when labour time may be limited. Switching to applying herbicide post-emergent could replace the pre-emergent application to a time when labour resources are more readily available. Local circumstance will determine whether or not this is relevant.

e) Benefits to subsequent crops
This is an area where there may be benefits, if herbicide resistant weeds are a problem (eg, resistance of windgrass to chlorosulfuron) and these require a dedicated herbicide application in the following crop (eg, wheat). A coordinated approach with different broad-spectrum herbicides being used in oilseed rape and wheat may therefore reduce herbicide costs in the crop rotation.

[21] A more uniform crop in terms of consistency relates to readiness for harvest rather than one part a crop being ready for harvest before other parts. As a result greater uniformity reduces incidence of pod shatter and loss of seed at harvest

A glyphosate or glufosinate based programme could reduce the use of residual herbicides which can have a carry-over effect requiring ploughing before the sowing of a follow-on wheat crop.

f) Conservation/low tillage
The availability of a simple weed control system, based on glyphosate or glufosinate, may facilitate some farmers moving to conservation/low tillage cultivation practices, which could result in cost saving, environmental gains and reduced energy use.

g) Glyphosate or glufosinate tolerant oilseed rape volunteers, gene escape and weed resistance
Oilseed rape volunteers, although sometimes present in cereals, are not considered to be a significant problem to farmers because farmers simply ensure that herbicide treatments in cereals include a herbicide in the tank mix that deals with them. Volunteers can be a problem in subsequent rapeseed crops, in peas, sugar beet and potatoes although as these do not generally follow an oilseed rape crop (it is common practice to follow oilseed rape with winter wheat), the problem tends to be minor. The possible development of glyphosate or glufosinate resistant weed rape problems in these subsequent crops may occur but will probably be a very minor problem/issue. Where necessary an alternative/different herbicide would be used within an existing tank mix, resulting in some minor additional cost[22] (relative to the herbicide costs incurred in year one of adoption). Any glyphosate or glufosinate tolerant volunteers would also have to be removed by other herbicides used on set-a-side (a new requirement for Polish farmers after EU accession), again possibly resulting in a small additional cost of using herbicides relative to the baseline, year one costs[23].

If some farmers were to require some additional herbicide used in a subsequent crop to deal with these problems, this might add a very small amount to total herbicide costs (eg, an extra 5%, which is equivalent to a 1% increase in total variable costs).

h) Summary of impact (quantifiable)
In summary, Table 4 shows that adoption of herbicide tolerant oilseed rape in Poland has the potential to deliver substantial improvements in gross margin profitability. Use of Roundup Ready oilseed rape could potentially result in a €84/ha to €126/ha (+55% to +82%) increase in gross margin, and use of Invigor oilseed rape could result in a €60/ha to €135/ha (+39% to +88%) increase in gross margin.

Table 4: Summary of impact of using GM oilseed rape on farm profitability in Poland (€/ha)

	Conventional (average performance)	Glyphosate tolerant (Roundup-Ready)	Glufosinate tolerant and hybrid (Invigor)
Price (€/tonne)	220	227.45-228.37	230.7-232.77
Yield (tonnes/ha)	2.3	2.645-2.76	2.875-2.99
Sales revenue	506	601-630	663-696
Variable costs			
Seed	20	50-60	50-60
Fertiliser	142	142	142
Crop Protection	85	53-56	110-142
Cost of spraying	30	30	30
Harvesting	75	75	75
Total variable costs	352	350-363	407-449
Base variable costs	247	245-258	302-344
Gross margin	**154**	**238-280**	**214-289**
Base gross margin	**259**	**343-385**	**319-394**

[22] There would probably not need to be an additional spray application
[23] This assumes that in the baseline glyphosate in used on set-aside to keep the land in 'good agricultural practice'

Source: Conventional performance data derived from the Polish Farm Advisory Service (WODR)
Notes:
1. Price of oilseed rape: premia for Roundup Ready based on reduced levels of impurities (1.27%), Invigor based on reduced levels of impurities and higher oil content (3%-4%)
2. Assumed yield improvements: 15%-20% for Roundup Ready, 25%-30% for Invigor
3. Recommended spray regimes for both products assumed to be 2 post emergent sprays
4. Cost of technology (seed premium) assumed to be +€30-+€40/ha
5. Cost of herbicides for weed control in conventional crop based on €39/ha, leaving €46/ha for desiccants and other crop protection products
6. Cost of herbicides based on recommended dose rates (used in relevant trials) and 2004 prices

3.2 GM herbicide tolerant sugar beet

3.2.1 Evidence of impact
A summary of literature on the possible impact of herbicide tolerant sugar beet (no commercial crop is currently grown in the world) that draws from trials and research shows the following:

- Impact on yield is likely to be positive and within the range of +15 to +30% (based on trials in Poland). This yield improvement identified in Polish trials is greater than the levels identified in trials in the UK and the USA (+5% and +15%) mainly because of the poorer average levels of weed control in conventional Polish sugar beet crops relative to crops in the UK and USA. In effect, Polish farmers could obtain yield gains from a combination of improved weed control and reduced phytotoxicity problems in the crop (less spraying and a reduced variety of herbicides used) whereas their UK/US counterparts would gain from reduced phytotoxicity and (more limited) improved weed control. Yield enhancement is likely to be greatest where farmers experience significant weed problems and have difficulty in maintaining reasonable control. Reduced levels of yield relative to conventional crops may, however arise if the technology is sold (possibly initially) in varieties that are not all leading varieties and where the weed control in the herbicide tolerant crop is left late (ie, after weeds have had time to become established). The latter case scenario may arise when farmers experiment with timing of spraying during early adoption and would probably not occur once experience has been gained;
- Impact on costs of production and profitability would be expected to be positive (see section 3.2.3). Clearly the extent to which profitability benefits will occur will depend on the technology fee charged (see below) and the level of cost savings experienced by growers. The greatest savings are likely to be where farmers currently have above average weed problems and control costs and the lowest level of savings will be with farmers with below average weed control costs/problems. In some cases, farmers with good weed control, and lower than average costs of control would probably not derive any benefit after paying the technology fee/seed premium;
- Some of the more intangible benefits cited in herbicide tolerant crops like oilseed rape are likely to important factors affecting adoption by farmers. These include convenience, gains from switching to minimum tillage and benefits in rotations/follow on crops like cereals, given that sugar beet is often considered to be a 'cleaning crop' in rotations.

3.2.2 Technology cost and demand issues
As with the application of GM technology to any crop, the impact on costs and profitability will be affected by the cost of technology. Drawing on the only work to date to impute a possible cost of the technology (in the UK: May 2003), this could be in the region of €30 to €40/ha. Some illustrations of possible impact based on this level of technology fee are presented in sub-section 3.2.3 below, although it is again highlighted that the price of the technology in Poland will be determined according to commercial criteria at the time of launch and may not be equal to the level assumed in this analysis.

Whether there is a market for GM sugar beet and whether there is a price differential between GM and non GM sugar beet are factors that Polish farmers will take into consideration when examining whether to use the technology.

a) *Will there be a market for GM sugar beet ?* Analysis reviewed for this paper[24] suggests that as the vast majority of sugar usage is used for human food, this is likely to be a crop in which GM crop adoption will be potentially slow and limited (relative to for example maize or oilseed rape). The important influence of sugar processors as the virtual 'monopoly buyers' of sugar beet will also play an important role in determining adoption. Whilst current policy of most EU-based sugar beet processors is not wanting to use GM sugar beet operates, there will be no domestic market for GM sugar. Nevertheless, if processors were to change their commercial policies (likely in the light of increased import competition following the full implementation of the Everything but Arms trade agreement with the 46 Least Developed Countries in 2008/09, upcoming reform of the EU sugar regime, and/or to service new non food market opportunities that may well develop (notably bio-ethanol)), it is probable that a market will develop where GM sugar can be sold. In addition, it is possible that, if the demand for bio ethanol were to develop in the EU, export market opportunities for Polish GM sugar could develop.
b) *Price differentials between GM and non GM sugar beet*. As applies to all GM crops, any assessment of the possible impact on profitability should take into account the limited nature of current farm level price differentials between GM and non GM crops and that the price differential is not always in favour of non GM supplies (see section 3.1).

