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Foreword

The Joint Research Centre's Institute for Prospective Technological Studies (JRC-IPTS) was a partner in the SIGMEA research project on “Sustainable Introduction of Genetically Modified Organisms into European Agriculture” funded by the European Commission's Sixth Framework Programme from 2004 to 2007. The objective of SIGMEA was to set up a science-based framework, including strategies, methods and tools,for assessing the environmental and economic impact of genetically modified crops and for effectively managing their development within European cropping systems. JRC-IPTS was the lead body for a work package looking into the socioeconomic dimension of GM crops in Europe.

Some of the results of this work package are summed up in this report which analyses the economic impact of the first GM crop introduced in European agriculture.

Seville, January 2008

Per Sørup
Head of *Agriculture and Life Sciences in the Economy Unit*
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Executive Summary

- Despite the extensive adoption world-wide of genetically modified (GM) crops, 102 million hectares in 2006, cultivation in the EU remains very limited. Scientific and policy debates on GM crops in the EU have focused on safety and less on the possible agronomic and economic impact on farmers. This lack of data is understandable since there is only one GM crop authorized for commercial cultivation in the EU, a type of GM maize resistant to maize borer attacks, known as Bt maize.

- Spain is the EU Member state with highest adoption rate of Bt maize in agriculture, since it was first introduced in 1998. In 2006, over 53,000 hectares of Bt maize were cultivated in Spain; 15% of the country's maize-growing area. However, adoption rate is currently as high as 60 % of maize area in some regions with high pressure of maize borers. This 9-year experience of commercial cultivation provides an opportunity to analyze ex-post the agronomic and economic performance of Bt maize, the first for a GM crop cultivated in the EU.

- Ex-post economic analysis of GM crop impacts are usually based on surveys of farmers cultivating GM crops under commercial conditions. A face - to-face survey amongst Spanish commercial maize farmers was conducted with the aim both of obtaining data on the agronomic and economic performance of Bt maize during three growing seasons (2002-2004), and of comparing the socio-economic profile of farmers who adopted Bt maize versus those who did not. The survey was conducted in 2005 in the three leading Bt maize-growing regions (Aragon, Catalonia and Castilla-La Mancha). A province was selected within each region based on the importance of maize cultivation and the presence of farmers growing Bt maize (the provinces of Zaragoza in Aragon, Albacete in Castilla-La Mancha and Lleida in Catalonia).

- Survey results show that farmers adopting Bt maize experienced higher average yields than conventional maize growers for the three growing seasons studied (2002-2004). These higher yields were, however, statistically significant only for the province of Zaragoza (a yield increase of 1110 kg/ha or 11.8%). Bt crops, like other pest-control technologies, produce variable yield gains depending mainly on local pest pressure and damage. The province of Zaragoza seems to have been particularly affected by maize borers.

- Yield gains for farmers adopting Bt maize translated directly into revenues increase, as no differences were found in the crop price paid to Bt or conventional maize farmers (0.13€ per kilogram). All Bt maize produced was sold for feed manufacturing, and therefore there seems to be no price premium for non-GM maize for feed in the regions studied. Pesticide and seed costs are two cost variables that showed differences between farmers who did or did not grow Bt maize.

- Insecticide-based control of maize borers is rather difficult due to the biology of the pest, yet some farmers still apply insecticides even when the treatment is ineffective. It was found that, on average, conventional maize farmers applied 0.86 treatments/year (2002-2004 period), compared with 0.32 treatments/year for Bt maize farmers. The percentage of farmers applying no insecticides for maize borers was 70 % for Bt maize growers and 42% for conventional maize growers. Estimates of the average cost for an insecticide application allowed calculations of the subsequent savings on pest control costs for Bt maize adopters.

- A price premium of Bt maize seeds relative to conventional seeds was observed, but it was significant only in Zaragoza, the province showing the highest yield increase for Bt maize. This suggests that seed distributors may adjust the price premium of GM seed reflecting the performance of the technology in a particular region.

- The on-farm economic balance for Bt maize was expressed as a difference in gross margin (total revenues minus variable costs) obtained by Bt maize farmers, compared with conventional maize farmers for 2002-2004. Gross margin differences mirrored the variability in agronomic yield increase described above. Gross margin increase was as high as 122/ha per year in Zaragoza, compensating for the significant price premium of Bt maize seeds. In Albacete or Lleida, where gross margin increases are smaller, adoption of Bt maize is facilitated by smaller price premium for Bt maize seeds.

- Finally, the survey included direct questions to farmers on their reasons for adopting/not-adopting Bt maize. The most quoted reason for adoption was "lowering the risk of maize borer damage". For GM insect-resistant crops, lowering the uncertainty from variable seasonal levels of pest infestations has been suggested as the primary incentive for adoption elsewhere. After "risk lowering", other reasons declared by Spanish farmers were "obtaining higher yields" and, perhaps surprisingly, "better quality of the harvest". The latter is backed by studies showing reduced grain damage and susceptibility to post-harvest fungal infection and contamination by mycotoxins associated to Bt maize. Reticence to change was, on the other hand, the main reason quoted by Spanish farmers for not adopting Bt maize.

- It is unlikely that the yield and economic effects reported by Bt maize adopters in Spain result from differences in the competence of the two groups of farmers surveyed. The socio-economic profile of farmers who adopted Bt maize and those who did not was compared. No statistical differences were found between the two groups for such variables as landownership, farm size, main crop cultivated, age, education, agricultural training or years of experience as maize grower. Although other factors not analysed in the survey (soil type, irrigation intensity, meteorological conditions) may show variation between farms, we attribute the differences primarily to the introduction of Bt maize varieties.

- There are very few reports on the economic performance of Bt maize in other parts of the world. For the United States, the largest grower of Bt maize, on-farm evidence is limited to the early years of adoption (1997-99) and points to very variable economic effects due to large differences in geographical incidences of maize borers. In South Africa, Bt maize yield advantage together with reduced pesticide costs increased income from €19.2 per hectare to €119 per hectare, a range similar to our findings in Spain.

- These data constitute the first large-scale, empirically-based estimation of the economic impact of a GM crop for EU farmers. Future socioeconomic analyses of GM crops in EU agriculture need to consider a new element: the costs incurred by farmers adopting GM crops to ensure coexistence with non-GM crops. Most EU Member States are now drafting specific coexistence measures for GM crop cultivation. Further socio-economic research should to evaluate the impact of these measures on the willingness of EU farmers to adopt GM crops and the extent to which coexistence costs will outweigh net gains in farmer's gross margin, as reported in this study.

1. Introduction and objectives of this research

It is more than ten years since the first genetically modified (GM) crops were introduced in agriculture. During this time (1996-2006) GM varieties with novel agronomic traits (commonly known as “first-generation GM crops”) have spread quickly in many parts of the world. In fact, adoption of GM crops has been progressing at a faster pace than other innovations in plant varieties, such as the introduction of hybrid maize decades ago. In the first year (1996) between 1.7 million and 2.6 million hectares of GM crops were grown, almost exclusively in a single country (USA). Eleven years later (2006) the area under GM crops had expanded to 102 million hectares in 22 countries (James, 2006).

Despite this wide adoption of GM crops at global level, in European agriculture adoption has been very low, and the number of authorised GM crops available to European Union (EU) farmers is small compared with other regions. In practice, the only GM crop currently available to EU farmers for cultivation is a GM maize resistant to insect pests, commonly known as “Bt maize”. Since it was first introduced in 1996 in the USA, Bt maize has spread quickly to become the second GM crop worldwide (after HT soybean) in terms of area sown (11.3 million hectares or 12.56% of the global area under GM crops in 2005) (James, 2005). Examples of countries growing Bt maize commercially include the USA, Canada, Spain, Argentina, Honduras, South Africa, Uruguay and the Philippines.

Within the EU Spain is the only country growing Bt maize varieties in significant quantities. The first were planted in Spain in 1998 covering about 20 000 hectares. By 2006 a total of 53 667 hectares of Bt maize varieties were being cultivated in Spain, which accounts for 14% of the country's maize-growing area (MAPA, 2007). France cultivated the second largest area with about 5000 hectares. Germany, Portugal, the Czech Republic and Slovakia also grew Bt maize in 2006 but reported comparatively small areas of about one thousand hectares or less.

Despite about nine years' experience of cultivating Bt maize in Spain, there is little evidence about the factors that might have affected farmers' decision whether or not to adopt the technology and the economic implications of their decision. Growing GM crops is considered a technological change that can have an impact on several economic variables at both farm and aggregate level. Understanding the process of adoption of GM crops is therefore of interest to policy-makers, scientists and agricultural stakeholders.

This report helps to fill these gaps by showing the results of a survey conducted amongst 402 Spanish maize farmers, some of them adopters others non-adopters of Bt maize technology. The objective is to identify the characteristics that make the difference between the two groups and to calculate the impact of Bt maize technology on farmers' yields, costs and returns over the 2002-2004 seasons.

The purpose of this study is in line with the general objective of the SIGMEA[1] research project, of which this research forms part. SIGMEA is funded by the European Commission's Sixth Framework Programme for research with the aim of setting up a science-based framework, including strategies, methods and tools, for assessing the environmental and economic impact of GM crops and for effectively managing their development within European cropping systems.

The report is organised as follows. Section 2 gives background information on the maize sector in Spain, describes Bt maize technology and shows the situation and development of the area under Bt maize in Spain. Section 3 describes the methodological approach taken for this research. Section 4 sets out results on the factors determining adoption of Bt maize by Spanish farmers and the profile of adopters. Section 5 highlights differences in agronomic and economic performance between adopters and non-adopters of Bt maize. Next, conclusions are drawn in Section 6. Finally, additional details on the sample analysis are given in annexes of this report.

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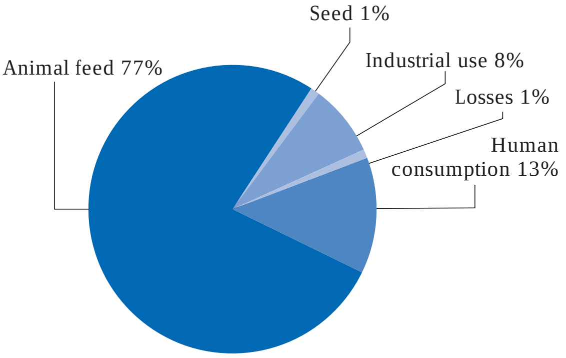
[1] SIGMEA: “Sustainable introduction of genetically modified crops into European agriculture”, Sixth Framework Programme, priority 8. This three-year project is coordinated by INRA (France) and NIAB (UK) and involves 44 partners from 12 European countries.

2. Background

2.1 Uses of maize

Maize (Zea mays) has many uses in food, feed and industry. For example, maize is used in animal feed for all types of livestock, for starch and cooking oil production, for breakfast cereals and for snacks such as popcorn. It is also widely used for producing biofuels (ethanol)[2]. However, the main application of maize is animal feed, for which more than 50% of all world maize production is used, with the figure reaching 77% in EU-15 (see Figure 1) (European Commission, 2006).

