# The farm level impact of using Bt maize in Spain


**Paper written by**

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# Table of contents



# Table of tables

# Executive summary

This paper examines the farm level impact of use of this Bt insect resistant maize in Spain.

*Spanish maize production, corn borer problems and conventional control measures*
In 2001/02, Spain planted 485,000 hectares of grain maize (11% of total EU plantings). Over 90% of this is irrigated. Bt maize is planted on 20,000-25,000 hectares (further expansion beyond this area has not occurred since 1998 due to a voluntary arrangement by the seed supplier Syngenta). The main locations where Bt maize is planted are Huesca, Zaragosa and Lleida provinces (regions of Aragon and Catalunya).

In terms of corn borer pressure all of the main regions where Bt maize is planted are regions with high or medium annual corn borer pest pressures – overall about a quarter of Spanish maize is probably in high corn borer pest pressure regions and a further 40% in regions with medium corn borer pest pressure

About 6%-20% of the Spanish maize crop area uses insecticide treatments to control corn borer attacks. Where used, treatment is applied either via irrigation water (for chlorpyrifos only) or by aerial (aeroplane) spraying. The average cost of treatment is €18-€24/ha treated via irrigation and €36-€42/ha treated by aerial spraying.

The majority of Spanish maize crops (35%-54% based in regions with medium to high corn borer pest pressure that do not use Bt seed plus 25% in regions with low infestation levels) do not use any active form of treatment for dealing with corn borer attack. This is mainly because of the variable nature of pest attack by year and location, a requirement to get the timing of spraying exactly correct (the 2-3 day period after eggs hatch) and this is not easy to arrange, the fact that eggs hatch over a three week period relative to the insecticide effectiveness period of a few days only, treatments are not very effective against borers that have already bored into stalks, limited awareness of the extent of damage and the perceived high cost of treatment.

The corn borer is estimated to cause an average of 15% yield loss in some regions of high annual corn borer pest pressure where no insecticides are used and an average yield loss of 10% in some regions even if insecticides are used but applied at sub-optimal times. Across the country the average yield loss is probably lower but within a range of 5%-7%[2]

*Impact of using Bt maize*
The cost of Bt maize seed relative to comparable alternatives is €18-€31/hectare, although for the majority of users who obtain their seed via co-operatives the lower end of this range is more representative.

As the damage that corn borer can cause to yield varies by location, year, climatic factors, timing of planting, whether insecticides are used or not and timing of insecticide applications, the positive impact on yields of planting Bt maize varies. In the Huesca region where high infestation levels are commonplace the benefit is an average 10% yield improvement (ie, 1 tonne/hectare on a base yield of 10 tonnes/ha) where insecticide treatments were previously used and, 15% where insecticide treatments were not previously used. Other research across a number of regions but limited to 1997 put the yield improvement at an average of 6.3% (within a range of 2.9% to 12.9%) whilst in some areas of low/medium pest attack the average yield improvement over the last four years has been about 1%.

[2] Clearly if insecticide treatments are applied at optimal times the yield losses can be reduced by 70% to 90% but as indicated, this is rarely possible, practical or cost effective

The impact of using Bt maize on costs is about +€18.5/hectare for the Bt seed and - €24 to -€102/hectare savings on no longer needing to spray for corn borer infestation and, in some cases no longer having to spray for spider mites (some farmers perceive beneficial insects having been destroyed by use of insecticides for ECB control). Where the conventional crop was not subject to insecticide use, the impact on this element of cost is zero. In addition, there are marginal cost savings relating to labour/management time in crop walking and/or applying some insecticides via irrigation systems.

The impact of using Bt maize on profitability for farms in the Huesca region of Spain are:

- in the Sarinena region (an area of high annual average ECB infestation), the positive balance on margins derived from using Bt maize has been +67€/ha to +€329.5/ha (average €146.5/ha). In terms of the base gross margin for maize grown in the region, this is equivalent to an improvement of +5.5% to +32.4% (average +12.9%). This improvement in profitability would go a significant way in offsetting the potential adverse effect on maize crop margins that would result from the EU Commission's Mid Term Review Proposals;
- in the Barbastro area (an area of low to medium annual average ECB infestation), the net result of using Bt maize has been 'break even' in term of cost and revenue changes (ie, not net change over four years);
- in break even terms, the cost of using the Bt technology is more than recouped via the savings on insecticide costs for farmers in the Sarinena area. For farmers that do not usually spray for ECB, the break even point for adoption (based on the 2001 harvest price of €123/tonne) is a yield benefit of 0.15 tonnes/ha (1.5% yield improvement relative to the 2001 average yield across Spain).

*Other impacts and issues*

- contribution to production risk management: for some farmers an important reason for using Bt maize is for insurance purposes – it takes away the worry of significant ECB damage occurring;
- a 'convenience' benefit derived from having to devote less time to crop walking and/or applying insecticides;
- grain quality improvements – Bt maize has lower levels of mycotoxins than conventional maize;
- a perceived human health (farmer and farm worker) benefit – reduced risks of accidents, spillage and exposure from using insecticides;
- perceived environmental benefits derived from no longer using some insecticides (see below);
- there are no barriers to use of the technology – small and large farmers use the technology (the average farm size of the Bt using farmer was 50 hectares or under (50 hectare being the average size in the Huesca region, although in the Zaragossa area, average sizes of under 20 hectares are commonplace);
- all GM maize is sold through normal marketing channels to users in the animal feed sector. No segregation of GM from non GM maize is required.

*Possible uptake of Bt maize in Spain*

Assuming that the Bt technology is commercially available in all leading varieties, with no supply restrictions on volumes of seed, we estimate that just under 36% of total maize planted in Spain would probably be planted to Bt maize if the technology were available in all leading varieties (173,000 hectares).

Assuming a 5% to 7% yield benefit over conventional maize, the potential impact on Spanish maize production of this level of adoption would be additional production of 88,000 to 123,000 tonnes (a 1.8% - 2.5% increase). In value terms (at the farm level), this is equal to an additional €10.82 to €15.22 million.

*Impact on the environment*
Based on the farmer evidence from the Huesca region of Spain, that the two insecticides currently used to control corn borer are almost exclusively used to control ECB attacks, if Bt maize were to become widely adopted to the level suggested above then these insecticides will probably be no longer used on Spanish maize crops. This would mean a net reduction in the area sprayed of 59,000-98,000 hectares and a reduction in active ingredient usage of 35,000-54,000 kgs. Relative to total insecticide usage on maize in Spain (including soil insecticides) this represents a reduction in the total area sprayed of 27%-45% and a reduction in active ingredient use of 26%-35%.