3.2.3 Possible impact in Poland

Both GM herbicide tolerant sugar beet and fodder beet have been extensively tested in the UK, France and Denmark. Trials have also taken place in Poland between 1998 and 2000. Drawing on these findings and assuming that the trait is made available in leading varieties adapted to Polish agronomic conditions, the following impacts could occur:

- A reduction in variable costs associated mostly with lower level of expenditure on herbicides. Based on the trials spray regimes used in Poland (2 or 3 spray runs of 2 litres of glyphosate) and 2004 prices for glyphosate (Roundup brand and generic versions), the average cost of herbicides applied would fall from about €59/ha to between €9ha and €13/ha if 2 sprays are used, and to between €14/ha and €19/ha if 3 spray runs are used. If farmers achieved reasonable weed control on a 2 spray run regime this would also deliver an additional saving of about €6/ha from cutting the average number of spray runs from 3 to 2. Assuming a technology fee/seed premium of €30-€40/ha, this would result in an approximate net saving on variable costs of between zero (based on a seed premium of €40/ha and using three spray runs) and €26/ha (based on a seed premium of €30/ha and using two spray runs). For above average performers, with average herbicide expenditure levels of €90/ha, the savings would be larger;
- Based on Polish trials data, an increase in yield within a range of 15% to 30%. At 15% (relative to an average yield of 35 tonnes/ha) this is equal to an additional €168/ha in revenue and at 30% it is equal to an additional €336/ha;
- The net (quantifiable) impact on average sugar beet gross margins of using GM herbicide tolerant sugar beet (Table 5) could be between +€184/ha (+32%) and €362/ha (+62%);
- Possible additional cost savings might materialise from greater management flexibility, adoption of minimum tillage practices, improved rotational weed control and reduced stubble control. These possible savings will vary by farm;

[24] For example, Brookes G & Barfoot P (2004) Coexistence of GM and non GM arable crops: the non GM and organic context in the EU; PG Economics (2003) Consultancy support for the analysis of the impact of GM crops on UK farm profitability – both papers available on www.pgeconomics.co.uk

- The possibilities of herbicide tolerant volunteers and resistant weeds developing might add a minor additional herbicide cost relative to the initial glyphosate based treatment (see oilseed rape above, section 3.1.3). In sugar beet this would probably be even less of an issue than in oilseed rape.

Table 5: Impact of using GM glyphosate tolerant sugar beet on Polish sugar beet gross margins (€/ha)

	Conventional (average performance)	GM (glyphosate tolerant)
Price (€/tonne)	32	32
Yield (tonnes/ha)	35	40-25-45.5
Sales revenue	1,120	1,304-1,456
Variable costs		
Seed	113	143-153
Fertiliser	119	119
Crop protection	79	29-39
Cost of spraying	18	12-18
Harvesting	211	211
Total variable costs	540	514-540
Base variable costs	311	291-311
Gross margin	**580**	**764-942**
Base gross margin	**809**	**993-1,165**

Source: Conventional performance data derived from the Polish Farm Advisory Service (WODR)
Notes:

1. Price of sugar beet. The baseline price of €32/tonne is retained for the comparison, because a) the intention is to demonstrate the impact of the technology excluding the impact of joining the EU sugar regime and b) by the time GM sugar beet is possibly made available to Polish farmers the EU sugar regime will have undergone reforms. The proposed reforms would see the minimum price for beet fall from the current EU level of about €47/tonne to about €28/tonne. Given this level of price cut, it is likely (and assumed) that Polish prices will fall back to 2003 levels
2. Yield: range of impact based on +15% to +30%
3. Seed premium based on +€30/ha to +€40/ha
4. Low end of crop protection based on two spray runs of generic glyphosate, high end of range based on three spray runs of Roundup brand
5. Cost of spraying based on two or three spray runs
6. Herbicide costs estimated to be 75% of total crop protection costs for conventional sugar beet (ie, €59/ha), leaving the balance of €20/ha as non herbicide products – these are sprayed on both the conventional and GM crop

3.3 GM maize

3.3.1 GM herbicide tolerant maize

a) Evidence of impact

There is very little published work on the yield impact of herbicide tolerant maize. Research in North America (related to commercial planting experience and trials) and unpublished trials in Europe (EU 15) show a yield neutral impact. We are not aware of any trials of herbicide tolerant maize that have examined yield impacts having taken place in Poland.

If the evidence of trials of other herbicide tolerant crops (oilseed rape and sugar beet) in Poland, (where higher yield impacts were identified than were found in trials in the EU 15, or in commercial experience in North America), is taken as a possible indicator of performance in Poland, then a positive yield impact might arise in Poland. If so, this would arise from improved levels of weed control on farms that currently use sub-optimal levels of herbicide use and/or reductions in the level of 'knock-back' to plant growth that can arise when some post emergent herbicides are used. However, as the average levels of herbicide use on maize crops in Poland is only marginally lower than levels of expenditure and use on maize crops in countries like France, this suggests that levels of weed control in Polish maize crops is probably on a par with EU 15 maize weed control levels[25]. Any positive yield impact would therefore probably be related to reduced 'knock-back'.

The impact on costs of production and profitability will depend on factors such as the level of weed problems, current levels of expenditure on herbicides and the technology fee charged. The greatest savings are likely to be where farmers currently have above average weed problems and control costs (including problems of weed resistance to atrazine) and the lowest level of savings will be with farmers with below average weed control costs/problems. In some cases, farmers with good weed control, and lower than average costs of control would probably not derive any benefit after paying the technology fee/seed premium. In the USA, the cost savings have been estimated to be €33/ha before taking into account the cost of the technology and €21/ha net of the technology cost (seed premium). In addition, the phasing out of the use of atrazine in the EU will also affect the potential impact on costs of using GM technology because the future alternatives to atrazine (which will act as the baseline for comparison) may be more expensive that an atrazine-based control regime (see c) below).

Lastly, some of the more intangible benefits cited in herbicide tolerant crops like oilseed rape will be important factors affecting farmer adoption. These include convenience and simplicity gains from switching to minimum tillage and benefits in rotations/follow on crops.

b) Technology cost and demand issues

The impact on profitability will be affected by the cost of technology. Drawing on commercial experience in North America, this could be in the range of €12/ha to €18/ha. Some illustrations of possible impact based on this level of technology fee are presented in sub-section c) below, although it is again highlighted that the price of the technology in Poland will be determined according to commercial criteria at the time of launch and may not be equal to the level assumed in the analysis below.

Issues such as whether there is a market for GM maize and is there a price differential between GM and non GM maize may also affect use of the technology. Literature that has examined the issue of GM/non GM markets[26], suggests that because of the significant share of grain maize usage is in the feed sector (and all forage maize), there is likely to be a reasonable market for GM maize, even if GM maize and sweetcorn was to be excluded from markets that service direct human food consumption. Price differentials between GM and non GM grain may affect the profitability impact assessments made by farmers considering adoption. However, farm level price differentials between GM and non GM crops in general have tended to be very low and not always in favour of non GM supplies. Also, as a significant proportion of grain maize and most forage maize is consumed on-farm, the crop is not often traded, making this issue largely redundant in any assessment of whether to adopt or not.

c) Possible impact in Poland

The two GM herbicide tolerant maize 'products' that may become available to Polish farmers are:

- Liberty Link maize, which is tolerant to the herbicide glufosinate-ammonium;
- Roundup Ready maize, which is tolerant to the herbicide glyphosate.

The main impacts of using these traits in Poland are examined further below[27].

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[25] This comparable level of average herbicide expenditure on maize crops in Poland probably reflects the widespread use of atrazine as the leading herbicide used for the control of weeds in maize crops in Europe. Atrazine is no longer a patent protected product and therefore is widely available in a variety of generic products and at low prices

[26] For example, Brookes G & Barfoot P (2004) Coexistence of GM and non GM arable crops: the non GM and organic context in the EU; PG Economics (2003) Consultancy support for the analysis of the impact of GM crops on UK farm profitability – both papers available on www.pgeconomics.co.uk

[27] And assuming that these traits are made available in leading varieties adapted to Polish agronomic conditions

Possible reductions in production costs
Expenditure by average performing commercial Polish grain maize farmers on crop protection was €69/ha in 2003, of which €66/ha was on herbicides. This could fall depending weed types, weed pressure and timing of applications in either post-emergent application in the autumn and/or the spring. If glyphosate is used and applied at 2 spray runs of 2 litres/run, the cost of treatment (excluding the cost of the spray runs which are estimated to the same pre and post use of the GM technology) would be between €7/ha and €10/ha depending on whether branded Roundup is used or a generic glyphosate is used. This suggests a (herbicide) cost saving of €53-€57/ha. For the below average performing grower, spending €31/ha (based on 1 treatment of atrazine), the cost savings would be smaller (€18/ha to €22/ha).