Figure 1: Average internal use of maize in EU-15 in 2002-2003



Source: Compiled by the authors from European Commission (2006) data

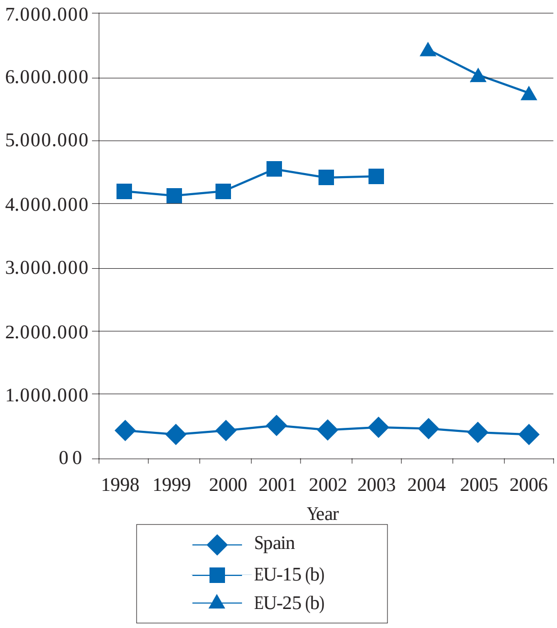
2.2 Main figures and characteristics of the maize sector in the EU and Spain

Maize is an important crop in European agriculture. In 2006 EU-25 grew grain maize on about 5.8 million hectares, which equals 4% of the utilised agricultural area (EUROSTAT, 2006). The two new Member States that joined the EU on 1 January 2007, Bulgaria and Romania, added about 3 million hectares to the EU total. The new figure is still far from the area cultivated by the leading producer in the world, the USA with 30 million hectares in 2005. China and Brazil follow the USA in terms of hectares of maize, with EU-27 next. The maize area cultivated in EU-25 each year has declined significantly over the last few years due to the return to 10% compulsory set-aside[3], less favourable climatic conditions in some regions of the EU and the first implementation of the single farm payment scheme (European Commission, 2006) (see Figure 2).

Grain maize production in EU-25 totalled about 51 million tonnes in 2005. Assuming an on-farm selling price of €0.11 per kilogram (net of VAT) this results in EU maize output worth €5.500 million. In terms of external trade, EU-25 imported 4 million tonnes in 2004 and about 3 million tonnes in 2005.

Within EU-25 Spain is the fourth producer of maize, cultivating about 379.000 hectares of grain maize in 2006 (MAPA, 2006b). This is 6.5% of the total maize-growing area in EU-25 and has fluctuated moderately over recent years, mainly as a consequence of water availability for irrigation and variations in fuel prices (see Figure 2).

Figure 2: Grain maize area harvested



Source: Compiled from (a) MAPA (2006b) (b) EUROSTAT (2006) data

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[2] About 13% of US grain maize production is used to produce ethanol.

[3] Compulsory set-aside increased from 1.9 million hectares in 2004 to 4.0 million hectares in 2005.

Maize is cultivated all over Spain. The regions with the largest maize-growing areas are Castilla-Leon, Extremadura and Aragon (122.738, 56.066 and 62.765 hectares respectively in 2006) (see Table 1 for the 2005 figures). Due to the climate conditions in Spain, more than 90% of the total maize area cultivated is irrigated (MAPA, 2006b). Average maize yields per hectare from irrigated land in Spain are clearly higher than from non-irrigated land (9.7 tonnes/ha *v* 3.1 tonnes/hectare) (MAPA, 2002).

According to a survey conducted by the Spanish National Statistics Office, 80 701 farms in Spain were growing grain maize in 2005 (INE, 2006) (see Table 1). This figure has dropped by nearly 48% since 1999 when 154.292 farms were cultivating grain maize. Most of this fall had already occurred by 2003 (91.907 maize-growing farms), mainly as a consequence of the increase in average farm size. The second fall, from 2003 to 2005, is, above all, a consequence of the marked (13%) contraction in the maize-growing area.

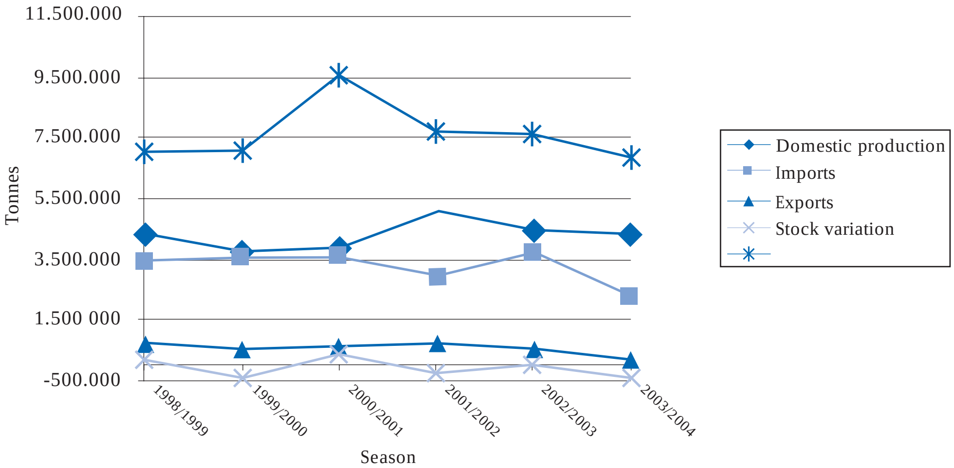
■ *Table 1: Number of Spanish farms growing maize and area cultivated by region in 2005*

Region	Number[a] of farms	Area[b] (hectares)	Region	Number[a] of farms	Area[b] (hectares)
Andalusian	4.802	35.885	Valencia	60	166
Aragon	9.410	59.399	Extremadura	5.316	64.970
Asturias	2.063	284	Galicia	33.591	24.108
Balearic Islands	66	253	Madrid	994	11.743
Canary Islands	930	369	Murcia	16	14
Cantabria	784	727	Navarre	2.115	12.298
Castilla-La Mancha	4.090	44.072	Basque Country	659	6
Castilla-Leon	11.868	135.109	La Rioja	180	145
Catalonia	4.476	32.175	TOTAL	80.701	421.723

Source: Compiled from (a) MAPA (2006b) and (b) INE (2006)

Average annual consumption of maize in Spain is about 7.6 million tonnes. As is the case for the whole of the EU, most of the consumption is for animal feed. Domestic production averages just 4.3 million tonnes which, together with small exports of processed maize, creates a need to import large volumes (3.2 million tonnes a year) (see Figure 3). Spain imports this maize mainly from France and non-EU countries (e.g. Argentina and the USA) (MAPA, 2006a).

■ *Figure 3: Maize production and trade balance in Spain*



Source: Compiled from MAPA (2006a)

In Spain most cereals are marketed via grain elevators. About one third of these are cooperatives and the rest companies and sole traders. Normally local grain elevators buy the produce and sell it through grain merchants to grain processors to make feed or flour (MAPA, 2006a).

2.3 Introduction and development of Bt maize in Spain

Insect pests are a major problem for agricultural crops worldwide, and maize is no exception. The Mediterranean corn borer (MCB), *Sesamia nonagrioides*, appears to be the most damaging maize pest in Spain and other Mediterranean countries, causing significant yield and economic losses. Damage from these pests is a direct consequence of insect feeding and stalk tunnelling causing plant lodging and further losses at harvest.

Chemical control of maize borers in conventional maize crops is particularly difficult because insecticide sprays are effective only in the narrow time span between egg hatch and larvae boring into stems. Because of the ineffectiveness and additional cost, many maize farmers do not spray insecticides specifically for controlling corn borers and tend to accept the yield losses.

Bt maize is the common name given to genetically modified varieties of maize expressing the insecticidal toxins from the soil bacterium *Bacillus thuringiensis* (Bt). The plants then become genetically resistant to corn borer attacks. Bt maize is therefore expected to produce higher yields than conventional maize in areas where corn borers are a problem. Like most pests, the intensity of corn borer attacks and the resultant yield losses vary from year to year. Also, corn borer pressure is not evenly distributed between maize-growing regions, reflecting the variability of agro-climatological conditions in Europe and Spain. Therefore the agronomic and economic performance of Bt maize versus its conventional counterpart is expected to depend on the location and time.

Commercial release and adoption by farmers of Bt maize varieties in Europe has been influenced by regulatory and political developments. In February 1997 the European Union authorised the first cultivation of Bt maize (transgenic event Bt-176 by the company Syngenta). Following the green light from the EU, two commercial varieties derived from Bt-176 were entered in the Spanish Register of Commercial Varieties in 1998. The first Bt maize was planted in Spain in the same year. Syngenta put on the market enough seed to sow 20.000 hectares of Bt maize in 1998, roughly 5% of the area under maize in Spain (see Table 2).

During the period 1998-2002 no further novel GM maize events (or any other GM crops) were authorised for cultivation in the EU. During this period Syngenta voluntarily limited the amount of Bt-176 maize seed sold in Spain. The area planted with Bt maize in Spain remained fairly stable (adoption rate: 5-6%), with the exception of 2001 when it levelled off due to a shortage of GM seed supply from Syngenta. In 2003 the EU approved cultivation of new Bt maize (transgenic event MON-810 by Monsanto). New commercial Bt maize varieties were cultivated and the area increased, to peak at about 58.000 hectares of Bt maize in 2004 and stabilise at about 53.000 hectares in 2005 and 2006 (MAPA, 2007) (see Table 2). By 2006 over 45 commercial varieties of Bt maize were available to Spanish farmers, the vast majority based on the GM event MON-810, produced and marketed by more than 10 local and multinational seed companies. This year 14% of total grain maize grown in Spain was GM. This is just below the figure for the whole world (14% in 2005 and about 17% in 2006) (FAOSTAT, 2006; James, 2005; James, 2006).

Spain's Bt maize-growing area shown in Table 2 was cultivated by about 11 000 farmers in 2004 and 10 000 in 2005 and 2006[4]. They are in many regions of the country but are unevenly distributed. Within Spain three regions accounted for about 90% of the total area under Bt maize in 2006, averaging 80% over the period 1998-2006. These are Aragon (23.734 hectares of Bt maize in 2006), Catalonia (20.365 hectares) and Castilla-La Mancha (4.176 hectares) (see Table 2). Bt maize accounts for 42% of total grain maize production in Aragon, 60% in Catalonia and 12% in Castilla-La Mancha.

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[4] The total number of farmers growing grain maize is multiplied by the rate of adoption of Bt maize.

Table 2: Distribution and development of Bt maize in Spain by region (season and hectares)

Region	1998	1999	2000	2001	2002	2003	2004	2005	2006
Andalusia	780	2.800	1.500	450	1.800	2.067	2.770	2.875	298
Aragon	11.500	7.300	9.000	4.250	9.200	12.592	25.547	21.259	23.734
Asturias	0	0	0	0	0	6	0	0	0
Balearic Islands	2	2	26	0	30	6	29	29	0
Castilla-La Mancha	4.500	6.800	5.650	870	4.150	7.682	8.197	7.957	4.176
Castilla-Leon	200	360	270	0	0	74	0	12	0
Catalonia	1.700	3.000	4.500	3.250	5.300	5.430	15.699	16.830	20.365
Extremadura	1.000	2.500	2.500	600	1.500	1.899	2.026	1.171	2.071
La Rioja	25	30	30	0	0	0	35	41	122
Madrid	660	1.560	1.970	1.940	780	1.034	1.385	155	80
Murcia	0	0	0	0	0	0	12	0	0
Navarre	1.760	300	220	80	500	1.387	2.446	2.604	821
Valencia	190	300	150	100	20	72	73	293	0
Total	22.317	24.952	25.816	11.540	23.280	32.249	58.219	53.226	53.667
Total grain maize area	459.146	394.000	433.146	512.497	465.134	484.833	484.327	421.723	379.174
Adoption rate	5%	6%	6%	2%	5%	7%	12%	13%	14%

Source: Compiled from Spanish Ministry of Agriculture (MAPA) (2007)

2.4 GM crops as an agricultural innovation: a review

In agriculture, as in other sectors, new technologies rapidly replace others. There is a wide range of literature on adoption and dissemination of technology in agriculture. It covers both the innovations (e.g. crop varieties, inputs, machinery and installations) and methods of analysis (e.g. diffusion equilibrium models, behavioural modelling, temporal and spatial diffusion models, empirical adoption studies, operational research and technology acceptance models). Farmers differ substantially in terms of both their farm structure and their characteristics when it comes to taking the decision whether or not to adopt a new technology.