Based on some trade perceptions that these insecticides are sometimes used to control other target insects like heliothis and cut worms, the savings on insecticide use could be lower, possibly by up to two-thirds (ie, reducing the spray area by 15,000-32,000 ha and ai use by 12,000-19,000 kgs).

# 1 Introduction

The commercial planting of genetically modified crops in the European Union (EU) is currently very limited. This largely stems from the moratorium on granting approvals for new GM crop plantings introduced by the Council of Ministers in 1999. One variety of insect resistant maize (the variety *Compa CB* from Syngenta Seeds) was approved for planting in 1998 (before the moratorium) but has only been taken up on a commercial basis in Spain.

This paper examines the farm level impact of use of this Bt insect resistant maize in Spain and draws comparisons with reported impact of the same technology in the USA (the country in which the largest area of insect resistant maize has been planted to date).

The research undertaken for this paper used a combination of desk research/analysis and field research in the Huesca region of Spain (an area where a significant proportion of the Bt maize is planted in Spain). The field research took place in July 2002.

The paper[3] is structured, after this introduction, as follows:

- Section 2: Spanish maize production, GM maize plantings, corn borer problems and conventional control methods;
- Section 3: the impact of Bt maize at the farm level;
- Section 4: possible national level impact of adoption (if the technology was freely available in all leading varieties).

[3] The author acknowledges funding for the research came from Agricultural Biotechnology in Europe (ABE). The contents of the paper are, however the independent and objective views of the author and have not been influenced by any member of ABE – this was a condition of undertaking the research

# 2 General: Spanish maize production, corn borer problems and conventional control measures

### *2.1 Maize production*

In 2001/02, Spain planted 485,000 hectares of grain maize[4] and produced 4.95 million tonnes of maize (Table 1). In an EU context, Spain is the third largest maize producer behind France and Italy, accounting for about 11% of total EU plantings and about 13% of EU production in 2001/02 (in France and Italy, 1.89 million hectares and 1.15 million hectares respectively were planted in 2001-02).

**Table 1: Maize production base in Spain 2001-02**

| | Area ('000 hectares) | Average yield (tonnes/ha) | Production ('000 tonnes) |
|---|---|---|---|
| Spain | 485 | 10.21 | 4,950 |
| France | 1,889 | 8.51 | 16,075 |
| Italy | 1,152 | 9.40 | 10,830 |
| **EU 15** | **4,425** | **8.80** | **38,933** |

Sources: EU Commission, Coceral

Within Spain, the largest concentrations of maize production are in the regions of Castilla y Leon and Aragon, followed by Extremadura, Castilla La Mancha and Andalusia (Figure 1).

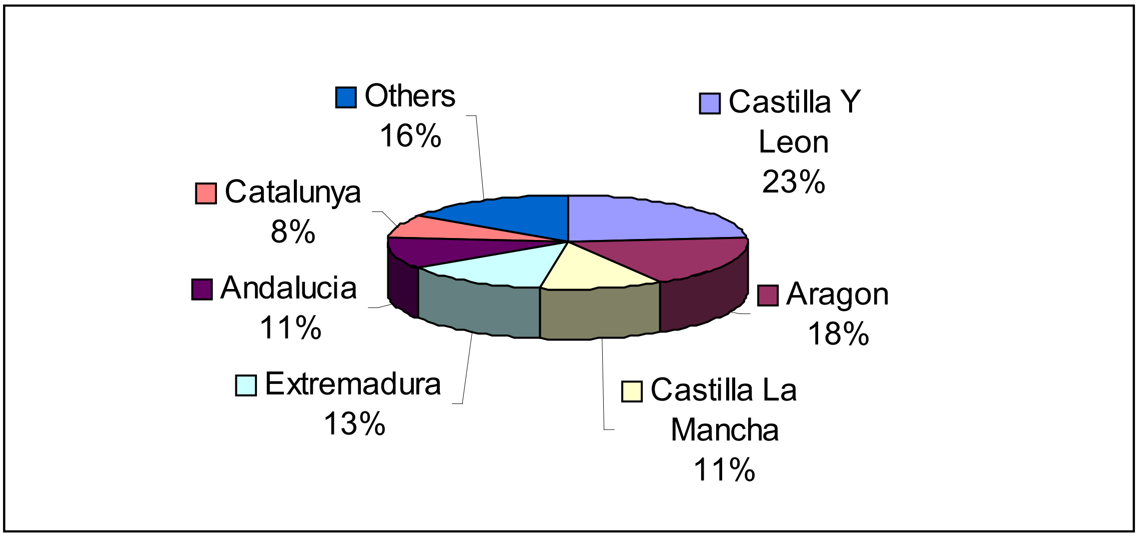


**Figure 1: Maize production in Spain 2001 by region (Source: MAPA)**

An additional important differentiating factor of maize-producing regions in Spain is whether crops are irrigated or not. The vast majority of production (just over 90%) is irrigated, with the balance dryland production. The largest dryland production areas are found in the Northern regions (where rainfall is highest) of Galicia (66% of dryland production) and Catalunya (18% of dryland production).

[4] Forecast plantings for 2002/03 are roughly the same as for 2001/02

Average yields on irrigated crops are naturally higher (at 11.8 tonnes/ha average in 2001/02) relative to dryland production (4.5 tonnes/ha in 2001/02).

Of the seed used in the Spanish maize sector, supplies are dominated by two companies; Pioneer and Syngenta Seeds, which together, account for about 70% of total maize seed sales.

### *2.2Bt maize in Spain*

Bt maize[5] containing a gene from a soil bacterium, *Bacillus Thuringiensis,* is the only insect resistant crop currently commercially available in the EU. Whilst several Bt maize products have been approved for commercial use outside the EU, the only variety that is available on the market in Spain is the variety *Comba CB'* (Bt 176) from Syngenta Seeds. Approval for its commercial use in the EU was first given in 1998, since when EU Member States have adopted a moratorium on the further approval of GM crops *per se.* As a result, Bt maize is currently only available commercially in Spain although there are some, limited trial plantings in France and Germany.