If Liberty Link maize is used, glufosinate is typically recommended for application at between 2-3 litres/ha at a cost of €16/litre. Therefore two applications would cost €64-€96/ha. Based on these costs, herbicide costs for the average and above average performing maize grower would either be similar to current levels of expenditure for some farmers or would result in an increase in average herbicide expenditure of up to €30/ha as a result of using glufosinate tolerant maize.

Taking into account the cost of the technology, and based on an assumed additional cost (seed premium) of €12-€18/ha (see section b) above) this would result in the net costs of using the technology for the average and above average performing farmer to be:

- For glyphosate tolerant maize, the impact on the variable costs of seed and crop protection expenditure would be savings of between €35/ha and €45/ha;
- For glufosinate tolerant maize, the impact would be additional costs of between €10/ha and €48/ha.

Using these assumptions for the volumes of herbicide used, current prices of the herbicides and the assumed price of the technology, this suggests that production cost savings would arise for most growers using glyphosate tolerant maize. For below average performing growers, currently spending about €31/ha on herbicides, the impact on costs is between zero and + €9/ha (ie, a possible increase in costs). For growers considering the use of glufosinate tolerant maize, interest in take-up of the technology may be attractive if 2 spray runs are sufficient. If 3 spray runs are required, there would be a net increase in costs making the technology less attractive.

Looking at the post atrazine ban scenario, the cost of the most likely alternative, post-emergent herbicide treatments are either broadly similar (based on the use of the product Titus (active ingredient ronsulfuron)) or slightly more expensive (€73/ha, based on the use of the product Mais Ter (active ingredients antidotium, ronsulfuron and idosulfuron)). The GM herbicide tolerant alternative, could therefore become even more attractive for some farmers.

Possible yield increases
The scope for yield benefits is likely to be limited (see a) above). Possibilities may arise from more efficient weed control (where there is currently limited use of herbicides or resistance has developed to some products (eg, atrazine)) and/or less *"knock-back"*.

Summary of impact (quantifiable)
Summarising the possible impact of using GM herbicide tolerant maize in Poland on farm profitability, Table 6 shows that adoption of the technology has the potential to deliver improvements in gross margin profitability for most maize producers. Use of Roundup Ready maize is likely to deliver the largest net profitability gains (€35/ha to €78/ha equal to +23% to +51%). A similar positive picture applies to the potential impact on the cost of production of forage maize (Table 7).

Table 6: Summary of impact of using GM herbicide tolerant grain maize on farm profitability in Poland (€/ha)

	Conventional: average performance	Glyphosate tolerant (Roundup Ready)	Glufosinate tolerant (Liberty Link)
Price (€/tonne)	118	118	118
Yield (tonnes/ha)	5.67	5.67-5.95	5.67-5.95
Sales revenue	669	669-702	669-702
Variable costs			
Seed	82	94-100	94-100
Fertiliser	111	111	111
Crop Protection	69	12-16	67-99
Other variable costs	253	253	253
Total variable costs	515	470-480	525-563
Base variable costs	262	217-227	272-310
Gross margin	**154**	**189-232**	**106-177**
Base gross margin	**407**	**442-485**	**359-430**

Source: Conventional performance data derived from the Polish Farm Advisory Service (WODR)
Notes:
1. Assumed yield impact is zero to + 5% (the latter based on possible reduction to knock-back)
2. Recommended spray regimes for both products assumed to be 2 post emergent sprays
3. Cost of technology (seed premium) assumed to be +€12 to +€18/ha
4. Cost of herbicides in conventional crop based on €66/ha, leaving €3/ha of other crop protection products
5. Cost of herbicides based on estimated dose rates and 2004 prices

Table 7: Summary of impact of using GM herbicide tolerant forage maize on farm profitability in Poland (€/ha)

	Conventional	Glyphosate tolerant (Roundup Ready)	Glufosinate tolerant (Liberty Link)
Dry yield (tonnes/ha)	10.2	10.2-10.71	10.2-10.71
Variable costs			
Seed	52	64-70	64-70
Fertiliser	162	162	162
Crop Protection	64	19-23	74
Other variable costs	48	48	48
Total variable costs	326	293-303	348-354
Variable cost per tonne	**32.0**	**27.4 to 29.7**	**32.5 to 34.7**

Source: Conventional performance data derived from the Polish Farm Advisory Service (WODR)
Notes:
1. Conventional costs based on extension service data for 2003 (WODR Gdansk)
2. Assumed yield impact is zero to plus 5% (the latter based on possible reduction to knock-back)
3. Recommended spray regimes for both products assumed to be 2 post emergent sprays
4. Cost of technology (seed premium) assumed to be +€12-+€18/ha
5. Cost of herbicides in conventional crop based on €54/ha, leaving €10/ha of other crop protection products
6. Cost of herbicides based on estimated dose rates and 2004 prices

3.3.2 GM insect resistant (Bt) maize

a) Evidence of impact

Commercial experience
Detailed empirical impact analysis is available from Spain, the primary location in the EU where Bt maize has been grown commercially since 1998. Impact on yield, not surprisingly varies according to the level of corn borer infestation, with regions where infestation levels are high recording +10% yield improvements relative to yields obtained if insecticides have been previously used as the main form of pest control. Where no insecticide use has been previously been used, the yield gains from using Bt maize have been +15%. Across Spain as a whole, the average yield improvement from using Bt maize has been about +6%. Impact on costs of

production and profitability has shown positive and negative effects, although on balance the net impact on profitability has been positive. For some farmers costs of production have increased post adoption, mainly because of the cost of the technology and the fact that they had previously not used insecticides to control corn borer problems. Cost savings tend to greatest where insecticides were previously used to control corn borer. Other benefits identified for the technology have been increased management flexibility and convenience, reductions in contractor costs (for spraying) and a contribution to reducing production risk (peace of mind).

Pre-commercialisation: relevant trials in Europe
In the more Northerly/Easterly European context of grain maize production, there is limited data available (the GM crop is not grown commercially[28]). Extensive large plot trials have, however been conducted in Germany, between 1998 and 2002[29]. The findings were similar to those identified in Spain. Yield gains of +12% to +13% were identified relative to previously untreated crops, with the yield gains relative to insecticide treated plots being +3% to +4% (on a base yield of about 9.5 tonnes/ha). Impact on costs of production and profitability of Bt maize in Germany was estimated to be between +€83/ha and +€93/ha.

b) Technology cost and demand issues
The cost of technology will affect the impact of adoption on profitability; the higher the cost, the lower the positive impact on returns and vice versa. Drawing on Spanish experience, the cost of the technology could be in the region of €18-€30/ha. As Spanish prices for the technology are broadly comparable with prices in other countries (eg, USA), it is reasonable to assume that similar prices would be charged in Poland.