Most of the literature has found that economic variables are major determinants of technological change and of adoption of innovations (Griliches, 1957; Griliches, 1960). However, adoption and dissemination can also be considered a function of the characteristics of the technology (cost, ease of use, expected benefit and support of labour), of farming conditions (pest pressure) and of farms' and farmers' characteristics (wealth, education, aversion to risk and farm size) (Batz, 1999; Chaves and Riley, 2001; Sheikh et al., 2003). The influence exerted by external factors depends on the time and place. It is of interest to policymakers, stakeholders and scientists to observe the role played by all these factors in adoption of innovations such as GM crops.

There are only a few studies on adoption of GM crop technologies. For instance, Marra et al. (2003) cite an original work by Hyde et al. (1999) which, based on experts' opinions, found that “mean profitability estimates varied systematically with European corn borer (ECB) pressures” in Indiana (USA) and that “high levels of absolute risk aversion could make Bt corn attractive under certain circumstances". Farmers' advisers, extension educators and academic researchers suggest that farmers use Bt maize as a sort of insurance against pest damage. However, market uncertainties, low commodity prices, the high price paid for GM technology and seasons with low levels of infestation could turn Bt maize into an investment which adds to the risk. In fact it has been empirically demonstrated that Bt maize can increase risk at the margin (Hurley et al., 2004).

Fernandez-Cornejo and McBride (2002), using data from a US survey at one point in time (1998), found that adoption of HT maize was positively related to farm size. The same study also analysed Bt maize but drew no clear conclusion on the effect of this variable. Other variables, such as education, experience, corn borer infestation and economic risk reduction (by contracting locks in prices or by lowering the likelihood of yield losses due to insect pressure), had a positive and significant impact on adoption of both GM maize types. Based on the same survey data, in 1998 Fernandez-Cornejo et al. (2002) found that larger farms and better educated farmers have responded positively to adoption of HT soybean in the USA. Crop price was another significant positive factor in adoption. However, in this case the proxy for risk and use of production/marketing contracts had no significant influence on adoption of HT soybean. Fernandez-Cornejo et al. (2003) pointed out that adopters of GM cotton and soybean did so firstly to increase yields through improved pest control, secondly to cut pesticide costs, thirdly to increase planting flexibility and, finally, for a combination of reasons.

Payne et al. (2003) asked maize producers in the major US maize-growing states about the likelihood of them adopting GM rootworm-resistant Bt maize once it becomes available[5]. Thirty-five per cent of the respondents (sample size: 1.587 farmers) answered that they would be either likely or very likely to adopt the technology. Using an ordered logit model, the authors found a positive correlation between the likelihood of adoption and farmers' age (up to 49 years old) and farm size. Growers of ECB-resistant Bt maize were also willing to adopt the technology. Export-oriented producers from the Eastern Corn Belt were less likely to adopt. Finally, off-farm labour was found to have a negative impact on adoption of this new technology. This last finding does not tally with a more recent nationwide survey of soybean farms, which associated adoption of HT soybean with a significant increase in off-farm household income for the population analysed (Fernandez-Cornejo et al., 2005). In the first study off-farm labour is considered a variable with an impact on the likelihood of adoption, while in the second it is considered an effect of actual adoption.

Another paper, also based on survey data but this time from China, found no statistically significant differences between Bt and non-Bt farms in terms of farm size, cotton area or the age or education of the head of the farm household (Huang et al., 2002).

Theoretically, adoption of GM crops is size-neutral since the technology is delivered in the seed, which is completely divisible and can be used in any amount, unlike technologies such as tractors or other machinery which require heavy capital investment and many acres over which to spread the costs of acquisition. However, according to the literature reviewed above, farm size may have affected adoption of HT soybean and HT corn in the USA (Fernandez-Cornejo and McBride, 2002). The reason for this could be that farm size may be a surrogate for other factors such as those mentioned above (e.g. wealth) which affects the early phases of adoption but is very unlikely to have an impact on dissemination.

Most of the papers reviewed used economic models for their analysis. However, Flett et al. (2004) criticised this, saying that these models "do not fully explain farmers' behaviour with regard to technology adoption". Like other authors, they argued that "economic models adequately explain farmers' behaviour with regard to technology adoption when the innovation is easy to adopt, adoption has clear economic advantages, the innovation has low complexity, and there are no other intervening considerations". As an alternative, they used a technology acceptance model to explain adoption and use of four dairy farming technologies, surveying 985 New Zealand farmers. The model focused on two key attitudinal components - perceived usefulness (PU) and perceived ease of use (PEOU) - and has already been used in several studies on technology adoption (Featherman and

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[5] Maize rootworm is considered an economically very important insect pest. According to some authors, maize rootworm might cause more damage to maize than ECB.

Pavlou, 2003; Ghorab, 1997; Koufaris and Hampton-Sosa, 2004). They also studied the economic factors affecting decision-making on whether to adopt and use the technologies under consideration. The results showed that the farmers surveyed evaluated the PU of a technology, but also, separately, the PEOU. Economic factors have been demonstrated to be crucial in the PU driving adoption. However, there is something beyond this and PEOU is still a relevant factor in decisions on technology adoption. Adopters found the technologies easy to understand and use, while non-adopters found these aspects more difficult. This could be considered to be the case for potential adoption of the targeted GM crops in the EU. PEOU can be adversely affected by, for example, co-existence rules calling for shelter and isolation distances.

This research looks at all the factors that could have affected adoption of Bt technology in Spain, both on the side of perceived usefulness and on the side of perceived ease of use.

Another paper, also based on survey data but this time from China, found no statistically significant differences between Bt and non-Bt farms in terms of farm size, cotton area or the age or education of the head of the farm household (Huang et al., 2002).

Theoretically, adoption of GM crops is size-neutral since the technology is delivered in the seed, which is completely divisible and can be used in any amount, unlike technologies such as tractors or other machinery which require heavy capital investment and many acres over which to spread the costs of acquisition. However, according to the literature reviewed above, farm size may have affected adoption of HT soybean and HT corn in the USA (Fernandez-Cornejo and McBride, 2002). The reason for this could be that farm size may be a surrogate for other factors such as those mentioned above (e.g. wealth) which affects the early phases of adoption but is very unlikely to have an impact on dissemination.

Most of the papers reviewed used economic models for their analysis. However, Flett et al. (2004) criticised this, saying that these models “do not fully explain farmers' behaviour with regard to technology adoption”. Like other authors, they argued that “economic models adequately explain farmers' behaviour with regard to technology adoption when the innovation is easy to adopt, adoption has clear economic advantages, the innovation has low complexity, and there are no other intervening considerations”. As an alternative, they used a technology acceptance model to explain adoption and use of four dairy farming technologies, surveying 985 New Zealand farmers. The model focused on two key attitudinal components - perceived usefulness (PU) and perceived ease of use (PEOU) - and has already been used in several studies on technology adoption (Featherman and

Pavlou, 2003; Ghorab, 1997; Koufaris and Hampton-Sosa, 2004). They also studied the economic factors affecting decision-making on whether to adopt and use the technologies under consideration. The results showed that the farmers surveyed evaluated the PU of a technology, but also, separately, the PEOU. Economic factors have been demonstrated to be crucial in the PU driving adoption. However, there is something beyond this and PEOU is still a relevant factor in decisions on technology adoption. Adopters found the technologies easy to understand and use, while non-adopters found these aspects more difficult. This could be considered to be the case for potential adoption of the targeted GM crops in the EU. PEOU can be adversely affected by, for example, co-existence rules calling for shelter and isolation distances.

This research looks at all the factors that could have affected adoption of Bt technology in Spain, both on the side of perceived usefulness and on the side of perceived ease of use.

2.5 Context surrounding adoption of the technology

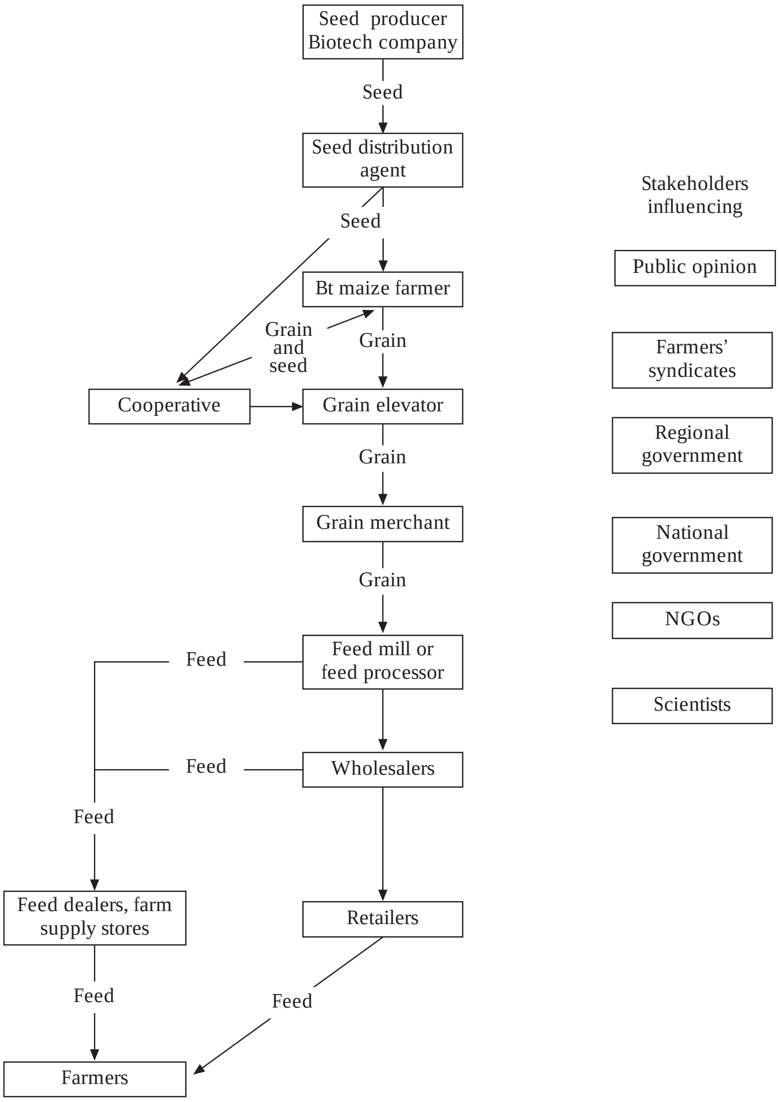
Despite the fact that GM crops have features in common with other agricultural innovations, their adoption could be influenced by the existing public controversy. This cuts across the fields of economics, ethics, politics, law, ecology, health and culture (Weick and Walchli, 2002). Proponents defend GM crops as a way to feed the rapidly growing world population, increase farmers' income and quality of life and improve the impact of agriculture on the environment. Opponents argue that GM crops will pose a risk to human health, produce herbicide- and pesticide-resistant weeds and pests and endanger biodiversity. Detractors also see the co-existence of GM, conventional and organic crops as impossible.

Disparities are also found between levels of acceptance on farms and amongst consumers. On the demand side, consumers currently see little benefit in buying GM food, apart maybe from a lower price. On the contrary, consumers, sometimes strongly influenced by opponents and the mass media, view consumption of these products as risky. They will accept or reject GM food and their purchase decisions will shape the demand curve for such food and, consequently, affect adoption and/or dissemination of GM crops.