In Spain, Bt maize (the variety *Comba*) was first planted commercially in 1998 when seed sufficient to plant 20,000-25,000 hectares was sold. Since 1998, the area planted to Bt maize has remained at this level (equal to 4%-5% of total Spanish maize plantings but a higher share in some regions, eg, 13% of plantings in Catalunya) because of a voluntary arrangement by Syngenta Seeds to limit seed availability until the EU wide moratorium on new GM approvals is lifted. Thus, currently whilst a quantity of Bt maize is commercially available to Spanish farmers it is limited both in volume and to one of the leading varieties. For comparison purposes, in the USA where Bt maize has been commercially available since 1996 (and in all leading varieties), the proportion of the US crop planted to Bt varieties has been 18% to 26% between 1998 and 2002[6].

The main regions in which this limited volume of Bt maize seed has been planted, over the last 3-4 years in Spain are shown in Table 2. The highest concentration of use is in Huesca, Zaragosa and Lleida provinces.

**Table 2: Main regions growing Bt maize in Spain 1998-2002**

| Province | Region |
|---|---|
| Huesca | Aragon |
| Zaragosa | Aragon |
| Lleida | Catalunya |
| Girona | Catalunya |
| Albacete | Castilla la Mancha |
| Badajoz | Extremadura |
| Sevilla | Andalusia |

Source: Syngenta Seeds, Spain

[5] Bt maize produces a protein that is toxic when ingested by certain lepidopteron insects (insects that go through a caterpillar stage). In particular, the main insect pest it is effective against that attacks maize is the European Corn Borer (ECB). The Bt technology is considered to be a novel approach to controlling these insect pests because the 'insecticide' it produces is throughout the plant and lasts over the life of a plant. As a result it is much more effective than conventional or biological insecticides because it cannot be washed off or broken down by other environmental factors

[6] The variation being 19% in 1998, 26% in 1999, 19% in 2000, 18% in 2001 and 22% in 2002

### *2.3 European Corn Borer (ECB) pest pressure in Spain*

The ECB is the main insect pest that attacks maize crops in Spain. Nevertheless, its incidence and impact varies by region and year, being significantly influenced by local climatic conditions and planting times. For example, in the Huesca region, farmers indicated that cold winters help reduce the over-wintering population and can contribute to reduced pest pressure in the following growing season. Also, early planted crops (eg, in April) tend to be better able to withstand attacks relative to later plantings[7].

Drawing on unpublished information provided by Syngenta, Monsanto and Pioneer (that classifies regions into the three categories of high, medium and low ECB pest pressure – based on average infestation levels over a number of years), it is evident that of the regions listed in Table 2 (regions where Bt maize plantings are concentrated), Huesca, Zaragosa, Lleida and Girona are regions with high ECB pressure and Albacete, Badajoz and Sevilla are regions with medium ECB pressure.

Overall, based on this source of information, 25% of maize planted in Spain is probably in regions classified as suffering high ECB pest pressure (mostly Aragon and Catalunya) and a further 40% is in regions classified as suffering medium ECB pest pressure. A similar pattern of pest pressure and concentration of Bt maize use is exhibited in the USA, where ECB pressure is widely considered to increase westwards and the highest incidence of Bt maize usage is found in the more Western states of Kansas, Nebraska, and South Dakota and the more western parts of Iowa, Minnesota and Missouri[8].

### *2.4 Control of ECB before GM technology/the alternative*

Spanish maize farmers tend to use one of two main alternative approaches to dealing with ECB infestations. These are:

a) *Treatment with insecticides*

Key features of this approach are:

- Treatment is based on use of two insecticides *chlorpyrifos and synthetic pyrethroids,* of which chlorpyrifos is the most widely used (83%-88% of the total treated area: Table 3);
- These insecticides are used only for the treatment of ECB by farmers in the Huesca region of Spain and subject to one or two treatments[9]. Thus, the annual average area of maize treated with these insecticides in the last three years has been between 29,500 hectares and 98,000 hectares (6%-20% of the total Spanish maize crop);
- Treatments tend to be either via addition to irrigation water (chlorpyrifos only) or from aerial spraying (by aeroplane);
- The cost of these treatments (in the Huesca region) are €18-€24/treated hectare via irrigation and €36-€42/treated hectare by aerial spraying.

[7] Around Sarinena, some farmers plant maize in late May as a follow-on crop to beans. This maize is more susceptible to ECB attack than earlier planted crops

[8] Source: Fernandez-Cornejo J & McBride W (2002) Adoption of bio-engineered crops, USDA Agricultural Economics Report No 810

[9] As reported by farmers interviewed in the course of the research. Some trade sources perceive that these insecticides are also used against other target pests such as Heliothis and cut worms

**Table 3: Insecticide use in Spain for treating ECB 1999-2001**

| | **Annual average 1999-2001: Treated area (hectares)** | **Annual average 1999-2001 active ingredient used (kgs)** |
|---|---|---|
| Chlorpyrifos | 49,000-86,000 | 35,000-56,400 |
| Synthetic pyrethroids | 10,000-12,000 | 120-140 |
| **Total** | **59,000-98,000** | **35,120-56,540** |

Sources: AMIS Global and Produce Studies Research, UK

*b) No use of insecticides (ie, no active policy for dealing with ECB)*

Drawing on the information in a) above relating to use of insecticides, and section 2.3 (ECB pest pressure), it is clear that the majority of Spanish maize farmers do not treat their crops for ECB (80% plus of the crop is not receiving insecticide treatments). Whilst a significant proportion of this can be attributed to low levels of ECB pest pressure (35% of the maize growing area has historically experienced low levels of ECB pest pressure), some of the crop that is not treated with insecticides is in regions which have traditionally suffered medium to high levels of ECB infestation levels[10]). A similar pattern of limited use of insecticides to control ECB was found in the USA. For example, USDA (1985) estimated that 4% of the US Corn Belt only was treated with insecticides for ECB and other USDA surveys in Iowa and Illinois (1990) put the state level use of anti ECB insecticides at less than 5% of maize crops.