Issues such as whether there is a market for GM maize and is there a price differential between GM and non GM maize may also affect use of the technology. The relevant literature reviewed (see section 3.1.2), suggests that there is likely to be a reasonable market for GM maize (in the feed sector), even if GM (grain) maize and sweet corn were to be excluded from markets that service direct human food consumption. Price differentials between GM and non GM maize may also affect the profitability of possible adoption. However, evidence from Spain illustrates that the GM crop has been sold to the feed industry without segregation and has received the same prices as non GM maize.

c) Possible impact in Poland
Drawing on the extensive impact analysis of the technology in Spain, and to a lesser extent Germany[30], the following impacts could occur:

- a reduction in variable costs associated with reduced levels of expenditure on insecticides. This will, however only apply to those Polish grain maize growers who will be using insecticides to control the ECB at the time when GM (Bt) maize becomes commercially available. Evidence of insecticide use in recent years shows negligible use of insecticides by Polish maize growers for ECB control. Against this background, adoption of the technology in Poland is likely to result in a net increase in costs of production, associated with the relevant seed premium/cost of the technology. Based on Spanish costs, this additional cost is likely to be between €18/ha and €30/ha. It should, however also be noted that as ECB is becoming a more prevalent pest in Poland, the use of insecticides to control the pest is likely to occur in the next few years. As such, by the time of possible commercialisation of the Bt technology in grain maize seed suitable for growing in Poland, there may well be some farmers who will derive cost savings from its use (as a replacement for insecticides);

[28] With the exception of a very small area in Germany
[29] We are not aware of any trials having been conducted in Poland
[30] And assuming that this trait is made available in leading varieties adapted to Polish agronomic conditions

- Based on Spanish and German data, an increase in yield within a range of 3% to 6% might be achieved across regions where corn borer is a problem (southern most regions). This could be higher in localities with high levels of infestation. A 3% increase yield, at 2003 prices is equal to an extra €20/ha and a 6% increase in yield is equal to +€40/ha;
- The net (quantifiable) impact on grain maize gross margins of using GM insect resistant maize (Table 8) could be between -€10/ha (-6%) and +€22/ha (+14%) for the Polish grower with average returns and yields. This suggests that Bt technology will only be of benefit to farmers with medium to high levels of ECB infestation. Based on average yields and 2003 prices of maize, the threshold for breakeven from using the technology (excluding consideration of intangible benefits: see below) is a yield gain of about 0.2 tonnes/ha or +3.5%. Clearly for above average performers (with higher average yields) the threshold for adoption works out as a lower % increase (eg, for high performers with average yields of 7.1 tonnes/ha, the threshold for adoption of 0.2 tonnes/ha is +2.8%)
- Possible additional cost savings might materialise from greater management flexibility, improved production risk management and lower levels of mycotoxins (which could result in downgrading or rejection of maize by purchasers).

Table 8: Impact of using GM (Bt) insect resistant maize on average Polish grain maize gross margins (€/ha)

	Conventional	GM (Bt) insect resistant
Price (€/tonne)	118	118
Yield (tonnes/ha)	5.67	5.84-6.01
Sales revenue	669	689-709
Variable costs		
Seed	82	100-112
Fertiliser	111	111
Crop protection	69	69
Other variable costs	253	253
Total variable costs	515	533-545
Base variable costs	262	280-292
Gross margin	**154**	**144-176**
Base margin	**407**	**397-429**

Source: Conventional performance data derived from the Polish Farm Advisory Service (WODR)

Notes:

1. Price of grain maize based on 2003
2. Yield: range of impact based on +3% to +6%
3. Seed premium based on +€18/ha to +€30/ha
4. Crop protection assumed to be unaltered (ie, no treatments for corn borer were being used on the conventional crop)

4 National level impact of using GM arable crops

Building on the evidence presented in section 3, this section briefly examines the possible aggregated impact of using the GM agronomic traits of herbicide tolerance in oilseed rape, maize and sugar beet and insect resistance in maize.

4.1 Production

The estimated impact on Polish production of the three crops is summarised in (Table 9). The key points to note are as follows:

Assumptions

- The assumed areas planted to each crop are based on our forecasts for plantings in five years time (see section 2.3). These forecast areas reflect current/recent trends in areas planted, gross margins of the crops and likely EU policy changes that will apply (in

particular reform of the sugar regime should result in reductions in the level of quota for directly supported production and cuts in the level of support payments[31]);
- The proportion of the area planted to each crop assumed to adopt GM technology shows a range, based on factors such as adoption levels in comparable crops in countries that have already adopted the technology (eg, oilseed rape in Canada), estimates of possible levels of pest infestation (eg, for ECB in maize) and our qualitative views on possible adoption rates. The analysis also assumes that the GM traits are made available in leading varieties adapted to Polish agronomic conditions;
- The expected yield impact of using herbicide tolerant maize is neutral. However, this relates to comparisons with the current weed control regime in which atrazine is the primary product used. With its expected ban on use across the EU 25 of a whole in the next few years, the main alternative products (largely post emergent herbicides) can have a negative impact on plant growth and yield via 'Knock-back'. Hence, the 'top end of the range' used for impact includes a possible 5% yield improvement for avoidance of this yield 'knock-back';
- Seed breeders will work collaboratively with the technology providers to develop GM traits in Polish cultivars, obtain variety listing and commercialise these varieties.

Possible impact
- *Oilseed rape*: adoption of GM herbicide tolerance technology (including GM hybrid vigour combined with glufosinate tolerance) on 65% of the Polish crop could result in a 10% to 19% increase in national production levels;
- *Sugar beet*: adoption of herbicide tolerant (to glyphosate) technology on 65% of the crop could also lead to a 10% to 19% increase in production. Given the influence of EU sugar quotas on the sugar production levels eligible for support (and the expected reforms to the regime), this suggests that adoption of the technology would facilitate additional reductions in the area devoted to sugar beet (ie, maintaining production on a smaller area) and/or additional volumes of sugar beet available for export without subsidy support or for use in non food sectors (eg, for bio-ethanol[32]);
- *Maize*: use of GM (Bt) insect resistant technology in 20% of the Polish grain maize crop would result in modest increases in production of between 0.6% and 1.2%. Use of herbicide tolerance technology on 35% of the combined forage and grain maize crops may deliver no net gains to national production levels, although with the expectation of atrazine no longer being available, and the main alternatives to atrazine possibly having a small negative impact on yield (through 'knock-back' of the crop), it is possible that a yield gain of up to 5% may arise. This equates to a net production gain equal to about 1.28% of total production.

Table 9: Aggregate production impact of adopting GM technology on national production of oilseed rape, sugar beet and maize (tonnes)

	Herbicide tolerant oilseed rape using GM Roundup tolerance	**Herbicide tolerant oilseed rape using GM Invigor**	**Herbicide tolerant sugar beet**	**Insect resistant (Bt) grain maize**	**Herbicide tolerant maize (grain & forage)**
Area (ha) 2003	426,000	426,000	286,000	360,000	600,000
Forecast area (ha) 2009	511,000	511,000	257,000	468,000	773,000
Baseline production: tonnes (1)	1,176,000	1,176,000	9,009,000	2,654,000	5,765,000

[31] The proposals for reform include a 30% cut in the support price for sugar. This would result in support prices falling from about €47/tonne for beet to about €29/tonne. In effect, this will result in the price of sugar beet in Poland 'reverting' back to levels immediately prior to accession (as used in the gross margin analysis presented in section 2)
[32] A sector expected to develop rapidly in the EU over the next few years

Yield impact (% change)	+15 to +25	+25 to +30	+15 to +30	+3 to +6	No change to +5%
Assumed adoption rates %	65	65	65	20	35
Impact on production (tonnes)	+115,000 to +153,000	+191,000 to +229,000	+898,000 to +1,757,000	+15,910 to +31,820	0 to +74,000
% change in national production	+10 to +13	+16 to +19	+10 to +19	+0.6 to +1.2	0 to +1.28

Sources: Baseline herbicide usage data (AMIS Global)
Notes:

1. Baseline production based on forecast area planted 2009 and 2003 average yields
2. Yield impacts: see section 3

4.2 Impact on value of production and farm incomes

The estimated impact on the added value for Polish production of the three crops is between +€55 million and +€116 million. In terms of additional farm (gross margin) income there would be an increase of between €67 million and €123 million (Table 10).

Table 10: Aggregate value impact of adopting GM technology on national production of oilseed rape, sugar beet and maize (€)

	Herbicide tolerant oilseed rape using GM Roundup tolerance	Herbicide tolerant oilseed rape with GM hybrid vigour	Herbicide tolerant sugar beet	Insect resistant (Bt) grain maize	Herbicide tolerant maize (grain & forage)
Impact on farm level value (€ million)	+25.2 to +33.6	+42 to +50.4	+28 to +56	+1.9 to +3.76	0 to + 6.16
Impact on farm (gross margin) profitability: € million	+27.9 to +41.9	+19.9 to +44.9	+30.8 to +60.6	zero to +2.0	+8.0 to +15.8

Sources: Baseline herbicide usage data (AMIS Global)
Notes: Assumptions: see above and section 3

4.3Environmental impact

4.3.1 Volumes of pesticide applied

Drawing on the information and analysis presented in sections 2 and 3, the potential impact on the use of herbicides in the three crops in Poland is summarised in Table 11. This suggests that the volume of herbicides applied to the three crops would be expected to fall by between 35% (based on all of the GM oilseed rape being Invigor) and 54% (based on all of the GM oilseed rape being Roundup Ready).