One important point in Spain is that all the GM maize grain produced is sold for animal feed production (cattle, dairy or poultry) (de Saja, 2006). Therefore, Spanish Bt maize farmers must be placed in the context illustrated in Figure 4. Many stakeholders directly or indirectly related to maize producers could affect farmers' decision-making on whether or not to adopt biotechnology. The animal feed sector also uses about 4 500 000 tonnes of soybeans, of which 98.7% are GM. Under the GM Food and Feed Regulation (Regulation (EC) Nº 1829/2003[6]), products such as meat, milk and eggs from animals fed on GM animal feed do not need to be labelled.

Subsequent research will try to clarify whether or not the controversy has affected adoption of Bt maize in Spain and which have been the factors behind adoption.

Figure 4: Context of Spanish Bt maize farmers



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[6] Regulation (EC) No 1829/2003 of the European Parliament and of the Council of 22 September 2003 on genetically modified food and feed.

2.6 Previous studies on the on-farm economic impact of GM crops

Ex post analyses of the effects of adoption and dissemination of GM crops are of two types. The first and most frequently performed study the local, farm-level impact of adoption, the second the aggregate effects and economic welfare distribution. Farm-level analyses are usually based on surveying samples of farmers (adopters and non-adopters of the technology) (Fernandez-Cornejo et al., 2002; Gouse et al., 2005; Huang et al., 2002; Qaim and de Janvry, 2003; Qaim and Traxler, 2005; Thirtle et al., 2003). They provide data on the economic and agronomic performance of the GM crops and on the use of inputs (pesticides, energy, etc.) compared with conventional crops. The data gathered are analysed with statistical and econometric tools. The results produced by farm-level studies provide the starting-point for aggregate studies, which estimate the global economic welfare generated by adoption of GM crops and its distribution between economic operators (farmers, seed suppliers, research companies and consumers) or geographical regions (Falck-Zepeda et al., 2000a; Falck-Zepeda et al., 2000b; Qaim and Traxler, 2005; Traxler et al., 2003). The significance of aggregate results therefore depends on the quality of the farm-level data. Computable general or partial equilibrium models are normally used for aggregate studies on welfare (see Gómez-Barbero and Rodriguez-Cerezo, 2006 for a complete literature review).

This report focuses on the economic impact of adoption of Bt maize at farm level. Gouse et al. (2005) surveyed 33 large-scale yellow maize producers to gather data for the 1999/2000 and 2000/2001 production seasons. Four South African provinces were analysed. Farmers cultivating Bt maize achieved yields ranging from 7% to 12% higher than conventional maize farmers. This yield advantage together with lower pesticide costs resulted in income increases ranging from €19.2 per hectare to €119 per hectare. In the USA the evidence available is limited to the early years of adoption and points to very variable on-farm economic effects due to large geographical differences in the incidence of corn borers. Carpenter and Gianessi (2001) reported that average yields of Bt maize were higher than those of conventional maize during the period 1997-1999. In yearly analyses Bt maize growers obtained an average economic advantage of €37 per hectare.

However, the economic impact of higher yields plus small savings in pest control costs is sometimes offset by higher GM seed prices. In 1998 and 1999 Bt maize growers obtained lower income per hectare than conventional maize farmers (difference of about €3 in both years). A similar result was reported by Fernandez-Cornejo and McBride (2002) for the 1998 season. Hyde et. al. (1999) also found that the on-farm economic impact of Bt maize varied systematically with maize borer pressure in Indiana (USA).

What then is the incentive for adopting Bt maize in the USA? Marra et al. (2003) reviewed the role of risk, uncertainty and learning in the adoption of new agricultural technologies. They took the example of GM insect-resistant crops (Bt crops) where uncertainty stems primarily from variable seasonal levels of pest infestation. They concluded that farmers with “high levels of absolute risk aversion” contemplate Bt maize as an attractive technology. Farmers' advisers, extension educators and academic researchers suggest that farmers use Bt maize as “insurance” against crop losses in the long term. On the other side, market uncertainties, low maize prices, the price paid for the technology (GM seed) and seasons with low levels of infestation are economic risk factors when deciding to adopt Bt maize.

3. Methodological Approach

3.1 Methodology

As mentioned in the introduction, the general objective of this study is to produce evidence about the factors that might have affected Spanish farmers' decision whether or not to adopt Bt maize technology and to calculate the differences in agronomic and economic performance between adopters and non-adopters. To achieve these objectives, the research draws on data from an ad hoc survey of maize growers conducted in 2005. As shown in the previous section, ex post analyses of adoption and dissemination of GM crops are solidly based on surveys of samples of farmers.

The data obtained from this survey were then analysed with the appropriate statistical tools to identify differences between adopters and non-adopters of Bt technology in terms of farms' and farmers' characteristics, farmers' gross margin, economic welfare created and changes in pesticide use.

3.2 Selection of geographical areas studied

The regions where the fieldwork was carried out were selected on the basis of the area and rate of adoption of Bt maize. Table 2 showed that the three leading regions cultivating Bt maize were Aragon, Catalonia and Castilla-La Mancha. These three regions together accounted for about 90% of the total area under Bt maize in 2006, averaging 80% over the period 1998-2006.

Within each region the specific locations (provinces) for the survey were selected on the basis of the presence of adopters of Bt maize. Secondary information was collected from previous research and on the advice of various organisations with knowledge of the topic (farmers' cooperatives, academia and trade unions). The provinces selected were Zaragoza (39% of the total maize-growing area in Aragon), Albacete (51% of the total maize-growing area in Castilla-La Mancha), and Lleida (75% of the total maize-growing area in Catalonia).

3.3 Fieldwork and data collection

Stratified random sampling was used, as first the research needed to split the population (maize growers) into two separate subgroups - adopters and non-adopters of Bt technology. After that, simple random samples were taken separately from each group in each province.

In order to establish the size of the total sample, the study considered that altogether the universe of Bt farmers in the three regions consisted of approximately 4 800 individuals in 2004 (the base year for the survey). A sample of 200 growers of Bt maize would be representative of this population. With this total sample size the data gathering worked with a degree of error lower than 5% over the total population, assuming a maximum indeterminacy (p = q = 50%) and within a reliability of 95.5%.

A pre-coded structured questionnaire was tested on a pilot sample and, finally, sample farmers were interviewed personally during May and June 2005. The fieldwork was conducted in the provinces of Albacete, Lleida and Zaragoza, targeted on Bt and conventional growers with an a priori distribution of 50% (200 + 200). The interviews lasted twenty minutes on average.

4. Results: Factors Determining Adoption of Bt Maize By Spanish Farmers and Profile Of Adopters

4.1 General description of farmers surveyed

Three groups of maize farmer were identified: non-adopters, full adopters and partial adopters maize growers. The first was made up of 184 individual farmers who stated that they grow only conventional maize. The second consisted of 195 farmers who stated that they grow only Bt maize. Finally, the survey also identified a small group of 23 farmers who stated that they cultivate both types of maize (Table 3). This last group of farmers is excluded from the economic analysis (Section 5) since the information they provided was aggregated and not segregated by type of maize. In addition, the number of individuals belonging to the Bt + conventional maize growers group in each of the three provinces was too small for any statistical analysis.

Table 3: Number and types of maize grower surveyed

	Province			
Types of maize grower	Albacete	Lleida	Zaragoza	Total
Non-adopters	61	52	71	184
Full adopters	42	66	87	195
Partial adopters	2	16	5	23
Total province	105	134	163	402

The survey showed that 76.9% of the farmers interviewed have cereals as their main source of on-farm income. 92% of the farmers cultivated maize either as their main crop or as their second crop in terms of hectares during the reference year (2004). The average area cultivated per farm, whether owned, rented or under any other type of tenure, is 45 hectares although this varies considerably (standard deviation = 61 hectares). Screening the data to avoid outliers, for example considering only farms with cultivated areas below 300 hectares, the average is now about 40 hectares and the standard deviation about 42 hectares.

4.2 Comparison between the three types of farmer

4.2.1 Farm specialisation

Table 4 shows the frequencies for the variables “main farming source of income” and “types of maize”. About 77% of both conventional farmers and Bt maize farmers specialise in cereals. The figure is practically the same for the partial adopters group. Application of the Chi-square test to Table 4 found that the specialisation of the farm or main farming source of income is not statistically related to adoption of Bt technology.

Table 4: Main farming source of income

Main activity	Non-adopters	Full adopters	Partial adopters
Cereals	142	149	18
Other agricultural products	13	12	0
Vegetables	4	5	0
Vineyards	7	5	0
Olive groves	1	1	0
Citrus and other fruits	9	14	2
Bovine: meat	3	3	0
Sheep/goats	4	0	1
Pigs	1	6	2
Total	184	195	23

4.2.2 Main crop cultivated

Table 5 shows the main crop cultivated on the farm for each of the three groups of farmer surveyed. Maize is the main crop on the farm (in terms of area) for the vast majority of farmers in all three groups surveyed. 83% of either full or non-adopters grow maize as their main crop. The percentage is higher for the partial adopters group (96%). To test if the two category variables are statistically independent, the Chi-square test was applied to the data in Table 5. This found no relationship between the main crop cultivated in terms of area and the type of farmer.

Table 5: Main crop cultivated on the farm (in terms of hectares)

Main crop cultivated	Non-adopters	Full adopters	Partial adopters
Maize	152	162	22
Wheat	8	11	1
Other crops	24	22	0
Total	184	195	23

4.2.3 Farmers' age

Most of the farmers are married men older than 54 years symmetrically distributed around the median value of 54 with a standard deviation of about 12 years. A one-way ANOVA analysis showed no age differences between the three groups of farmer.

4.2.4 Farmers' education

The farmers were asked about their studies. Their level of education is usually low. About 70% of the farmers interviewed had not gone beyond primary school. The Chi-square test statistically confirmed that there are no differences between the three groups of farmer regarding education.

4.2.5 Further agricultural training or specialisation in the type of maize cultivated

The farmers were also asked if they had followed any kind of agricultural training or specialisation in any subject related to farming. 46% of those polled had attended further training courses. There are no statistical differences between the three groups of maize grower.

4.2.6 Experience as crop/cattle farmers

The farmers were asked how long they had been working as farmers. Most of them had been farming for many years. The average is about 35 years, a sign of an ageing population. Additionally, on average, the farmers had been working for 32 years on the same farm. A non-parametric one-way analysis of variance detected no difference between the three groups of farmer regarding either experience as a farmer or experience on the farm they own or where they work.

4.2.7 Dedication to farming

The farmers were asked about their dedication to farming. Table 6 shows figures for this variable. Most of the respondents are full-time farmers (82.75%). Chi-square analysis on Table 6 found no statistical relationship between part-time and full-time farming and the type of maize grown by the farmer.

Table 6: Dedication to farming

Main activity	Non-adopters	Full adopters	Partial adopters
Works only on the farm	149	161	21
Other activities	33	34	2
Total	182	195	23

When the 69 farmers in Table 6 who stated that they have another occupation were asked about their other activities, 33% replied that they have an alternative non-agricultural job, 24% own a professional consultancy or office and 11% work freelance/occasionally on another activity. Statistical analysis found no relationship between farmers' different off-farm occupations and the type of maize they grow.