The main reasons why a significant proportion of the Spanish maize crop is not treated with insecticides that target ECB are:

- A farm level 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 (trade sources suggest that between 70% and 90% of yield losses can be alleviated if spraying is optimal). However, practicalities, time requirements and cost considerations mean that actual practices are rarely optimal or economic (see below);
- The insecticides may kill certain beneficial insects/organisms that are natural predators of other maize pests (eg, spider mites). Some farmers interviewed indicated that additional insecticide use (of chemicals other than chlorpyrifos and synthetic pyrethroids) were often required to deal with spider mite attack and damage;
- Timing of spraying is important to maximize effectiveness because sprays are effective only during a short period after eggs hatch and before larvae bore into stalks. Spray too early and the insecticides degrade before all larvae have hatched and spray too late and early hatchers will have already bored into stalks. This requires management time for crop walking and being able to secure the services of aeroplane sprayers when required. As such, it is not always possible to undertake frequent crop walking and/or to get spraying undertaken when required;
- The cost per treatment is widely considered to be high relative to perceived effectiveness (see below);
- Whilst it is accepted that products are safe for use in accordance with manufacturers guidelines, chlorpyrifos is considered, by some farmers, to be a difficult and hazardous product to use;

[10] Assuming that 65% of the Spanish crop suffers medium to high pest pressure and 6%-20% is subject to insecticide treatment and a further 5%-10% is planted to Bt maize, this leaves 35%-54% of the crop in medium to high infested regions using no active husbandry practices to deal with ECB attack

- 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 (eg, some Bt maize users indicated that it was only after using Bt maize that they realized fully what adverse impact the ECB caused).

Overall, the perceived limited effectiveness of existing insecticide treatments was borne out by information provided by the Association of Spanish Maize Producers (AGPME), relating to maize grown in the Monegros region of Huesca. Here (a region of high ECB infestation) ECB is estimated to cause a yield loss of 10%-40% (annual average 15%) in the absence of any insecticide treatment and a yield loss of 5%-20% (annual average of 10%) even if insecticides are used. This evidently shows that, for most growers in the area, it is not possible to get spraying undertaken at optimal times (if this was possible, trade sources suggest that 70%-90% of the yield loss could possibly be alleviated) An additional source of information that largely corroborates this assessment is presented in Table 4 – this shows an average yield loss of 6.1% in 1997, a modal impact of 8%-9% and maximum losses of up to 24.6%. In interpreting this data, the reader should note that this data refers to one year (1997) only and therefore is not necessarily representative of a typical, average year. It does, however, highlight the variability of corn borer impact on yields both across and within regions and the difficulties that farmers have in getting spraying undertaken at optimal times that would possibly, otherwise, give high levels of effectiveness against corn borer[11]. For comparison purposes yield loss estimates of ECB damage in the USA are an average of about 5%, although the losses in some states like Texas and Colorado are regularly put at an annual average of in excess of 15%.

**Table 4: Maize yield losses from corn borer in Spain 1997**

| Region | Average % loss of yield across sites monitored in region | Most common average (mode) yield loss | Maximum loss % |
|---|---|---|---|
| Albacete | 6.4 | 8-9 | 9.6 |
| Girona | 12.9 | 14-16 | 24.6 |
| Huesca | 6.5 | 8-9 | 21.2 |
| Lleida | 4.4 | 8-9 | 9.1 |
| Madrid | 2.9 | 2-4 | 5.9 |
| Zaragosa | 6.1 | 8-9 | 22 |
| **All regions above** | **6.1** | **8-9** | **N/a** |

Source: Alcade E (1999) Symposium de Sanidad Vegetal. Sevilla
Notes:

1. N/a = not applicable
2. Results based on monitoring of a sample of fields in each region in 1997

Also, some farmers appear to accept some degree of loss rather than incur the cost of (only partially effective) insecticide treatments. For example, many US farmers are perceived to be prepared to accept losses of 3%-6% before considering using formal methods of control like insecticides or Bt technology (Source: Fernandez-Cornejo J & McBride W (2002).

[11] That trials data suggest is possible

# 3 Impact of using Bt maize in Spain

### *3.1 Nature of Bt maize user in Spain*

The typical profile of a Bt maize user in the Huesca region is:

- Average farm size of 50 hectares of which about 30 hectares are planted to maize. All of the crop is irrigated;
- Most farmers typically plant 4-5 different varieties each year. Bt maize is one of these and currently tends to account for 20%-25% of the area planted (ie, 6-7.5 hectares);
- Some of the farmers are typically 'innovators' and above average performers – eg, some of the farmers interviewed obtained average yields of 13-15 tonnes/hectare relative to the average for the region of 9-10 tonnes/hectare;
- Many (concentrated in areas of high average ECB infestation levels) have been using insecticide treatments in an attempt to control corn borer. Others, where local infestation levels are typically lower tend to not use any insecticide treatments.

### *3.2 Cost of the technology*

The recommended cost price of Bt maize seed sold by Syngenta Seeds in Spain in 2002 (variety *Comba CB)* is €131.24/bag. With a requirement to use about 1.6-1.7 bags per hectare, this makes the recommended cost per hectare of €210-€223/hectare. This compares with the recommended cost price of an equivalent conventional (non GM) hybrid maize seed of €112.90/bag (€181-€192/hectare)[12] suggesting that the cost of the Bt technology is €29-€31/hectare. However, whilst this represents the recommended price differential, many farmers access the technology at lower prices to this via the co-operatives that they are members of. For example, the Maize Producers Association of Spain (AGPME) indicated that local co-operative groups sell seed to their members at lower prices than those recommended by manufacturers and in the case of Bt maize, the additional cost of Bt maize seed over comparable, conventional alternatives is about €18-€19 euros/hectare[13] (the cost of Bt maize is however roughly the same as a conventional maize that has been treated '*with Gaucho'* – a seed treatment from Bayer CropScience that protects against aphid attack and has a recommended cost price of an additional €28-€29/hectare). By comparison, the additional cost of using Bt maize in the USA was estimated at €26/ha in 1997, €21.5/ha in 1998 and 1999 and €16-€17/hectare in 2001 (Source: Gianessi et al (2002)), although other US analysts have put the additional cost at anywhere between €23/hectare and €28/hectare (eg, Benbrook (2001) estimated the cost at €24.5/ha in 1996-98 and €24.5/ha 1999-2001). Clearly the additional cost or premia attributed to Bt maize seed in the USA depends on the conventional seed with which the comparison is made (there are also several Bt varieties available, each with different prices and some charging for the 'technology' via an area-based technology fee), the € to $ exchange rate used, the volume of seed per bag assumed to be required to plant one hectare and the year in which the comparisons are made.