Table 11: Possible impact on use of herbicides of using GM technology (kg formulated product applied)

	Usage 2003 (kg)	Usage with application of GM technology	Change (kgs)	% change
Oilseed rape	1,839,760	696,680 (RR) to 1,520,180 (Invigor)	-319,580 (Invigor) to -1,143,080 (RR)	-17 (Invigor) to -62 (RR)
Sugar beet	1,382,520	561,865 (RR)	-820,655	-59
Maize	982,660	658,710 (RR)	-323,950	-33
Total	**4,204,940**	**1,917,255 to 2,740,755**	**-1,464,185 to -**	**-35 to -54**

			2,287,685	

Sources: Baseline herbicide usage data (AMIS Global)
Notes:

1. Assumed penetration rates for GM crops: oilseed rape and sugar beet 65%, maize 35%
2. RR = Roundup Ready (tolerant to glyphosate), Invigor = tolerant to glufosinate
3. The baseline areas assumed to be planted to each crop are 2003 plantings. This is to provide a directly comparable rate of herbicide usage between current usage and the potential if GM crops are used

In relation to the environmental impact of using GM (Bt) insect resistant maize, this is likely to be limited. This is 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 technology.

4.3.2 Toxicity of products applied: levels of mammalian toxicity

Whilst the analysis presented in section 4.3.1 relating to changes in the volume of herbicide applied represents one measure of possible environmental impact, it is, at best, an imperfect measure of what are the external effect of the herbicides.

Taking the analysis a step further in terms of an environmental indicator[33], the analysis below explores the impact in terms of one environmental indicator; the impact on mammalian toxicity. This indicator is derived from the widely available measure of acute oral toxicity to mammals, the rat oral LD50 dose[34]. This number provides a standardised measure of acute toxicity and allows aggregation across a number of herbicides. It therefore provides one measure of potential environmental impact. Using LD50s is, however a crude way of comparing impact because it does not take into account degradation or long term effects.

For the purpose of the present comparisons, LD50s were related to the actual volumes of formulated product applied to and the area sprayed of the three crops in 2003 to quantify the total LD 50 dosage per product and crop. These values were then compared with the potential volumes and areas likely to be sprayed using GM herbicide tolerant crops to derive the 'post GM crop' values for total LD 50 dosage per crop. A summary of the results is presented in Table 12. This suggests that significant environmental benefits could accrue if the GM herbicide tolerant crops were adopted at the levels of penetration assumed (65% for oilseed rape and sugar beet and 35% for maize).

Table 12: Possible impact on mammalian toxicity (LD 50) dose levels from herbicide use: current versus post GM technology

	LD 50 total number of doses 2003 (million)	LD 50 doses after application of GM technology (million)	Change (millions)	% change
Oilseed rape	887	194 (RR) to 683 (Invigor)	-205 (Invigor) to -693 (RR)	- 23 (Invigor) to – 78 (RR)
Sugar beet	549	186 (RR)	-363	-66
Maize	249	181 (RR)	-68	-27
Total	**1,685**	**561 to 1,050**	**-636 to –1,124**	**-38 to -67**

Sources: Baseline herbicide usage data (AMIS Global)
Notes:

1. Assumed penetration rates for GM crops: oilseed rape and sugar beet 65%, maize 35%
2. RR = Roundup Ready (tolerant to glyphosate), Invigor = tolerant to glufosinate

[33] Drawing on the approach taken by Nelson G & Bullock D (2003) Simulating a relative effect of glyphosate resistant soybeans, Ecological Economics 45, 189-202
[34] An LD 50 dose is the amount of product that kills 50% of the tested animals (expressed in mg of formulated product per kg of bodyweight)

3. The baseline areas assumed to be planted to each crop are 2003 plantings. This is to provide a directly comparable rate of herbicide usage between current usage and the potential if GM crops are used
4. For some products the LD 50 rates are listed as greater than 5,000. Consequently, all products with such LD 50 ratings are assumed to have a rating of 5,000. This overstates the overall level of LD50 doses applied

4.3.3 Other environmental impacts

Additional benefits are likely to accrue from adoption of the technology in these three crops. Drawing on the evidence researched and presented in Appendix 1, a move away from the use of more persistent, residual herbicides to more environmentally benign products should lead to *reductions in the level of herbicides that can enter groundwater supplies.

In addition, reduced frequency of spraying, of crops like sugar beet, will result in lower fuel use and additional facilitation of the adoption of low/no tillage systems. Both have the potential to deliver reduced levels of greenhouse gas emissions.

Appendix 1: Production base for the three crops in Poland

A.1 Oilseed rape

A.1.1 Production

In 2003, Poland harvested 426,000 hectares[35] and produced about 754,000 tonnes of oilseed rape (Table 13). In the European context, Poland has the fourth largest area planted to the crop and is the fourth largest producer after Germany, France and the UK.

Table 13: European oilseed rape areas 2003: some of the main producing countries

	Area (hectares)
Poland	426,000
France	1,083,000
Germany	1,280,000
UK	477,000
Czech Republic	338,000

Sources: Coceral & various national statistical sources

In recent years the area planted to oilseed rape in Poland has been broadly within the range of 400,000 to 500,000 hectares. Almost all of the crop is winter oilseed rape. The crop is also estimated to be all 'conventionally' grown with no reported certified organic oilseed rape.

Average oilseed rape yields have recently been within a range of 1.75 tonnes/ha and 2.7 tonnes/ha (1.77 tonnes/ha in 2003). These are lower than average yields in other leading oilseed rape producing countries in the EU 15 (3.0 to 3.5 tonnes/ha across France, Germany and the UK for 2002 and 2003).

Within Poland, the main region growing oilseed rape is Wielkopolsko-Slaski which accounts for about 30% of total plantings, followed by Pomorsko-Lubuski and Nadwislanski. Overall, the oilseed rape area is concentrated in the Western half of the country.

A.1.2 Profitability

Oilseed rape plays an important part in the conventional Polish arable crop rotation:

- It does not harbour pests and diseases of cereals;
- It is a good entry crop for wheat allowing for good nutrient carry over and enhanced wheat yields;
- It integrates well into the cropping system requiring low labour contribution and the smoothing out of labour requirements because of its early drilling and harvesting time.

Its profitability is illustrated in Table 14. In 2003 the average gross margin was €154/ha, with a base gross margin of €259/ha. As with all agricultural enterprises, there is a range of performance, with below average performers earning a gross margin of €74/ha and the best performers earning gross margins of €257/ha.

[35] Forecast plantings for 2004 are about 510,000 hectares

Over the last few years, gross margin profitability of oilseed rape has tended to be lower than for maize and wheat but higher than other cereals (barley and rye: Table 15). With the exception of sugar beet it is the most profitable break crop.

Table 14: Gross margin profitability for oilseed rape in Poland 2002/2003 (€/ha)

	Low	Average	High
Price (€/tonne)	220	220	220
Yield (tonnes/ha)	1.53	2.3	3.1
Sales revenue	337	506	682
Variable costs			
Seed	20	20	20
Fertiliser	113	142	177
Crop Protection	46	85	108
Cost of spraying	18	30	36
Harvesting	66	75	84
Total variable costs	263	352	425
Base variable costs	179	247	305
Gross margin	**74**	**154**	**257**
Base gross margin	**158**	**259**	**377**

Sources: European Arable Crop Profit Margins 3rd edition, Polish Advisory Service (WODR)
Notes: Prices and yields based on averages for 2002 and 2003, costs based on 2003

Table 15: Base gross margin comparisons: oilseed rape with leading other arable crops (€/ha)

	2003
Oilseed rape	259
Maize	407
Winter wheat	312
Barley	209
Sugar beet	809

Sources: European Arable Crop Profit Margins 3rd edition, Polish Advisory Service (WODR)

A comparison of the base gross margin profitability of oilseed rape in Poland with the leading producing countries in the EU 15 (Table 16) shows:

- The average oilseed rape base gross margin in Poland is significantly lower than the average base gross margin in leading EU countries, even after exclusion of the direct payment that EU 15 growers received;
- The main reasons for the differences in gross margins are higher yields in the EU 15. However, EU 15 producers are heavier users of inputs than their Polish counterparts, with, for example the average expenditure on base variable inputs in the three leading EU 15 oilseed rape producing countries being about €305/ha compared to €247/ha in Poland.