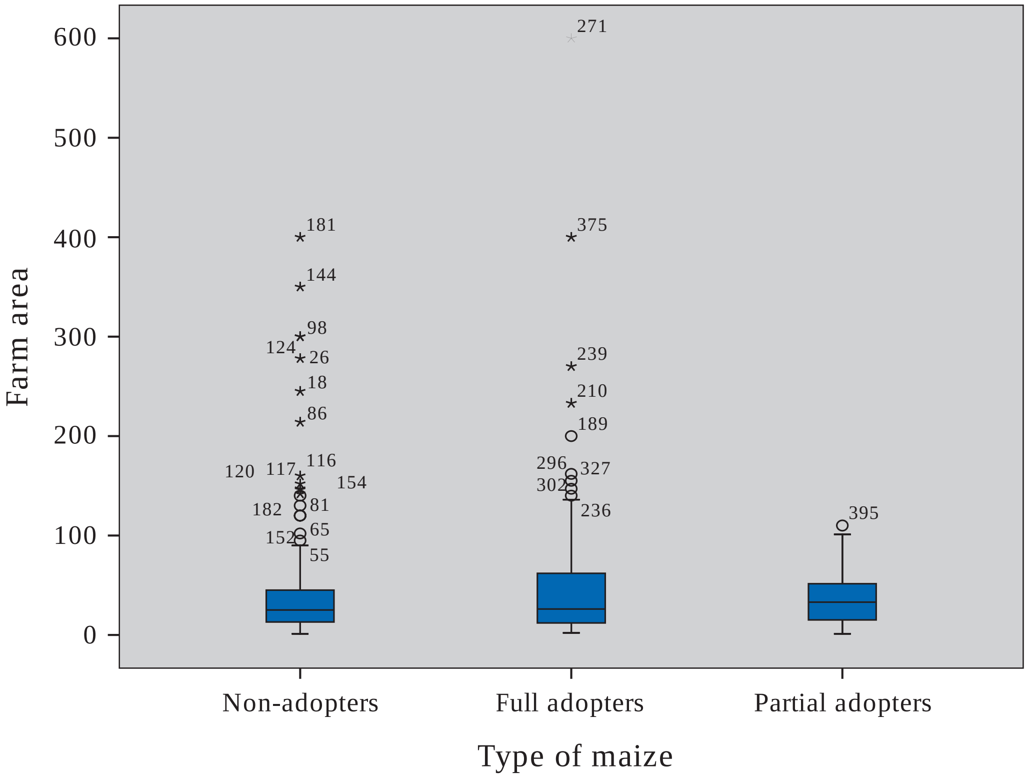
4.2.8 Farmers' participation in cooperatives and other institutions

72% of the farmers in the sample are members of cooperatives and 12% are members of agricultural processing companies. Only 2% of the farmers belong to farmers' associations or unions. No differences were found between non-adopters, full adopters and partial adopters regarding participation in such institutions.

4.2.9 Farm size

As mentioned in the general analysis, the area cultivated varied considerably, with an average farm size of 45 hectares. Figure 5 shows the distribution of this variable by type of farmer. The median is similar for the two main groups (conventional farmers: 25 hectares; full adopters: 26 hectares) and moderately higher for partial adopters (33 hectares).

Figure 5: Farm cultivated area distribution



The average areas cultivated per farm are shown in Table 7 together with the standard deviations and after screening out a farm of 600 hectares. Again no differences in farm size were found between Bt and conventional farms (44 and 43 hectares respectively). The corresponding analysis of variance (ANOVA) shows no statistically significant relationship between adoption of Bt maize and farm size on the 402 farms surveyed in Spain.

Table 7: Area cultivated per farm by type of farmer

Types of farmer	Average	Number of cases	Standard deviation	Median
Non-adopters	43	184	60	25
Full adopters	44	194	50	26
Partial adopters	39	23	30	33
Total	43	401	54	25

4.2.10 Recent trends in maize-growing area by type of farmer

The farmers were asked how long they had been cultivating either conventional or GM maize. Most of them are experienced maize growers; 95% of the conventional maize growers have more than five years' experience cultivating their current maize variety, whereas Bt growers are less experienced with their current variety. This is logical because Bt maize has been available in Spain only since 1998.

Table 8 shows that for all three types of maize grower the area of maize cultivated has been very stable for the four-year period (averaging 11.8 hectares). There are no statistical differences between the three groups of farmer regarding the area of maize cultivated[7].

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[7] ANOVA shows an F value of 1.27 and a significance of 0.29.

Table 8: Situation and development of maize cultivated by type of farmer

Type of maize farmer		Maize area 2000 (hectares)	Maize area 2001 (hectares)	Maize area 2002 (hectares)	Maize area 2003 (hectares)	Maize area 2004 (hectares)
Non-adopters	Average	11.13	11.70	11.68	11.60	11.63
	Number of cases	134	139	149	153	169
	Standard deviation	11.67	13.80	13.96	14.12	17.69
Full adopters	Average	11.75	11.12	11.21	10.24	11.01
	Number of cases	63	86	113	142	179
	Standard deviation	12.94	11.93	12.49	11.42	16.26
Partial adopters	Average	18.57	18.20	18.00	17.06	17.05
	Number of cases	14	15	15	17	21
	Standard deviation	15.12	14.93	13.85	13.08	13.31
Total	Average	11.81	11.90	11.83	11.28	11.63
	Number of cases	211	240	277	312	369
	Standard deviation	12.38	13.28	13.41	12.95	16.80

4.2.11 Land ownership

Table 9 shows that 57% of the farmers own all the land they farm, 37% cultivate both their own and rented land and, finally, 6% cultivate only rented land.

Table 9: Type of land tenure (number of farmers and percentage)

	Non-adopters	Full adopters	Partial adopters	TOTAL
Owns all the land	108 (59%)	113 (58%)	6 (26%)	227 (57%)
Owns part and rents part	61 (33%)	73 (38%)	16 (70%)	150 (37%)
Owns no land	15 (8%)	8 (4%)	1 (4%)	24 (6%)
Total	184	194	23	401

On comparison of the three groups of farmer, the “Bt + conventional maize” group displays differences in type of land tenure from the “conventional” and “Bt maize” groups. Farmers cultivating both types of maize at the same time seem to cultivate both their own and rented land at the same time. This is confirmed by a Chi-square test with a 0.01 level of significance[8]. However, when the same analysis is carried out for the two main groups (conventional and Bt maize) the relationship between the two variables is not significant[9].

As for land tenure in hectares, the area owned is slightly larger for conventional maize growers (23 hectares) than for Bt maize adopters (19 hectares) (see Table 10). Bt + conventional maize farmers differ more from the other two groups and own 28 hectares. However, ANOVA found that land ownership and type of maize cultivated are not statistically related.

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[8] Pearson Chi-square value 13.94; asymptotic significance 0.0074. Likelihood ratio value 13.63; asymptotic significance 0.0085.

[9] Pearson Chi-square value 3.05; asymptotic significance 0.216994. Likelihood ratio 3.08; asymptotic significance 0.2194

Table 10: Area owned (hectares)

Type of maize	Average	Number of cases	Standard deviation
Non-ats	23	60	32
Full adopters	18	73	16
Partial adopters	28	16	22
Total	121	149	24

4.2.12 Farm labour employed

Adoption of Bt maize has no impact on the amount of farm labour employed, according to this survey. Table B22 (annex B) illustrates different types of farm labour (paid or non-paid) on the maize farms surveyed in Spain. The analysis of variance found no statistical relationships between this variable and the type of maize adopted.

Most of the farmers enlist family help with their farming activities either very occasionally or never. The Chi-square analysis shows no statistical significance for the relationship between use of family help and type of maize grower. Both types are members of families who, in principle, have the same chances to obtain off-farm income.

4.2.13 Machinery

On average 85% of the farmers have one or two tractors. There is a slight difference in the number of tractors between the three groups. However, this difference disappears when only full adopters and non-adopters are compared. Therefore, it can be concluded that the two main groups show no significant difference in number of tractors, while partial adopters seem to have more.

Similar figures are observed for ownership of other types of machinery, such as combine harvesters/seed drillers. In both cases no statistically significant differences were observed between the two main groups of farmer analysed (full adopters and non-adopters), but some differences were when partial adopters are considered.

4.2.14 Grain price obtained by farmers

Potential differences in the price received by farmers for Bt or conventional maize were analysed using survey data. The farmers were asked how much they were paid for one kilogram of grain maize in 2004. No statistical difference was found between the price received by Bt maize farmers or conventional maize farmers, which averaged €0.128 per kilogram (see Table 11). The median is in fact the same for all three groups of farmer (€0.13 per kilogram).

Table 11: Harvest price (€/kg) received by maize farmers surveyed in Spain in 2004

Type of maize farmer	Average	Number of cases	Median	Standard deviation
Non-adopters	0.129	169	0.130	0.018
Full adopters	0.127	184	0.130	0.019
Partial adopters	0.130	23	0.130	0.018
Total	0.128	376	0.130	0.018

These findings tally with the Spanish feed industry's claims that it has never benefited directly from the introduction of Bt maize in Spain in the form of a reduction in raw material costs, since there was no difference between the prices it had to pay for Bt or conventional maize (de Saja, 2006). As mentioned earlier, 100% of the GM maize produced is used in animal feed.

4.2.15 Perceived usefulness of the technology

The farmers were asked to rank their perception of maize borer damage suffered during an average year on a scale from 1 (no damage) to 10 (extensive damage due to infestation). Table 12 shows the answers to this question.

Table 12: Farmers' perception of maize borer damage

Perception of maize borer damage	Non-adopters	Full adopters	Partial adopters
	(Number of cases and percentage)		
1 (minimum damage)	40 (26.0%)	110 (66.7%)	4 (17.4%)
2	46 (29.9%)	34 (20.6%)	6 (26.1%)
3	28 (18.2%)	11 (6.7%)	6 (26.1%)
4	17 (11.0%)	1 (0.6%)	1 (4.3%)
5	10 (6.5%)	2 (1.2%)	3 (13.0%)
6	4 (2.6%)	1 (0.6%)	1 (4.3%)
7	4 (2.6%)	4 (2.4%)	1 (4.3%)
8	2 (1.3%)	1 (0.6%)	1 (4.3%)
9	3 (1.9%)	1 (0.6%)	0 (0.0%)
10 (maximum damage)	40 (26.0%)	110 (66.7%)	4 (17.4%)
Total	154	165	23

Most of the farmers rated the impact between 1 and 4, i.e. low. Table 12 shows that their perception of corn borer impact is linked to the type of maize cultivated. 87% of the Bt maize farmers put the impact between 1 and 2, whereas only 55% of the conventional farmers perceive the same level of damage. Bt maize growers perceives that suffer less damage to their crops than growers of conventional maize[10].

4.2.16 Insecticide use

The analysis also compared use of insecticides by Bt and conventional maize farmers in Spain for controlling maize borers. Chemical control of maize borers is difficult because insecticide sprays are effective only in the narrow time span between egg hatch and larvae boring into stems. Because of the ineffectiveness and additional cost, many maize farmers do not spray insecticides specifically for controlling corn borers and accept the yield losses, but no precise figures with statistical relevance were available. This survey showed that 56% of the farmers interviewed did not apply insecticide against maize corn borer.

Table 13 illustrates the number of applications of insecticide by Spanish farmers to control maize borer, depending on the type of maize grown. The main finding is that 42% of the non- adopters use no insecticides at all to control corn borers, and that this figure increases to 70% for full adopters. 21% of non-adopters apply two or more sprayings per year, and this figure falls to 2% of full adopters.

On average, the conventional maize growers applied 0.86 sprayings a year compared with 0.32 by the full adopters (see Table 9 in Section 3.4).

Table 13: Number of annual treatments against maize borer by type of maize

Number of applications of corn borer pesticide	Non-adopters	Full adopters	Partial adopters
	(Number of cases and percentage)		
0	77 (42%)	136 (70%)	15 (65%)
1	68 (37%)	56 (29%)	4 (17%)
2	29 (16%)	3 (2%)	2 (9%)
3	8 (4%)	0 (0%)	2 (9%)
4	2 (1%)	0 (0%)	0 (0%)
Total	184	195	23

The Pearson's Chi-square test applied to Table 13 has a p-value less than 0.001 which means there is a statistical relationship between the number of applications of pesticides against maize borer[11].