[12] This comparison is with the nearest equivalent (and leading variety) sold by Syngenta called Dracma. Both are considered to be some of the leading late maturing varieties available in Spain. This is also a broadly comparable price with the other leading varieties of Pioneer (the other main supplier of maize seed to the Spanish market). Some lesser used varieties supplied by other companies tend to sell for prices up to 15% lower than the prices of Syngenta and Pioneer seed

[13] One farmer interviewed indicated that the additional cost of Bt maize was about €30/hectare – in line with the recommended prices of Syngenta. The differential with some of the lesser used varieties than the leading ones of Pioneer and Syngenta (that trade at lower prices) is also higher and could be as high as €35/hectare. However, for the purposes of analysis in this paper the €18/€19 hectare differential is used because this compares with the cost of comparable and leading varieties supplied by the two companies that supply 70% of the total Spanish market and reflects the price paid by a significant number of users (the majority of maize farmers in Spain are members of co-operatives which themselves are members of AGPME)

### *3.3 Impact on yield*

As indicated in section 2, the damage that ECB can cause to yield varies by location, year, climatic factors, timing of planting, whether insecticides are used or not and the timing of application. Not surprisingly, this means that the positive impact on yields of planting Bt maize varies. Based on the sources referred to in section 2, the yield benefits obtained from using Bt maize are:

- an average 10% yield improvement (ie, 1 tonne/hectare on a base yield of 10 tonnes/ha) where insecticide treatments were previously used (Sarinena region of Huesca and an area of high average ECB infestation levels). The range of yield improvements being within a range of 5%-20% (Source: AGPME based on four years observation 1998-2001 and feedback from members of the Sarinena co-operative);
- an average 15% yield improvement (ie, 1.5 tonne/hectare on a base yield of 10 tonnes/ha) where insecticide treatments were not previously used (Sarinena region of Huesca and an area of high average ECB infestation levels). The range of yield improvements being within a range of 10%-40% (Source: as above);
- an average of 6.3% yield improvement on trial plots across a number of regions in 1997 – within a range of 2.9% to 12.9% yield improvement (Table 5);
- 1%-1.1% average yield improvement (about 0.15 tonnes/hectare) average over the four year 1998-2001 – source: one farmer in the Barbastro area of Huesca – an area of low to medium average corn borer infestation[14].

**Table 5: Yield comparisons of Bt and conventional maize in Spain 1997 (tonnes/hectare)**

| Region | Bt average yields | Conventional crop yields | % difference |
|---|---|---|---|
| Albacete | 14.2 | 13.34 | +6.4 |
| Girona | 13.63 | 12.07 | +12.9 |
| Huesca | 13.35 | 12.54 | +6.5 |
| Lleida | 13.72 | 13.13 | +4.5 |
| Madrid | 14.70 | 14.28 | +2.9 |
| Zaragosa | 12.01 | 11.32 | +6.1 |
| **All regions above** | **13.30** | **12.51** | **+6.3** |

Source: Alcade E (1999) Symposium de Sanidad Vegetal. Sevilla
Notes:

1. N/a = not applicable
2. Results based on monitoring of a trial plots of 1000 metres square in each region in 1997

These results show a number of similarities with findings from the USA. Without providing an exhaustive list of US-based studies undertaken since 1997, Table 6 below taken from Marra et al (2002) provides a summary of such works in recent years. The US evidence illustrates significant variation in impact by year and region, with a US average yield benefit of just over 5%[15], although in some of the main corn growing states of the Mid West the range was between 5.34% in Iowa and 13.69% in Minnesota (Table 6).

[14] This farmer indicated that, in his location 1998 had been an average level of attack for the area, 1999 and 2001 had seen little/no infestation and 2000 had been a higher than average year for corn borer attack

[15] Some others, notably Benbrook (2001) estimate the net yield benefit to US maize yields over the 1997-2001 period to be 3% but with states such as Colorado and Texas respectively experiencing the greatest gains. These two states have high annual ECB pest pressure (13% and 17% annual yield loss attributed to ECB attack) and accounted for 37% of the total US gains from using Bt maize yet planted only 6.3% of the area planted to Bt varieties

**Table 6: Summary of farm level impact on yield of Bt maize in the US 1997-2000**

| State | Number of studies examined | Average yield benefit of Bt maize: tonnes/ha (1) | Average benefit % | Range |
|---|---|---|---|---|
| Corn Belt | 6 | +0.68 | +8.12 | +4 to +12.8 |
| Illinois | 4 | +1.02 | +12.26 | +1.1 to +22.6 |
| Iowa | 5 | +0.45 | +5.34 | +2.2 to +9.2 |
| Kansas | 3 | +0.49 | +5.87 | +2.8 to + 9.0 |
| Minnesota | 1 | +1.14 | +13.69 | +13.69 to +13.69 |
| Nebraska | 2 | +0.46 | +5.57 | +3.2 to +7.9 |
| South Dakota | 2 | +0.65 | +7.75 | +5.8 to +9.7 |
| **USA as a whole** | **5** | **+0.42** | **+5.04** | **+2.5 to +9.0** |

Source: Taken from Table 7 of Marra et al (2002) The pay-offs of agricultural biotechnology: an assessment of the evidence, International Food Policy Research Institute
Notes:

1. In the original work, yield benefits are presented in bushels per acre. These values have been converted to tonnes/hectare and compared in % terms against an annual average US maize yield for the period 1997-2000 (the period in which most studies applied) of 8.345 tonnes/ha
2. % figures in column 4 have been rounded

### *3.4 Impact on costs*

The main cost elements of maize production affected by any decision to use Bt maize are the additional cost of the Bt seed relative to conventional seed and costs expended on crop protection measures (ie, on insecticides). In addition, there may be some changes to labour and management costs.

The key relevant baseline costs for growing maize in the Huesca region of Spain in 2002 are (Table 9):

- €150/hectare seed costs[16];
- €114-€222/hectare agro-chemical costs comprising €90-€120/hectare herbicide costs and €24-€102/hectare insecticides (€24-€84/hectare for corn borer control and possibly €18/hectare for control of spider mites).

Where no insecticide control is used as the baseline (in regions of low to medium average ECB infestation levels like around Barbastro), insecticide use is usually zero, hence total crop protection costs are €90-€120/hectare for use of herbicides.