Table 16: Comparison of base gross margins for oilseed rape: Poland and leading EU 15 producers (€/ha): average of 2002/03 and 2003/04

	Gross margin inclusive of area payment	Gross margin excluding area payment
Poland	Not applicable	259
Germany	775	439
France	819	478
UK	845	488
Denmark	757	427

Source: European arable crop profit margins 2nd and 3rd editions
Notes:

1. Base gross margins are the average of the two years 2002/03 and 2003/04
2. Base gross margins are used for comparison purposes because of the differences between countries about what other variable costs (other than seed, fertiliser and crop protection) are used to calculate gross margins. These differences complicate any attempt to compare gross margins and mean that such data is not fully comparable between countries

A.1.3Weed pressure and conventional control

Weeds are a major problem faced by all arable crop farmers in Poland. The main weed problems in oilseed rape include both broad-leaved and grass weeds (Table 17), although in terms of conventional treatment, 60% of the area sprayed targets broad-leaved weeds and 40% targets grass weeds.

Table 17: Main weeds in oilseed rape in Poland

Broad-leaved/dicotyledons	Grass weeds/monocotyledons
Anthemis ssp	Cereal volunteers
Galium aparine	Apera spica-venti
Centaurea cyanus	Agrooprons repens
Papaver rhoeas	

Source: Kleffmann – based on target weeds for which herbicides are sprayed

Drawing on farm level herbicide usage data on oilseed rape in Poland (Table 18), the following key points have been identified:

- Almost all (95%) of the crop receives at least one herbicide treatment per year;
- The main herbicides used are: pre-emergent – alachlor, clomazone and trifluralin (pre-emergent products accounted for 60% of the total spray area, including pre-sowing treatments),
- The main post emergence products used were quizulofop p ethyl, metazachlor and haloxyfop methyl;
- Pre-sowing treatment accounts for about 5% of the total sprayed area;
- Roundup herbicide is the main desiccant used but was applied in 2003 to only 8% of the total crop;
- The average number of spray applications per hectare of crop receiving treatment in 2003 was 1.4;
- Average expenditure on herbicides per hectare of crop grown was approximately €44/ha in 2003. This is equal to about 52% of total expenditure on crop protection products – the balance being accounted for by fungicides and insecticides[36]. This compares with data from advisory service sources which puts average expenditure on herbicides at €70/ha, comprising €31/ha on desiccants and €39/ha for weed control;
- The total tonnage of product ingredient used in 2003 was about 1,840 tonnes.

Table 18: Oilseed rape herbicide use in Poland 2003 (hectares)

Active ingredient	Spray area	Product weight (kg)
Clomazone	314,480	258,810
Alachlor	243,000	967,310
Metazachlor	68,030	146,390
Trifluralin	62,050	101,310
Quizulofop p ethyl	53,780	68,900
Haloxyfop methyl	35,830	17,980
Fluazifop p buytl	24,050	22,930
Others	160,200	261,130
Total	**961,420**	**1,839,760**

[36] In terms of spray area, herbicides accounted for 46% of the total spray area, fungicides 22% and insecticides 32% (2002 and 2003 average)

Source: AMIS Global

Relative to levels of expenditure on herbicides in the leading EU 15 countries, levels of expenditure in Poland are generally lower. For example, the range of expenditure in Poland on herbicides, in 2003 was between €13/ha and €49/ha compared to a range of €42/ha and €75/ha in the UK and France[37] This lower level of expenditure on crop protection products largely reflects lower levels of profitability in Poland which results in less funds being available for input purchasing and for accessing reliable spraying equipment. These problems are most apparent amongst small farmers who dominate the structure of production in agriculture *per se.* For example, only 22% of the Polish agricultural area is accounted for by farms over 100 hectares in size, with 54% of the area accounted for by farms under 15 hectares.

A.2 Sugar beet

A.2.1 Production

The area planted to sugar beet in Poland in 2003 was 286,000 hectares (producing about 13.8 million tonnes of beet). In a European context, Poland has the third largest area planted to this crop and is the third largest producer after Germany and France (Table 19).

Table 19: European sugar beet areas 2003: some of the main producing countries

	Area (hectares)
Poland	286,000
France	367,000
Germany	435,000
Italy	205,000
UK	162,000

Sources: Coceral & various national statistical sources

The sugar beet area has been stable in recent years because of production quotas introduced in the late 1990s (mainly to mirror the way in which the EU sugar regime operated prior to accession). The crop is all ‘conventionally’ grown with no reported certified organic sugar beet area.

Average sugar beet yields have been between 40 and 50 tonnes/ha in the last few years (46 tonnes/ha in 2003). This compares to yields ranging from 49 to 72 tonnes/ha in the UK, France and Germany over the 2002-2004 period.

Within Poland, the main regions growing sugar beet in 2003 were Wielkopolsko-Slaski (31% of the total), followed by Nadwislanski (23%), Lubelski (17%) and Srodkowo-Polski (14%).

A.2.2Profitability

Typical variable costs and levels of gross margin profitability from growing sugar beet in Poland are shown in Table 20. In 2003, the average gross margin was €580/ha and the average base gross margin was €809/ha. There is, however a broad range of performance, with average gross margins within a range of €381/ha to €795/ha. In general, gross margin profitability of sugar beet over the last few years has been higher than other arable crops: Table 15).

Table 20: Gross margin profitability for sugar beet in Poland 2003 (€/ha)

	Low	Average	High
Price (€/tonne)	32	32	32
Yield (tonnes/ha)	25	35	45

[37] Sources: Poland based on Kleffmann data, UK and France based on other sources (ADAS in the UK and Synthese Agriculture in France)

Sales revenue	800	1,120	1,440
Variable costs			
Seed	113	113	113
Fertiliser	86	119	147
Crop Protection	31	79	130
Cost of spraying	6	18	30
Harvesting	183	211	225
Total variable costs	419	540	645
Base variable costs	230	311	390
Gross margin	**381**	**580**	**795**
Base gross margin	**570**	**809**	**1,050**

Sources: European Arable Crop Profit Margins 3rd edition, Polish Advisory Service (GODR)

Base gross margin profitability comparisons for sugar beet between Poland and the leading producing countries in the EU 15 (Table 21) show:

- The average sugar beet base gross margin in Poland was substantially lower than the average base gross margin in leading EU countries;
- The main reasons for the differences in gross margins were higher (support) prices and yields in the EU 15. It should be noted that since Poland joined the EU, its sugar producers have (from 2004) access to full EU sugar support prices (€47/tonne) and using this price as the baseline for re-calculating the 2003 base gross margin would see the value increase to €1,334/ha. EU 15 producers tend to spend more on inputs, especially seed and crop protection than their counterparts in Poland. For example, average expenditure on seed and crop protection in Poland was €113/ha and €79/ha respectively compared to average expenditure in the UK, France and Germany of over €200/ha on seed and between €183/ha and €237/ha on crop protection.

Table 21: Comparison of base gross margins for sugar beet: Poland and leading EU 15 producers (€/ha): average of 2002/03 and 2003/04

	Gross margin
Poland	809
Germany	2,131
France	2,375
UK	1,635
Denmark	1,847

Source: European arable crop profit margins 2nd and 3rd editions
Note: Base gross margins are used for comparison purposes because of the differences between countries about what other variable costs (other than seed, fertiliser and crop protection) are used to calculate gross margins. These differences complicate any attempt to compare gross margins and mean that such data is not fully comparable between countries

A.2.3Weed pressure and conventional control

The main points of note relating to conventional control of weeds in sugar beet crops are (Table 22):

- almost all (about 99%) of the crop receives at least one herbicide treatment per year;
- in terms of expenditure, control for broad-leaved (dicotyledonous) weeds is the main target, accounting for about 70% of total herbicide expenditure;
- the use of both pre and post emergent sprays are commonplace, although post-emergent spraying dominates usage in terms of expenditure – accounting for 68% of total expenditure (64% in terms of weight of product applied);
- tank–mixing of products used post-emergence is commonplace;
- the main active ingredients used are desmediphan, ethofumeate & phenmediphan (and combinations of these) and metamitron;

- Pre-sowing treatment accounts for about 3% of total (area) treatments;
- The average number of spray applications was 2.8;
- Average expenditure on herbicides per hectare of crop grown was about €90/ha in 2003[38]. In terms of total expenditure on crop protection[39], herbicides account for nearly three-quarters of total expenditure with the balance split roughly equally between fungicides and insecticides;
- The total tonnage of product ingredient used in 2003 was 1,383 tonnes.