4.2.17 Farmers' estimates of future harvest losses due to maize borer

The farmers were asked what percentage of harvest losses they expected to suffer in the next year due to the maize borer if they were to use Bt or conventional maize. Table 14 summarises the quantitative assessment given by the farmers. On average, current adopters estimated that switching to only conventional maize in the following year would mean a harvest loss of 13% due to maize borer. Current non-adopters estimate this figure at 9.5%.

Table 14: Farmers' estimates of next year's harvest losses due to maize borer

	Type of farmer (current year)	
Possible type of maize next year	Adopter	Non-Adopter
	(percentage of normal harvest and number of cases)	
Only conventional maize	-13.6% (73)	-9.5% (55)
Only Bt maize	-1.2% (162)	-1.7% (42)

Another finding is that non-adopting farmers think that adoption of Bt maize would reduce their harvest losses from 9.5% to 1.7% which is very significant. This proves that, on average, Bt maize farmers see the technology as effective. The next section analyses whether these non-adopters consider adoption cost-effective.

4.3 Bt maize farmers' opinions on Bt technology

The analysis set out above was based mainly on the technical, demographic and socio-economic characteristics of the farmers. Additionally, the questionnaire was also an opinion poll. The farmers were asked directly about the main reasons for their decision to adopt or not to adopt Bt maize technology. They were asked to rank a limited number of answers (reasons for adopting) from 1 (not important at all) to 5 (very important). Table 15 ranks the reasons given by farmers for adopting Bt maize (194 respondents).

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[10] Chi-square test results: Pearson Chi-square value 79.315; asymptotic significance 0.000.

[11] Pearson Chi-square value 79.315; asymptotic significance 0.000.

Table 15: Reasons given by farmers in Spain for adopting Bt maize

Order of importance maize farmer	Reasons for adopting Bt maize	Average score	Standard deviation
1	Lower risk of losses due to maize borer	4.61	0.602
2	Higher yields	4.44	0.795
3	Ensures better quality of harvest	4.27	0.939
4	Makes me feel safer/guarantees me more security	4.24	0.949
5	Guarantees a greater income	4.20	0.963
6	Facilitates my work, being a technology that makes cultivation easier	3.95	1.332
7	Saves costs on plant health products	3.65	1.439
8	The technician or technicians that I have consulted recommended its use	3.48	1.486
9	My regular seed supplier recommended that I use it	3.44	1.593
10	Environmental impact on my farm is lower because I can decrease application of pesticides	3.29	1.372
11	Makes me feel I am at the forefront of biotechnological progress	3.24	1.369
12	All farmers around me are using it	2.94	1.357

Note: 194 farmers answered.

Calculation of the relative number of farmers ranking the statements 4 or 5 produced the following conclusions:

Primary reasons for adopting the technology:

- 94.8% of the farmers consider that Bt maize is sure to eliminate losses due to maize borer.
- 85.5% of the farmers believe that production increases with Bt maize.
- 80.9% of the farmers feel that Bt maize reduces risk.
- 78.5% of the farmers consider that the technology has a positive impact on product quality.
- 74.2% of the farmers state that profits increase as a result of using Bt maize.
- 65.4% of the farmers consider that the technology makes crop management easier.
- 58.3% of the farmers think that the technology saves chemicals but 16.5% do not agree with this statement, while 22% are not clear about the subject.
- 56.6% of the farmers say that their input suppliers recommended that they use Bt maize.
- 54.2% of the farmers state that the technicians who assist them recommended the product.

Finally, one other interesting outcome of these direct questions is that farmers adopting Bt maize do not see themselves as technological innovators.

4.4 Conventional farmers' opinions on adoption of Bt technology

The same analysis was carried out for conventional maize farmers, who were asked to weight their reasons for non-adoption. To sum up, conventional farmers do not consider adoption of Bt maize cost-effective. Table 16 shows their reasons for non-adoption. Farmers were asked to rank them from 1 (completely disagree) to 5 (completely agree). The first reason for non-adoption is aversion to change, followed by lack of confidence in GM crops in general and the high cost of Bt maize seeds. The latter suggests that, on average, non-adopters believe that Bt maize is an effective agronomic tool but comes at a high cost which might offset gains. They do not see Bt maize as cost-effective.

Table 16: Reasons given by farmers for not adopting Bt maize

Order of importance	Reasons for adopting Bt maize	Average score	Standard deviation
1	I prefer not to change the type of crop. I do not really like change	3.51	1.282
2	I do not believe in these new kinds of product	3.17	1.165
3	The seeds are much more expensive	3.14	1.166
4	Corn borer does not really affect my crops	3.08	1.135
5	I do not think there would be an improvement in economic returns	2.91	1.282
6	It is looked on badly by society	2.86	1.183
7	I consider there would be no improvement in yields	2.86	1.221
8	I think it would be difficult to market the grain	2.64	1.270
9	I have more faith in use of insecticides o combat corn borer than in this type of crop	2.59	1.167
10	It is a complicated technology to use (one has to comply with co-existence or shelter regulations)	2.50	1.518
11	Makes me feel I am at the forefront of biotechnological progress	3.24	1.369
12	I have no chance of buying seed. My usual supplier cannot provide it	1.71	1.20

A count of the relative number of statements scoring 4 or 5 produced the following conclusions:

- 77% of the farmers do not like to change.
- There is no clear opinion on the impact of maize borer.
- The productivity gains from using Bt are unclear, but there is a widespread opinion that productivity is the same for both types of maize.
- No increase in profits is perceived.
- Pesticide is a convenient way to control pests.
- The farmers know about co-existence rules, including cultivating an area of conventional maize to avoid creating resistance, and consider them a bureaucratic cost.
- The farmers consider that the higher price paid for the seed is a problem for adoption.
- Some farmers have received advice not to cultivate GM crops.
- Some farmers perceive a risk with marketing the maize.
- The social impact of Bt is not decisive but should be considered.

Finally, conventional farmers were requested to weigh reasons that would lead them to adopt Bt maize. Farmers growing conventional maize would adopt Bt maize as a result of various factors, but the main two are maize borer impact on harvests and the seed price differential (see Table 17).

Table 17: Reasons given by conventional farmers for adopting Bt

Order	Reasons	Mean	Standard deviation
1	Higher incomes from grain marketing	3.68	1.247
2	An increase in CB infestation on my farm	3.65	1.207
3	A reduction in seed prices	2.77	1.302
4	If recommended by the technician	2.57	1.130
5	If I see neighbouring farmers use it	2.44	1.221

Note: 162 farmers answered.

It can be concluded that non-adopters are satisfied with conventional maize and do not perceive Bt maize as a cost-effective solution to the maize borer problem. They do not feel that a change in technology will be profitable.

5. Results: Economic Impact of Bt Maize on Spanish Farmers

5.1 Sources of on-farm economic impact

Adoption of GM crops can have potential on-farm effects, both on revenue and on costs, compared with their conventional counterparts. The scale and sign of their impact will tilt the balance, giving Bt maize growers an economic advantage or disadvantage. A priori, the profitability of a GM crop such as Bt maize at farm level depends on key variables such as:

- Differences in yield (Bt crops are expected to reduce yield losses due to pests);
- Differences in the market price of the harvest;
- Reduction in pest control costs (Bt crops are expected to reduce insecticide use);
- Differences in seed prices (GM varieties are more expensive than their conventional counterparts).

To estimate the on-farm economic impact of adoption of Bt maize in Spain, the gross margins of farmers cultivating Bt maize or conventional maize were calculated and compared for 2002, 2003 and 2004. The analysis was based on the data produced by the survey on the above-mentioned variables from a total of 184 individual farmers who stated that they grow only conventional maize (non-adopters) and 195 growing only Bt maize for comparison (full adopters). As mentioned in the previous section, the survey also identified a small group of 23 farmers who declared that they cultivate both types of maize, but these were excluded from the analysis since the economic information provided by these farms was aggregated and not segregated by type of maize (partial adopters).

5.2 Impact on revenue: yield differentials

The difference in yields between Bt and conventional maize in Spain is shown in this section.

The results show that Bt maize had yield advantages over conventional maize in the three years studied.

However, the yield increase obtained by Bt maize farmers in Spain shows clear regional differences and (less marked) temporal differences (see Figure 6). Differences in yield between Bt and conventional maize ranged from -1.3% in Albacete in 2003 to +12.1% in Zaragoza in 2002 (Tables 18, 19 and 20 for single-region analysis). These differences were only statistically significant in Zaragoza.

Bt technology seems to perform differently in the three regions, and this variability could be explained by heterogeneity between farmers, differences in pest pressure (Qaim et al., 2006), agro-ecological conditions and the fact that Bt technology may not yet have been introduced in varieties suitable for all regions (up until 2003 there were only two commercial Bt maize hybrids in Spain, whereas now there are over 50).

Figure 6: Yield differences between Bt and conventional maize in Spain by year

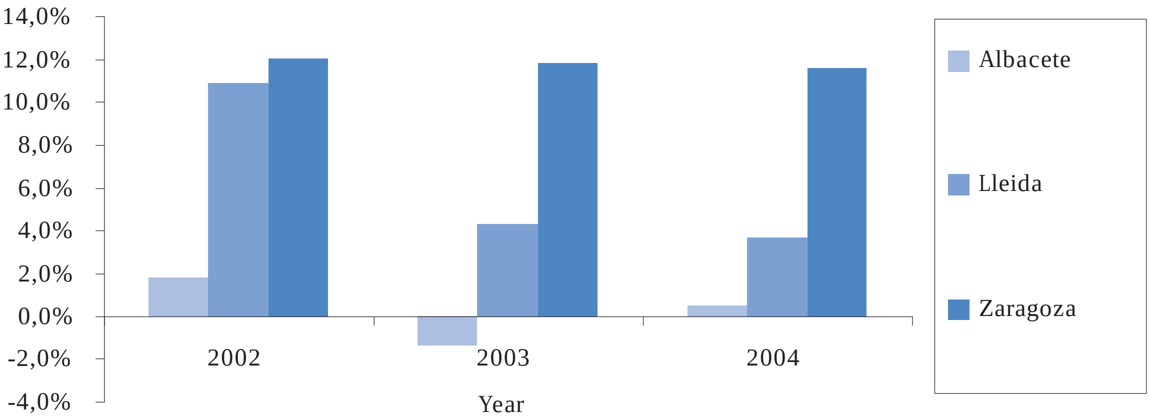

Table 18 shows the average yields for Bt and conventional maize in Albacete. The yield advantage of Bt over conventional maize ranged from -1.3% in 2003 to 1.8% in 2002 and 2004.

Table 18: Average yields for Bt and conventional maize in Albacete (2002-2004)

	Conventional maize			Bt maize			Bt/Conv.
Year	Mean (t/ha)	Standard deviation	Number of farmers	Mean (t/ha)	Variance	Standard deviation	% yield advantage
2002	12.14	2.00	40	12.36	1.77	29	1.8% ns
2003	12.01	2.29	43	11.85	1.86	33	-1.3% ns
2004	12.53	2.15	51	12.59	1.51	37	0.5% ns

ns= not significant at 5%

Table 19 shows the same data for Lleida. The yield advantage of Bt over conventional maize ranges from 3.7% in 2004 to 10.9% in 2002.