The impact of using Bt maize on these costs (Table 7) is:

- +€18.5/hectare (see section 3.2) for the Bt seed (if recommended prices are used this is €29/hectare);
- - €24 to -€102/hectare savings on no longer needing to spray for corn borer infestation and, in some cases no longer having to spray for spider mites (beneficial insects having been destroyed by use of insecticides for ECB control). Where the conventional crop was not subject to insecticide use, the impact on this element of cost is zero. It should also be noted that the prices of the main insecticides used to treat the ECB (chlorpyrifos and synthetic pyrethroids) have not changed significantly since Bt maize became available

[16] Add €29/hectare if the seed has been treated 'with Gaucho'

commercially in Spain (ie, there is no need to adjust downwards the value attributed to savings on insecticide use that might otherwise have occurred if the manufacturers of these insecticides had reduced prices as a competitive reaction to the launch of Bt maize).[17]

In addition, there are marginal cost savings relating to labour/management time in crop walking and/or applying insecticides via irrigation systems. Also there may be savings in energy/fuel use where aerial spraying is no longer required. This latter saving is, however not usually a benefit attributable to the farm level because most aerial spraying is undertaken by external contractors for which farmers pay an inclusive fee for the spraying.

**Table 7: Impact on key costs of maize production of using Bt maize in the Huesca region of Spain (€/hectare)**

| Cost element | Sarinena area: minimum | Sarinena: maximum | Sarinena: average | Barbastro area |
|---|---|---|---|---|
| Seed | +18.5 | +18.5 | +18.5 | +18.5 |
| Insecticide use | -24 | -102 | -42 | No change |
| Net change | -5.5 | -83.5 | -23.5 | +18.5 |
| Labour cost | Benefit | Benefit | Benefit | No change |

Note:

1. Labour change not quantifiable
2. If recommended seed prices are used (ie, a €29/hectare differential), then the net change in costs becomes +€23.5 in Sarinena minimum, - €73 Sarinena maximum and +€29 in Barbastro

No comparisons with the USA are presented in this sub-section as almost all analysis from the USA focuses on impact on profitability (see section 3.5 below). Also US analysis mostly refers only to the additional cost of using the Bt technology and does not consider impact on farms that have previously used insecticide treatments for corn borer[18].

### *3.5 Impact on profitability*

The impact of using Bt maize on profitability for farms in the Huesca region of Spain are summarized in Table 8 and Table 9. Key points to note are:

- in the Sarinena region (an area of high annual average ECB infestation), the positive balance on margins derived from using Bt maize has been +67€/ha to +€329.5/ha (average €146.5/ha). In terms of the base gross margin for maize grown in the region, this is equivalent to an improvement of +5.5% to +32.4% (average +12.9%). This improvement in profitability would go a significant way in offsetting the potential adverse effect on maize crop margins that would result from the EU Commission's Mid Term Review Proposals[19];

[17] As occurred in respect of some (competitor) herbicide prices when Roundup Ready soybeans were commercially launched

[18] Gianessi et al (2002) do take this into account in estimating the impact on yield/revenue but do not appear to consider spray costs or to disaggregate the cost change data from overall farm income impact

[19] Which proposes to reduce the intervention support price for grains like maize by 5% and to reduce area payments by 20% over a seven year period

- in the Barbastro area (an area of low to medium annual average ECB infestation), the net result of using Bt maize has been 'break even' in term of cost and revenue changes (ie, not net change over four years)[20];
- in break even terms, the cost of using the Bt technology is more than recouped via the savings on insecticide costs for farmers in the Sarinena area and therefore for farmers in high ECB infestation areas that traditional use insecticides (to control the ECB), the benefits of the technology are self evident. Yield benefits are in effect a bonus to these farmers. In contrast, for farmers that do not usually spray for ECB, the break even point for adoption (based on the 2001 harvest price of €123/tonne) is a yield benefit of 0.15 tonnes/ha (1.5% yield improvement relative to the 2001 average yield across Spain). Clearly if a higher price and differential for using Bt maize was used (eg, the recommended prices of Syngenta at €29/hectare differential), the break even point would require higher levels of yield benefit. In Barbastro the break even point would be an additional 0.235 tonnes/ha and in Sarinena, farmers who have traditional used only one insecticide treatment (via irrigation) would require a small yield improvement of 0.04 tonnes/ha to break even.

**Table 8: Impact of using Bt maize on key revenue and cost elements of maize production in the Huesca region of Spain (€/ha)**

| | Barbastro | Sarinena range | Sarinena average |
|---|---|---|---|
| Average yield (tonnes/ha) | 13-15 | 10 | 10 |
| Yield gain from using Bt maize (tonnes/ha) | +0.15 | +0.5 to +2.0 | +1.0 |
| Revenue gain | +18.5 | +61.5 to +246 | +123 |
| | | | |
| *Quantifiable cost changes* | | | |
| Seed cost | -18.5 | -18.5 | -18.5 |
| Crop protection cost | No change | +24 to +102 | +42 |
| Net balance | Nil | +67 to +329.5 | +146.5 |

Source: Field research July 2002: Barbastro example farm and Sarinena = members (500) of a local co-operative of maize producers
Notes:

1. Base price of maize used €123/tonne – average farm price September/October 2001
2. Cost of technology based on information provided by AGPME in respect of farmers in the Sarinena co-operative

**Table 9: Impact on base gross margins of using Bt maize in the Huesca region (Sarinena) of Spain (1998-2001: €/ha)**

| | Barbastro: conventional | Sarinena (average) conventional | Bt: Barbastro area | Bt: Sarinena range | Bt: Sarinena average |
|---|---|---|---|---|---|
| *Revenue* | | | | | |
| Price (€/tonne) | 123 | 123 | 123 | 123 | 123 |
| Yield (tonnes/ha) | 13-14.85 | 10 | 13.15-15 | 10.5-12.0 | 11 |