Table 22: Sugar beet herbicide use in Poland 2003 (hectares)

Active ingredient	Spray area	Product weight (kgs)
Desmediphan, Ethofumeate & Phenmediphan	286,610	313,630
Desmediphan & Phenmediphan	142,430	160,060
Metamitron	131,750	91,950
Ethofumesate & Phenmediphan	123,070	94,610
Ethofumesate	93,290	45,810
Chloridazon	69,760	204,680
Clopyralid	60,590	18,030
Quizulofop p ethyl	55,050	66,080
Lenacil	47,840	19,340
Others	220,210	368,330
Total sprayed area	**1,230,600**	**1,382,520**

Source: AMIS Global

A comparison of information on levels of expenditure on herbicides between Poland and the leading EU 15 countries shows lower levels of expenditure in Poland. In Poland, the range of expenditure on herbicides in 2003 was between €31/ha and €130/ha compared to an average of €106/ha in the UK and a range of €115/ha to €135/ha in France. As with oilseed rape, this reflects low levels of profitability especially for small farms. The more intensive, and above average performing sugar beet growers in Poland do spend comparable amounts on herbicides per hectare as their EU 15 counterparts.

A.3 Maize

A.3.1 Production

In 2003, the area planted to maize in Poland was about 600,000 hectares, comprising roughly 356,000 hectares of grain maize and 244,000 hectares of forage maize. In a European context, Poland has the eighth largest area planted to maize (Table 23).

Table 23: European maize areas (including forage maize) 2002/03: some of the main producing countries

	Area (million hectares)
Poland	0.6
Romania	2.9
France	3.2
Italy	1.72
Germany	1.6
Hungary	1.3
Serbia/Montenegro	1.2

[38] This compares with an average of €79/ha for all crop protection from farm extension service sources – this suggests that the crop protection data is collected mostly from above average performers

[39] Assuming total expenditure based on above average users (see table 20)

Spain	0.8

Sources: Coceral, FAO & various national statistical sources, Eurostat

In recent years the Polish maize area has increased significantly with the introduction of varieties suitable for Polish conditions. For example the area planted in the mid 1990s to grain maize was about 50,000 hectares. This increase in plantings probably reflects the level of profitability achieved for the crop relative to many alternatives (see Table 15).

Grain maize yields have varied in recent years between about 5.5 tonnes/ha and 6.7 tonnes/ha, with the average, over the last three years, being 6.12 tonnes/ha.

In regional terms, the main maize growing areas is Wielkopolsko Slaski (45% of total plantings). The next most significant regions are Srodkowo-Polski (11%), Nadwislanski (10%) and Pomorsko-Lubuski (8%).

A.3.2Profitability

Typical variable costs and levels of gross margin profitability from growing grain maize in Poland are shown in Table 24. In 2003 the average gross margin was €154/ha and the average base gross margin was €407/ha. The range around this average was, however fairly broad, with base gross margins being between €300/ha and €574/ha. Relative to other cereals (and oilseed rape) maize has tended to be the most profitable crop (in base gross margin terms: Table 15).

Table 24: Gross margin profitability for grain maize in Poland 2003 (€/ha)

	Low	Average	High
Price (€/tonne)	118	118	118
Yield (tonnes/ha)	4.25	5.67	7.1
Sales revenue	502	669	838
Variable costs			
Seed	82	82	82
Fertiliser	85	111	113
Crop Protection	35	69	69
Other variable costs	180	253	295
Total variable costs	382	515	559
Base variable costs	202	262	264
Gross margin	**120**	**154**	**279**
Base gross margin	**300**	**407**	**574**

Sources: derived from European Arable Crop Profit Margins 3rd edition, Polish Advisory Service (GODR)
Note: Yields and prices based on an average of 2002-03 and 2003-04

A comparison of the base gross margin profitability of grain maize in Poland with the leading producing countries in the EU 15 (Table 25) shows:

- The average grain maize base gross margin is lower than the average base gross margin in the leading EU countries, even after exclusion of the direct payment that EU 15 growers received;
- The main reasons for the differences in gross margins are higher yields in the EU 15 (an average of over 8 tonnes/ha in France and Germany, just under 8 tonnes/ha in Italy and about 10 tonnes/ha in Spain). However, EU 15 producers have significantly higher levels of expenditure on inputs than their Polish counterparts. For example, the average expenditure on seed and crop protection in Poland was €82/ha and €69/ha respectively. This compares with €165/ha on seed in Germany (€132-€220/ha in France) and €75/ha-€111/ha on crop protection in Germany (€56/ha-€93/ha in France).

Table 25: Comparison of base gross margins for grain maize: Poland and leading EU 15 producers (€/ha): average of 2002/03 and 2003/04

	Base gross margin inclusive of area payment	Base gross margin excluding area payment
Poland	Not applicable	407
Germany	1,019	545
France	963	475
Hungary	Not applicable	322
Italy	1,212	655

Source: European arable crop profit margins 2nd and 3rd editions
Note: Base gross margins are the average of the two years 2002/03 and 2003/04. Base gross margins are used for comparison purposes because of the differences between countries about what other variable costs (other than seed, fertiliser and crop protection) are used to calculate gross margins. These differences complicate any attempt to compare gross margins and mean that such data is not fully comparable between countries

A.3.3Weed pressure and conventional control

Key features relating to conventional control of weeds in maize crops are (Table 26):

- almost all (about 98%) of the crop receives at least one herbicide treatment per year;
- in terms of herbicide expenditure, control for dicotyledonous weeds is the main target, accounting for about 64% of total expenditure;
- both pre and post emergent sprays are used. Pre-emergent spraying dominates usage accounting for 63% by weight of product applied;
- the main herbicide active ingredient used is atrazine which accounted for 44% of the total spray area and 51% of the weight of product applied;
- The average number of spray applications was 1.1;
- Average expenditure on herbicides per hectare of crop grown (recorded through the AMIS Global (Kleffmann) crop protection survey[40]) was about €32/ha in 2003;
- In terms of total expenditure on crop protection, herbicides account for 95% plus of total expenditure with the balance accounted for by insecticides. In some years expenditure on insecticides has been recorded at even lower levels – generally insecticide treatments are not commonplace in Polish maize crops, with use varying on a regional and yearly basis according to insect pressure (the primary target for spray, where used has been frit flies/aphids);
- The total amount of product ingredient used in 2003 was 983 tonnes.

Table 26: Maize herbicide use in Poland 2003 (hectares)

Product	Spray area	Product weight (kg)
Atrazine	366,570	497,490
Nicosulfuron	142,770	140,850
Rimsulfuron	88,700	3,600
Antidotium, Foramsulfuron & Idosulfuron	77,730	10,830
Pendimethalin & Atrazine	29,410	115,300
Acetochlor	24,360	51,260
Dicamba	13,920	7,010
Sulcotrione	13,640	8,010
Atrazine & Flufenacet	11,620	27,780
Others	71,730	120,530
Total sprayed area	**840,450**	**982,660**

Source: AMIS Global (Kleffmann)

[40] This compares with a range of €32/ha to €68/ha estimated by extension service gross margin profitability data. This suggests that the Kleffmann data is drawn from a sample that over samples below average spenders on crop protection products

Compared to levels of herbicide expenditure in the leading EU 15 countries, these are broadly similar to levels of expenditure in France (€38/ha-€68/ha).