Table 19: Average yields for Bt and conventional maize in Lleida (2002-2004)

	Conventional maize			Bt maize			Bt/Conv.
Year	Mean (t/ha)	Standard deviation	Number of farmers	Mean (t/ha)	Variance	Standard deviation	% yield advantage
2002	11.51	1.66	11	12.66	2.00	10	10.9% ns
2003	11.52	1.60	14	12.01	1.64	20	4.3% ns
2004	11.75	1.73	17	12.18	1.86	34	3.7% ns

ns= not significant at 5%

Table 20 shows the yield differences in Zaragoza. The yield advantage of Bt over conventional maize ranges from 12,1% in 2002 to 11,6% in 2004.

Table 20: Average yields for Bt and conventional maize in Zaragoza (2002-2004)

	Conventional maize			Bt maize			Bt/Conv.
Year	Mean (t/ha)	Standard deviation	Number of farmers	Mean (t/ha)	Standard deviation	Number of farmers	% yield advantage
2002	9.87	1.47	39	11.06	1.19	49	12.1%***
2003	9.46	1.10	55	10.49	1.03	63	11.8%***
2004	9.53	1.20	59	10.64	1.29	70	11.6%***

***=significant at 0.01%

5.3 Impact on revenue: market price differentials

As shown in previous sections, the price of the harvest was similar regardless of the type of maize cultivated (Table 11).

5.4 Pesticide costs

Pest control costs were analysed using data from the survey on the number of applications of insecticide against corn borer by farmers using Bt or conventional maize. The survey also allowed estimation of the average cost of insecticide application (€21.10 per application per hectare[12]). The resulting calculations of pest control costs are summarised in Table 21. Bt maize farmers from the three provinces reported savings in pest control costs (€9.49 per hectare in Albacete, €3.17 per hectare in Lleida and €20.04 per hectare in Zaragoza).

Table 21. Pest control costs of Bt and conventional maize farmers

	Conventional maize		Bt maize		Conventional-Bt
Province	Average number of insecticide applications against maize borer (I)	Pest control cost (€/ha) (I*21.10)	Average number of insecticide applications against maize borer (II)	Pest control cost (€/ha) (II*21.10)	Savings in pest control costs reported by Bt maize farmers (€/ha)
Albacete	0.64 (61)	13.50	0.19 (42)	4.01	9.49
Lleida	0.21 (52)	4.42	0.06 (66)	0.00	3.17
Zaragoza	1.52 (71)	32.10	0.57 (87)	12.03	20.04

Note: Number of cases in brackets

5.5 Seed costs

The additional seed costs incurred by farmers using Bt maize were estimated from the survey. Companies developing GM seed usually recommend a "royalty fee" to distributors. Data from the survey showed that the price difference between GM and non-GM maize seed is not constant over time and varies between provinces. The temporal variability is difficult to explain due to the limited period observed (2002-2004). Price differentials for Bt maize seed between provinces are shown in Table 22 which gives the averages for the three-year period.

Table 22: Average seed costs (€/ha) for conventional and Bt maize farmers by province (2002-2004)

	2002			2002			2002		
Province	Conventional maize	Bt maize	Diff	Conventional maize	Bt maize	Diff	Conventional maize	Bt maize	Diff
Albacete	163.62 (24)	174.92 (24)	-11.30 ns	177.43(30)	180.97 (25)	-3.54 ns	176.78 (41)	182.84 (29)	-6.05 ns
Lleida	164.88 (4)	193.67 (25)	-28.79 ns	164.88 (4)	193.67 (25)	-28.79 ns	164.88 (4)	193.67 (25)	-28.79 ns
Zaragoza	171.56 (55)	211.22 (9)	-39.66***	174.03 (57)	222.20 (61)	-48.17***	178.32 (61)	218.95(72)	-40.64***

Note: Number of cases in brackets. Results are means followed by standard deviations and number of cases in parenthesis. Number of cases varies between the variables due to missing data. One-way analysis of variance is used to test the differences among means. ns= not significant at 5% and ***= significant and 0.1%.

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[12] Based on the sample and screening for outliers, the ratio "pesticide cost per hectare/number of applications" is estimated at €21.10 per application per hectare with a standard deviation of €16 per application per hectare.

GM seed price differences between provinces can be explained by various reasons. First, seed suppliers seem to be focusing on different provinces. The survey found that Bt 176 varieties are more present in Albacete, while MON-810 varieties are in Lleida and Zaragoza[13,14]. As mentioned earlier in this report, these two events were brought on to the market at different times and are therefore at different stages of the product life cycle. This could be reflected in diverging pricing policies. Secondly, the final price paid by farmers may also depend on their ability to negotiate (presence and role of cooperatives, farm size, etc). However, the survey shows that farmers' level of organisation seems relatively similar in Albacete and Lleida (where about 70% of Bt farmers are members of cooperatives) and higher in Zaragoza (with 97% of Bt farmers in cooperatives) where seed costs per hectare are much higher. The third reason is related to price discrimination policies followed by suppliers selling seed to different farmers at different prices, even though the costs of producing it are the same for all farmers. The price will therefore depend on farmers' willingness to pay for more expensive seed which, itself, will depend on the yields and income obtained. It should be added that average price differentials between GM and non-GM maize seed are highest in Zaragoza (where Bt maize gives the highest yield increase) and lowest in Albacete (where yield increases due to Bt maize are lowest).

In previous analyses Demont and Tollens (2004) stated that in 2002 at least 70% of Bt maize seed in Spain was marketed at an average price of €18.5 per hectare, while Brookes (2002) mentioned €29-31 per hectare as the range of the price differential. This analysis found similar average results, but one innovative outcome of this research is that the marketing strategy of seed suppliers adapts the total profit margin to the local profitability of Bt technology.

5.6 On-farm economic balance

Table 24 summarises the final on-farm economic balance obtained by Bt maize and calculates the difference in gross margin obtained by Bt maize farmers in the three provinces for 2002, 2003 and 2004. These calculations were made considering only those variables for which differences between Bt and conventional show statistical significance. The results mark the first empirical data on the economic performance of a GM crop in the EU.

Gross margin differences largely follow the variability in agronomic yield increase described above, that seems to be a key factor defining the economic balance. For the three growing seasons studied (2002, 2003 and 2004) farmers using Bt maize obtained higher gross margins than farmers growing conventional maize. These benefits, however, vary widely in the three regions studied (see Table 24), ranging from the highest gross margin difference in Zaragoza in 2002 (€135.08 per hectare) to small differences in Albacete (€9.49 per hectare) and in Lleida (€3.17 per hectare) both referred to 2002, 2003 and 2004.

A weighted average gross margin gain for adopters over non-adopters can be estimated combining each regional average for the three years period (i.e. €9.49 per hectare in Albacete, €3.17 per hectare in Lleida and €124.82 per hectare in Zaragoza) with the region's share of the total Bt maize-growing area in 2004 (i.e. Albacete 17.28%, Lleida 36.55% and Zaragoza 46.17%). This figure accounts for an average yearly gain of €60.43 per hectare.

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[13] Out of a total of 133 Bt farmers answering, it was found that in Albacete 63% cultivate Bt 176, while in Lleida and Zaragoza 80% and 94% respectively cultivate MON-810.

[14] Monsanto and Syngenta not only sell their Bt genes in their own hybrids but also license this gene to other companies, such as Pioneer, for use in theirs.

Table 23: Economic benefits of adopting conventional or Bt maize in three Spanish provinces over three growing seasons

	2002			2003			2004		
	Conventional maize	Bt maize	Difference	Conventional maize	Bt maize	Difference	Conventional maize	Bt maize	Difference
Albacete									
Yield (tonnes/ha)	12.14 ± 2.00 (n = 40)	12.36 ± 1.77 (n = 29)	0.22 ns	12.01 ± 2.29 (n = 43)	11.85 ± 1.86 (n = 33)	-0.16 ns	12.53 ± 2.15 (n = 51)	12.59 ± 1.51 (n = 37)	0.06 ns
Revenues from yield (€/ha)	1,578.20 ± 260.19 (n = 40)	1,606.80 ± 229.77 (n = 29)	28.60 ns	1541.80 ± 297.18 (n = 43)	1540.50 ± 242.93 (n = 33)	–20.08 ns	1628.90 ± 286.74 (n = 51)	1636.70 ± 193.95 (n = 37)	7.80 ns
Cost of maize borer pest sprays(€/ha)	13.50 ± 15.42 (n = 61)	4.01 ± 9.60 (n = 42)	9.49**	13.50 ± 15.42 (n = 61)	4.01 ± 9.60 (n = 42)	9.49**	13.50 ± 15.42 (n = 61)	4.01 ± 9.60 (n = 42)	9.49**
Seed cost (€/ha)	163.62 ± 37.32 (n = 24)	174.92 ± 42.14 (n = 24)	–11.30 ns	177.43 ± 40.1 (n = 30)	180.97 ± 35.56 (n = 25)	–3.54 ns	176.78 ± 32.32 (n = 41)	182.84 ± 38.32 (n = 29)	–6.05 ns
Gross margin increase for Bt maize adopters (€/ha)			9.49			9.49			9.49
Lleida									
Yield (tonnes/ha)	11.51 ± 1.66 (n = 11)	12.66 ± 2.00 (n = 10)	1.15 ns	11.52 ± 1.60 (n = 14)	12.01 ± 1.64 (n = 20)	0.49 ns	11.75 ± 1.73 (n = 17)	12.18 ± 1.86 (n = 34)	0.43 ns
Revenues from yield (€/ha)	1,496.3 ± 216.41 (n = 11)	1645.8 ± 260.38 (n = 10)	149.50 ns	1497.6 ± 208.51 (n = 14)	1561.30 ± 213.39 (n = 20)	63.70 ns	1527.50 ± 224.58 (n = 17)	1563.90 ± 241.76 (n = 34)	55.9 ns
Cost of maize borer pest sprays(€/ha)	4.43 ± 10.51 (n = 52)	1.26 ± 5.07 (n = 66)	3.17*	4.43 ± 10.51 (n = 52)	1.26 ± 5.07 (n = 66)	3.17*	4.43 ± 10.51 (n = 52)	1.26 ± 5.07 (n = 66)	3.17*
Seed cost (€/ha)	164.88 ± 43.87 (n = 4)	193.67 ± 60.28 (n = 25)	–28.79 ns	164.88 ± 43.87 (n = 4)	193.67 ± 60.28 (n = 25)	–28.79 ns	164.88 ± 43.87 (n = 4)	193.67 ± 60.28 (n = 25)	–28.79 ns
Gross margin increase for Bt maize adopters (€/ha)			3.17			3.17			3.17
Zaragoza									
Yield (tonnes/ha)	9.87 ± 1.47 (n = 39)	11.06 ± 1.54 (n = 49)	1.19***	9.46 ± 1.10 (n = 55)	10.49 ± 1.66 (n = 63)	1.03***	9.53 ± 1.20 (*n* = 59)	10.64 ± 1.29 (n = 70)	1.11***
Revenues from yield (€/ha)	1,283.10 ± 190.95 (n = 39)	1,437.80 ± 199.63 (n = 49)	154.70***	1229.80 ± 142.54 (n = 55)	1363.70 ± 215.15 (n = 63)	133.9***	1238.90 ± 155.49 (*n* = 59)	1383.20 ± 167.53 (n = 70)	144.30***
Cost of maize borer pest sprays(€/ha)	32.07 ± 18.13 (n = 71)	12.03 ± 11.43 (n = 87)	20.04***	32.07 ± 18.13 (n = 71)	12.03 ± 11.43 (n = 87)	20.04***	32.07 ± 18.13 (*n* = 71)	12.03 ± 11.43 (n = 87)	20.04***
Seed cost (€/ha)	171.56 ± 44.43 (n = 55)	211.22 ± 34.18 (n = 49)	–39.66***	174.03 ± 42.33 (n = 57)	222.20 ± 35.91 (n = 61)	–48.17***	178.32 ± 40.43 (*n* = 61)	218.95 ± 51.18 (n = 72)	–40.64***
Gross margin increase for Bt maize adopters (€/ha)			135.08			105.77			123.70

Data was obtained from a face-to-face survey conducted in 2005 amongst Spanish commercial maize farmers including 184 farmers growing only conventional maize and 195 farmers growing only Bt maize. The survey gathered data on yields, crop price, seed costs, and applications of pesticide against maize borer for growing seasons (2002, 2003 and 2004). Results consist of mean values followed by standard deviations and number of cases in parentheses. Number of cases varies between the variables due to missing data. One-way analysis of variance is used to test the differences among means. ns= not significant at 5%; *P<0.05; **P<0.01; ***P<0.001. Seed costs for 2004 are used for the three years in Lleida due to missing data for 2002 and 2003. Gross margin increase is computed from adding the differences in revenues from yield, in cost of maize borer pest sprays and in seed costs when they are statistically significant.