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

| | | | | | |
|---|---|---|---|---|---|
| Sales revenue | 1,599-1,827 | 1,230 | 1,617-1,845 | 1,292-1,476 | 1,353 |
| Area payment | 460 | 460 | 460 | 460 | 460 |
| Total revenue | 2,059-2,287 | 1,690 | 2,077-2,305 | 1,752-1,936 | 1,813 |
| | | | | | |
| *Base costs of production* | | | | | |
| Seed | 150 | 150 | 168.5 | 168.5 | 168.5 |
| Fertiliser | 211-301 | 211-301 | 211-301 | 211-301 | 256 |
| Crop protection | 90-120 | 114-222 | 90-120 | 90-120 | 105 |
| Irrigation | 211 | 211 | 211 | 211 | 211 |
| *Total of these variable costs* | *662-782* | *686-884* | *680.5-800.5* | *680.5-800.5* | *740.5* |
| *Total base variable costs* | *451-571* | *475-673* | *469.5-589.5* | *469.5-589.5* | *529.5* |
| **Gross margin** | **1,277-1,625** | **806-1,004** | **1,276.5-1,624.5** | **1,071-1,135.5** | **1,072.5** |
| **Base gross margin** | **1,488-1,836** | **1,017-1,215** | **1,487.5-1,835.5** | **1,282-1,346.5** | **1,283.5** |

Source: Fieldwork in Spain, July 2002: Barbastro example farm and Sarinena = members (500) of a local co-operative of maize producers

Notes:
1. Price = average farm level price for maize in September/October 2001
2. Area payments based on €63/tonne multiplied by the national irrigated maize reference yield of 7.3 tonnes/ha
3. Base variable costs = seed, fertilizer and crop protection only

Comparisons with research findings in the US show a number of similarities with this Spanish research. Much of the initial research into the impact of Bt maize in the US (examining impact in 1997 and 1998) provided conflicting evidence as to the benefit of the technology for adopters. For example, Gianessi and Carpenter (1999) estimated the benefit to be 45-54 $/ha in 1997 and a loss of 4.47$/ha in 1998, Ostlie et al (1997) estimated the benefit in 1997 at 17.8$/ha, the USDA (1999) identified positive returns on average across the country's maize regions in 1997 but negative returns for 1998. Similarly, Benbrook (2001) estimated that benefit accrued to the average maize farmer in 1996, 1997 and 2001 but losses were incurred in 1998, 1999 and 2000 and that overall, a net average loss occurred across all Bt maize grown between 1996 and 2001 of about €3.5/hectare. Lastly, Gianessi (2002) estimated the average impact (in a year of average corn borer attack) to be about +€22.5/hectare, derived from an average yield benefit of 3.5%.

The key points about this conflicting evidence[21] was that the respective reports were estimating average impact data from across a number of regions and were not necessarily relating them to corn borer pest pressure/incidence. As both, subsequent work in the US (eg, Gianessi 2002, Benbrook 2001) and these Spanish findings highlight, the level of impact on yield, costs of production and, in turn, returns are determined by actual pest pressure, historic pest pressure experience (which influences whether insecticide treatments might be used or not) and the prices used for both maize and the cost of the Bt technology. Pest pressure, impact on yield and prevailing husbandry practices towards the corn borer vary not only on an annual basis but regionally, including within a small locality. These factors should be taken into consideration when assessing the impact of a technology like Bt maize, which targets a sporadic and uneven pest like the corn borer.

[21] It has been interesting to note that some, anti GM activists, seized on the early findings of negative impact in 1998 as evidence of the inappropriateness of the technology and its lack of effectiveness. Clearly such sentiments were largely made without adequate appreciation of maize production husbandry and insect pressure/attack

### *3.6 Other impacts and issues*

Based on the field work undertaken in Spain, the following other impacts and issues were identified:

- Some farmers indicated that one additional reason for using Bt maize is for insurance purposes – it takes away the worry of significant ECB damage occurring and therefore represents an important tool for managing and reducing production risk. This point was particularly relevant for the farmers who indicated that over the four years of use they estimated that the net financial impact of using Bt maize was neutral. Use for these farmers was largely a function of its contribution to production risk reduction;
- There is 'convenience' benefit derived from having to devote less time to crop walking and/or applying insecticides. As noted in section 2, the effectiveness of insecticides is critically influenced by the timing of application;
- A small net saving in energy use – mainly associated with less use of aerial spraying, although these cost changes, mostly accrue to aerial spray contractors;
- There is a farm level perception that the quality of Bt maize is superior to non Bt maize from the perspectives of having lower levels of mycotoxins. Evidence from, for example, Bakan et al (2002) who examined *Fusarium* infection levels in Bt versus non Bt corn trial plots in five locations (three in France and two in Spain) found that Bt maize had up to ten times less fumonisin content than the non Bt varieties;
- For some farmers the Bt technology provides for human health (farmer and farm worker) benefits – reduced exposure to insecticides by not having to handle and/or come into contact with insecticides via spillage, error or incorrect application;
- In regions that traditionally suffer from high incidence of ECB attack and where farmers routinely spray insecticides, there are perceived environmental benefits derived from no longer using these insecticides. This benefit is explored further in section 4.

These impacts are/were difficult to quantify[22].

It is also important to note that the average farm size of the Bt using farmer was 50 hectares or under (50 hectare being the average size in the Huesca region, although in the Zaragossa area, average sizes of under 20 hectares are commonplace). This highlights that the technology has been adopted by small farmers and there does not appear to be any correlation between size and adoption. In other words, there is no minimum size of farm above which the adoption of the technology become economic (as sometimes happens with some new technologies that require investment in fixed costs to facilitate adoption).

Lastly, all of the Bt maize produced in Spain is sold through normal marketing channels to customers in the animal feed sector. Although some Spanish maize users in sectors that service the food manufacturing sector (notably starch manufacturers) actively source only non GM maize[23] (and obtain supplies mostly from regions that do not currently grow GM varieties), there is no active segregation of GM versus non GM maize production and trade in the GM maize growing regions. None of the farmers interviewed reported any problems in selling their crops or any requirements to segregate GM from non GM materials. These views are consistent with the author's understanding of the Spanish feed sector where the proportion of animal feed requiring ingredients (soyameal and maize) to be derived from non GM material is very low (probably less than 5% of total Spanish compound feed production).

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[22] Hyde (2001) estimated the crop walking cost saving potential in the US to be about €8/hectare

[23] And may pay a small premia of 1%-3% for this maize relative to bulk supplies that may contain GM material

# 4 Possible national level impact of Bt maize adoption

Building on the evidence presented in sections 2 and 3, this section briefly examines the possible impact of Bt maize at the national level in Spain.

### *4.1 Possible uptake of Bt maize in Spain*

The likely uptake of Bt maize in Spain presented below has been estimated assuming the technology is commercially available in all leading varieties, with no supply restrictions on volumes of seed[24].