A.3.4 Pest pressure and conventional control
In relation to the two most commonly found pests of maize in global terms:

- *Corn rootworm*. This is not a problem pest in Poland. There are, and have been no recorded incidents of corn rootworm infestations in Polish maize crops up to 2004. However, given the incidence of the pest in some nearby countries, monitoring, organised by the Institute of Plant Protection, is being undertaken in the southern border regions;
- *European corn borer (ECB)*. This pest is found in Poland. A few years ago its presence 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 have experienced some level of infestation. Whilst levels of infestation vary by year and region, approximately 10% of the crop in 2003 was estimated to have been infested with ECB, with the greatest levels of infestation (80%-100% of crops in some localities) found in the southern most regions (south of Wroclaw). 2004 is reported to be a year of low levels of infestation relative to 2002 and 2003.

Aphids are also reported to be pest of maize grown in Poland. As with all pest problems the level of infestation varies by region and year. 2004 is reported to be a 'bad' year for aphid infestations, especially at the time of seed germination.

In terms of pest control measures taken by Polish maize farmers, very little insecticide use is reported. In the last five years, market research data[41] shows no insecticide use in some years and very low levels of use in other years. For example, a maximum of 5% of the crop, in 2001, is reported to have received a single treatment for aphid control.

Overall, the lack of insecticide use on Polish maize crops, despite the increasing incidence of ECB infestation reflects the following reasons:

- 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 treatment is perceived to be high, especially if aerial treatment is used;
- For some farmers there is a perception of limited effectiveness of the insecticides: it may kill corn borers on the surface of the soil and plants at time of spraying but is less effective against corn borers that have bored into stalks. Also, egg laying can occur over a three week period and most insecticides are only effective for 7-10 days. In other words the insecticides are effective at time of spraying/soon after and would be effective if farmers initiated frequent spray programmes. However, practicalities, time requirements and cost considerations mean that actual practices are rarely optimal or economic.

[41] Sources: Kynetec and Kleffmann

Appendix 2: The future direction of policy

Looking forward several years when GM agronomic traits in the three crops may become commercially available, it is important to consider how the baseline of production for these crops would look compared to 2003/04.

A 2.1 General factors affecting farm profitability and the choice of production systems

There are several key factors that influence farm-level profitability for a particular cropping system:

- Short term profit factors (eg, crop yield, output prices, input costs);
- Dynamic factors (short to medium term): these include impacts on subsequent crop yields due to current fertiliser use, weed control, tillage method, crop disease incidence;
- Sustainability factors (eg, pesticide resistance, soil degradation);
- Risk factors (eg, yield and price variability, system flexibility, farmer attitude to risk);
- Whole farm factors (eg, machinery capacity, finance availability and cost, labour, farmer objectives, knowledge and experience).

How these factors impinge on individual farmers ultimately determines the way in which farms and farming systems are used. Not surprisingly, due to variation in the above five factors, the economic performance of farms can vary widely, both between and within regions. This means that when attempting to examine the potential impact of a new piece of technology (ie, GM cost reducing technology) there is likely to be significant variation in the impact at a local level. This is clearly shown in relation to the identified impact of commercially grown GM crops in North America and Spain.

Also, it is important to recognise that when considering different possible rates of application of farming inputs to a crop, there may be a reasonably wide range of input levels either side of the 'economic optimum' that delivers profit levels that are only marginally different from that attained at the optimum. In other words, there can be a reasonable margin for error, and scope for flexibility in choosing input levels, without substantially reducing profits.

A 2.2 EU accession and the Common Agricultural Policy (CAP)

One of the most important factors affecting the Polish arable sector between now and when GM technology may become available to farmers is EU accession. Over the period to 2011/12, Poland is transitioning to full accession of the EU's CAP and hence farmers will be operating within a different policy environment to that which operated up to May 2004 when Poland joined the EU. Of particular relevance to the three crops examined in this study are the following:

- Farmers are now eligible for the provision of direct support payments (payable on an area basis). These will increase each year during transition so that by 2011/12 the full rate of direct payments[42] will be received. Although the amount received by each farm will vary according to the size of farm, the way in which the measure is administered in Poland and the level of modulation applied after 2011/12[43], it is likely to be about €150/ha[44]. There will be no requirement to plant a crop in order to receive this payment. Relative to 2003 gross margins this is equivalent to a 30% and 97% increase in revenue and gross margin respectively for oilseed rape and an increase of 22% (revenue) and 97% (gross margin) for grain maize;

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[42] Called the Single Farm Payment

[43] The rate at which deductions are made to the single farm payment for funding measures such as agri-environment schemes, rural development measures and further reforms in the CAP

[44] Based on the full rate payable in 2011/12 less an assumed 20% modulation

- The EU sugar regime is scheduled for reform, probably starting in 2006/07. Although reforms have not yet been agreed, the EU Commission proposals are for a 37% cut in the support price for sugar beet payable to farmers, from €47/tonne to €27.4/tonne. For the Polish sugar beet grower this means that the price received for beet has risen on accession from about €32/tonne to about €47/tonne[45], and will by about 2008/09 have fallen back to near pre-accession levels. In addition, the volume of production eligible for support (the production quota) will fall by 16%. Farmers will also be given 'compensation' for this price cut via additions to the single farm payment.

A 2.3The future: structure, profitability and plantings of the three crops

Drawing on the summary presented above, the key points of relevance for Polish arable crop profitability over the next five to ten year period are:

- The Polish agricultural sector will be operating within a larger and more competitive internal EU marketplace;
- Levels of support for agriculture will be higher than prior to accession. The receipt of the SFP will, in effect, provide many Polish farmers with an important form of additional income. In turn this is likely to lead to additional investment in agriculture, both in terms of fixed assets and more intensive use of variable inputs (it is also likely to result in higher land values and labour costs). Drawing on examples of the impact of EU accession on the agricultural sectors in countries like Spain and Portugal, the process of accession (to higher levels of support than previously occurred) acts as a stimulus to investment, modernisation and re-structuring in the agricultural sector. As a result, levels of technical performance improve and an element of 'closing the productivity gap' with longer standing EU member states occurs over a number of years;
- Poland, operating within the EU market will be open to increasing levels of competition from world markets. This will apply to all sectors, including sugar production (by 2008/09);
- The Polish agricultural market environment will be subject to significant variability in prices (reduced role of policy support mechanisms for cereals and sugar and increased openness of markets);
- New demand for crops in non food uses (notably bio-fuels) can be expected to increase across the EU;
- In order to remain as competitive as possible in the EU marketplace, many Polish producers are likely to increasingly explore all forms of new technology that can assist them (eg, through yield enhancement, cost reductions), especially as accession is likely to raise the real costs of land and labour inputs. The planting of GM crops could be an approach taken to contribute to improved competitiveness or reduced risks provided farmers perceive that there is a market for the produce. Some may look at different cost reducing technologies or focus on higher value, niche product production where cost is less of a market driver. Others may choose to focus more on the production of 'Care' goods (eg, environmental set-aside, membership of agri-environmental schemes that target the delivery of environment and landscape goods for the wider public) and lastly, some may choose to exit from the sector.

Overall, the underlying future baseline for the Polish arable crop sector is one of accelerated structural change (consolidation of holdings, increase in the average size of farms) and the emergence of two main types of agriculture:

- The bulk of production will derive from commercial farms, that are larger in size, making greater use of technology, invest more in equipment and inputs – striving for improved technical and economic performance;

[45] Payable on the assumption that the sugar content is 16%, premia and discounts are payable around this for different sugar content levels

- A tail of smaller scale farms (large in number) that are part-time in nature, focus more on the production of niche products, agri-environmental ‘goods’ and subsistence crops.

In relation to three crops focused on in this study, evidence presented in Appendix 1 shows that oilseed rape, sugar beet and maize are three of the most profitable arable crops for Polish farmers. Based on examination of these levels of profitability relative to alternative enterprises, recent trends in profitability and plantings and the impact of EU accession on future profitability, our qualitative assessments of the future direction of plantings are as follows:

- Oilseed rape: the area planted is likely to increase, possibly by 20% over the next five years;
- Sugar beet: as policy (sugar quotas) play a key role in determining the plantings of sugar beet, the area devoted to sugar beet is likely to fall by about 10% by 2009 (in other words we assume that the Polish sugar area will fall by less than the quota reductions, with Poland producing some unsupported sugar (‘C’ sugar[46]) for export and for use on non food sectors;
- Maize: the area planted is expected to increase by 25% to 30% over the next five years.

[46] C Sugar does not receive direct support and effectively sells at world market prices

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