Drawing on the analysis presented in section 2 relating to ECB pest pressure in the different regions of Spain, we estimate that just under 36% of total maize planted in Spain would probably be planted to Bt maize if the technology were available in all leading varieties. This is equivalent to 173,000 hectares. This estimate was based on the following assumptions:

- All users will be on irrigated crops (which accounts for over 90% of total plantings);
- 75% of the maize crop in regions classified as 'suffering high annual average ECB pest pressure' are likely to adopt Bt maize. This adoption share draws on the views expressed by farmers in the Huesca region who generally indicated that if Bt maize was available in all of the leading varieties they would probably plant 70%-80% of their crop to Bt maize[25]. These farms are where the main benefits of the technology will be found;
- 40% and 10% respectively of the maize area in regions classified as 'suffering medium or low average annual levels of ECB pest pressure' will adopt Bt maize. The level of benefit is likely to be lower, on average than in the high infestation regions, and will have more of an insurance benefit for adopters.

If less optimistic assumptions are made about adoption on medium to low infestation regions (eg, 25% in medium infestation regions and zero adoption in low infestation regions), about 29% of the total Spanish maize crop would be planted to Bt maize (141,000 ha).

### *4.1 Production*

The potential impact on Spanish maize production is summarized in Table 10. Assuming that 36% of the Spanish maize crop (173,000 ha) is planted to Bt maize and the estimated benefit of the technology is between +5% and +7% on yield, the net impact is likely to result in additional production of about 88,000 to 124,000 tonnes (a 1.8% - 2.5% increase). In value terms (at the farm level), this is equal to an additional €10.82 to €15.22 million.

**Table 10: Potential impact on Spanish maize production of widespread adoption of Bt maize**

| | **Yield effect +7%** | **Yield effect +5%** |
|---|---|---|
| Area (hectares) | 173,000 | 173,000 |
| Average yield (tonnes/ha) | 10.21 | 10.21 |

[24] It is also necessary to assume that there are no significant problems in selling Bt maize in Spain. Currently, whilst maize used in some user sectors notably for starch/human food is required to be derived from non GM maize, the vast majority of maize use in Spain is for animal feed. In this user sector, there is currently very little demand (probably under 5% of the market) for non GM ingredients. We therefore consider it reasonable to assume that Spanish maize growers would not be faced with significant problems in selling Bt maize

[25] At this level of adoption, this would still provide for the recommended 20% refuge area plantings of non Bt maize

| | | |
|---|---|---|
| Yield impact of Bt maize (tonnes/ha) | +0.715 | +0.5105 |
| Impact on production (tonnes) | +123,700 | +88,000 |
| % change in total production (2001 harvest = baseline) | +2.5% | +1.8% |

Notes:
1. Average yield = national average 2001 crop
2. Farm price = €123/tonne

### *4.2 Farm level income*

Drawing on the analysis presented in section 3.5 for the benefits of the technology in regions with high ECB infestation, the positive contribution to farm gross margins is between €66.5/ha and €329.5/ha (average €146.5/ha). If this average benefit is extrapolated to the potential area of adoption of 173,000 ha, this produces a positive contribution to farm income of Bt maize of €25.3 million. However, given that some adoption is likely to be in regions with lower ECB damage the likely overall net benefit to farm income will be lower than this, but still potentially significant. For example, if the per hectare average benefit was reduced by 50% to €73/ha, the positive contribution to total farm income would be €12.6 million.

### *4.3 Impact on the environment*

As indicated in Section 3, the adoption of Bt maize is already resulting in a perceived positive impact on the environment, via reductions in the use of insecticides to control the ECB. If we assume that the insecticides chlorpyrifos and synthetic pyrethroids are used almost exclusively to control ECB attacks[26] (and are used mostly in regions with high infestation levels), it is reasonable to assume that if Bt maize were to become widely adopted to the level suggested above (36% of the total Spanish maize crop), then these insecticides will probably be no longer used on Spanish maize crops. Based on usage data for these insecticides from 1999-2001, this would mean a net reduction in the area sprayed of 59,000-98,000 hectares and a reduction in active ingredient usage of 35,000-56,000 kgs. Relative to total insecticide usage on maize in Spain (including soil insecticides) this represents a reduction in the total area sprayed of 27-45% and a reduction in active ingredient use of 26%-35%. Clearly if these insecticides are used by some farmers to control other target pests (eg, heliothis and cut worms), the impact on (reduced) insecticide use will be lower. Based on one trade source the reduced insecticide use could be only one third of the amount referred to above (ie, -19,000 to –32,000 sprayed ha and –12,000 to –19,000 kgs ai).

It is interesting to note that providing similar estimates of the perceived positive environmental benefits of Bt maize in the USA has been more difficult. This is because there are a greater number of insecticides used than in Spain and the main insecticides used on maize in the USA (chlorpyrifos, carbofuran, fonofos, permethrin, lambdacyhalothrin and methyl parathion) are often used to control the ECB and other pests such as rootworm, which are not considered to be problem pests in Spain[27]. Hence, some analysts in the USA have observed increased use of some of these insecticides in 1998 relative to 1997 and inferred this to be evidence of ‘no environmental benefits associated with Bt maize’ (eg, Benbrook). Clearly to provide robust and comparable US data with the Spanish evidence necessitates isolating the proportion of insecticides used on US maize that are purely for treating corn borer and not for treating other pests. To date we are not aware of any such analysis having been undertaken, although Gianessi & Carpenter (1999) has made estimates

[26] Based on the views expressed by farmers interviewed during this research
[27] With the exception of chlorpyrifos, none of these active ingredients are in the top ten active ingredients sprayed on Spanish maize (the top 10 active ingredients account for 91% of all insecticides sprayed on maize, including soil insecticides). This re-inforces the views expressed by farmers interviewed in the Spanish fieldwork that chlorpyrifos and synthetic pyrethroids are only used against ECB attack

that the introduction of Bt maize in the USA (1998 relative to 1995) resulted in a 50% reduction in the area sprayed for corn borer. This was based on an estimated 5% of the US maize crop being sprayed for corn borer in 1995 with this falling to 2.5% by 1998 (ie, prior to the launch of Bt maize in the USA, about 1.467 million hectares were treated with insecticides for corn borer and this fell to 0.74 million hectares by 1998). The same authors in 2002 put the benefit at a reduction in the volume of active ingredient of insecticides at 1,181 tonnes[28].

[28] Unfortunately the paper does not state the total volume (ai) of insecticide used on maize crops in the US

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