5.7 Aggregated economic impact

5.7.1 Aggregated on-farm economic impact

Taking the 2004 figure on the total Bt maize-growing area in Spain (58.219 hectares) along with a weighted average economic advantage of using Bt maize (€60.43 per hectare), a rough estimate of the aggregated economic welfare surplus obtained by Bt farmers in 2004 would be €3.5 million.

The increase in farmers' gross margin due to adoption of Bt maize in Spain is in line with one of the main objectives of the CAP, that is to improve the competitiveness of EU agriculture in order to be ready for more market-oriented production. The likely impact of adoption of other GM crops in EU farming (see Chapter 4) also points to a bigger gross margin for farmers. GM varieties could be regarded as a means of keeping agricultural activity sustainable from the economic point of view.

5.7.2 Distribution of welfare between large and small maize farms in Spain

Another interesting result from the survey is that adoption of Bt maize technology in Spain is not statistically related to farm size. Farms cultivating maize in Spain are quite heterogeneous, but the only factor prompting adoption of Bt maize was their perception of corn borer risk. Therefore currently the welfare created by Bt maize for Spanish farmers does not seem to be associated with large farms.

There is a possibility that this situation might change when the Spanish government (following EU guidelines) introduces mandatory technical measures for GM crop farmers to ensure co-existence with non-GM crops. This will be a novel cost to add to the balance for Bt maize in Spain, as discussed in other sections of this report, and larger farms are likely to cope better with this novel measure and to implement it at lower unit cost.

6. Discussion And Conclusions

This report analyses ex post the issues surrounding the adoption of the first GM crop introduced in EU agriculture. It is more than nine years since the first GM insect-resistant maize, known as "Bt maize", was planted in the EU, exclusively in a single Member State (Spain). Understanding the adoption of GM crops in the EU is of interest to policy-makers, scientists and agricultural circles due to the potential impact of this technological change on several economic variables at both farm and aggregate level. The JRC-IPTS has produced this report with the aim of presenting evidence about the factors that might have affected farmers' decision whether or not to adopt the technology and the economic implications of their decision.

A survey of Spanish maize farmers was conducted in three major Bt maize-growing areas (the provinces of Zaragoza in the Aragon region, Lleida in Catalonia and Albacete in Castilla-La Mancha). Three groups of maize grower were identified: 184 farmers growing only conventional maize (non-adopters), 195 growing only Bt maize (full adopters) and, finally, 23 farmers who stated that they cultivate both types of maize (partial adopters).

Comparison of the three groups of maize-grower revealed no statistical differences in the main crop cultivated in terms of hectares, the main crop contributing to on-farm income, age, education, further agricultural training or years of experience as farmers. No statistical relationship was found between individuals working as part-time or full-time farmers and adoption of Bt technology. As regards participation in institutions such as cooperatives, agricultural processing companies or unions, all three groups of farmer show the same profile. Again, no differences were found between them in terms of farm labour employed or family help on the farm either. In addition, the survey found that adoption of Bt maize in Spain is not statistically related to farm size or the area under maize. Finally, no differences were found in the price which farmers are paid for one kilogram of grain maize. These results are in line with an analysis of Bt cotton adoption in China which found no statistically significant differences in all the variables studied between Bt and non-Bt farms (Huang et al., 2003).

The variables which did show differences between types of farmer were those related to insect control. This is one feature for which Bt technology was developed. Both Bt and conventional maize farmers considered the technology capable of reducing harvest losses due to corn borer, although conventional growers did so to a lesser extent. The perceived usefulness of the technology was therefore higher amongst adopters.

The survey also included information on farmers' reasons for adopting or not adopting the technology. Economic variables, such as higher profit and lower economic risk, were found to be the main determinants for adoption. Conventional farmers mentioned reluctance to change their type of crop, lack of confidence in GM crops and the higher price for Bt maize seed as the main reasons for non-adoption. However, in general terms, conventional farmers would be willing to adopt the technology if they were to perceive clear economic advantages. The public controversy surrounding GM crops in the EU does not seem to have influenced adoption in Spain. These findings are supported by previous ex post studies on factors shaping adoption of GM crops (including Bt maize) elsewhere (Fernandez-Cornejo and McBride, 2002; Marra et al., 2003).

Regarding the on-farm implications of farmers' decisions on what production system to use (Bt or conventional maize), the survey also gathered data on the economic and agronomic performance of Bt maize and conventional maize over the 2002-2004 growing seasons. Bt maize adopters experienced higher average yields than conventional corn growers for the three growing seasons. However, these higher yields were statistically significant only for the province of Zaragoza (a yield increase of 1.110 kg/ha or 11.8%). Bt crops, like other pest-control technologies, produce variable yield gains depending mainly on local pest pressure and damage (Qaim et al., 2006) and the fact that Bt technology has not yet been introduced in varieties suitable for all regions (up until 2003 there were only two commercial Bt varieties, whereas now there are over 35). The same analysis conducted in other countries produced similar results. Carpenter and Gianessi (2001) reported that, on average, Bt maize yields in the USA were higher than those from conventional maize in 1997, 1998 and 1999. Gouse et al (2005) also found yield advantages for maize farmers who adopted Bt maize (10-11%), although these in turn depended on the place.

Bt maize seed was found to be more expensive in Spain than conventional seed, but with regional differences (e.g.€6.05 per hectare in Albacete, €28.79 in Lleida and €40.64 in Zaragoza, all in 2004). Finally, Bt maize farmers from the three provinces reported savings in corn borer control costs (€9.5 per hectare in Albacete, €3.2 per hectare in Lleida and €20 per hectare in Zaragoza). The question is, therefore, whether these lower pest control costs and the differences in yields currently outweigh the higher seed costs. The findings show that, on average, farmers who planted Bt maize achieved an annual gross margin higher than conventional maize farmers, despite paying a technology fee. These benefits, however, vary widely between the three regions studied, ranging from the highest gross margin differences in Aragon (€124.82 per hectare) to small differentials in Castilla-La Mancha (€9.49). This is largely a consequence of the spatial variability in yield mentioned above. There is scientific consensus that farmers use Bt maize as a sort of insurance as it reduces yield losses by corn borer (Fernandez-Cornejo and McBride, 2002; Marra et al., 2003). Beyond that, the economic advantage obtained will always depend on the level of pest pressure. Similar results have been found in South Africa, where the economic performance advantage of Bt over conventional maize growers ranged from €19.20 to €119 per hectare.

The number of applications of pesticide to control corn borer damage was also found to be related to the type of maize. 70% of Bt maize growers applied no insecticides to control corn borer pests, while 53% of non-adopters applied one or two sprayings. The survey found that, on average, conventional maize farmers applied 0.86 sprayings a year, while Bt maize farmers applied 0.32. This reduction is modest in absolute terms because, as shown earlier, the conventional method of maize borer control that Bt maize is replacing is not based on heavy use of insecticides.

All in all, it can be concluded that adoption of Bt maize in Spain has been a consequence of farmers trying to increase their profit, reduce the risk of yield losses due to corn borer or both. Empirical analysis has found that Bt maize can increase yields and bring farmers tangible economic benefits. However, when considering the future adoption and impact of GM crops in the EU, a new dimension has to be added: the costs incurred in order to ensure co-existence with non-GM crops. EU Member States have targeted GM crop farmers as the ones who have to take any measures necessary at farm level. No such framework for co-existence targeted on GM crop farmers is in place in other parts of the world where GM crops are cultivated. This raises new questions for adoption of GM crops by EU farmers and its economic balance.

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Annexes

Annex A: General description of the sample

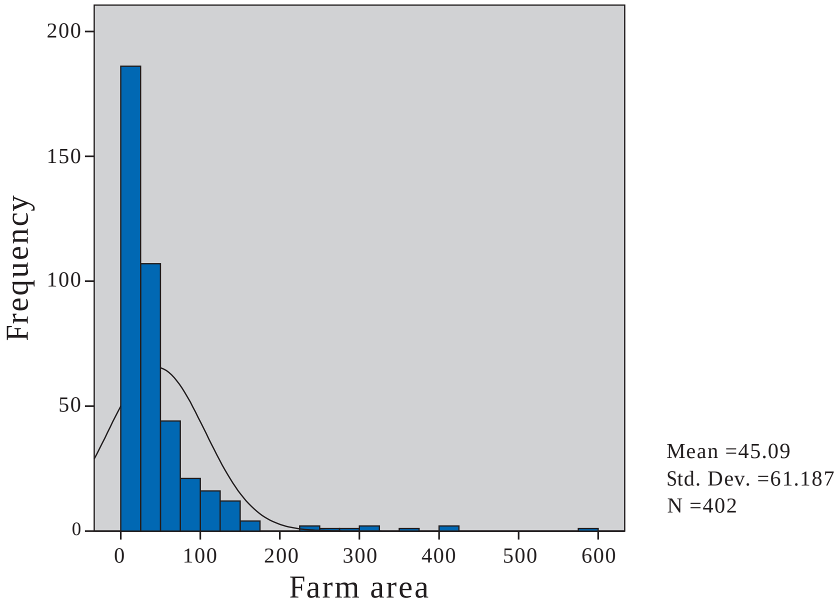
Table A1: Main agricultural source of income on the farm

Activity	Number of farmers	Percentage
Cereals	309	76.9%
Vegetables	9	2.2%
Vineyards	12	3.0%
Olive groves	2	0.5%
Citrus and other fruits	25	6.2%
Bovine: meat	6	1.5%
Sheep/goats	5	1.2%
Pigs	9	2.2%
Other agricultural products	25	6.2%
Total	402	100.0%

Table A2: Farm area cultivated by province

Province	Mean	Number of farmers	Standard deviation
Albacete	53.73	105	86.094
Lleida	31.51	134	46.106
Zaragoza	50.69	163	50.310
Total	45.09	402	61.187

Figure A1: Histogram for farm area cultivated



Annex B: Comparison Between The Three Types Of Farmer

Table B1: Chi-square test for main farming source of income

	Value	Degrees of freedom	Asymptotic significance (2-sided)
Pearson Chi-square	17.758	16	0.338264718
Likelihood ratio	21.446	16	0.161984514
Linear-by-linear association	1.9608	1	0.161422986
Number of valid cases	402		

Table B2: Chi-square test for main crop cultivated in terms of hectares

	Value	Degrees of freedom	Asymptotic significance (2-sided)
Pearson Chi-square	16.20	32	0.99083953
Likelihood ratio	21.01	32	0.93137269
Linear-by-linear association	1.36	1	0.24381691
Number of valid cases	402		

Figure B1: Farmers' age

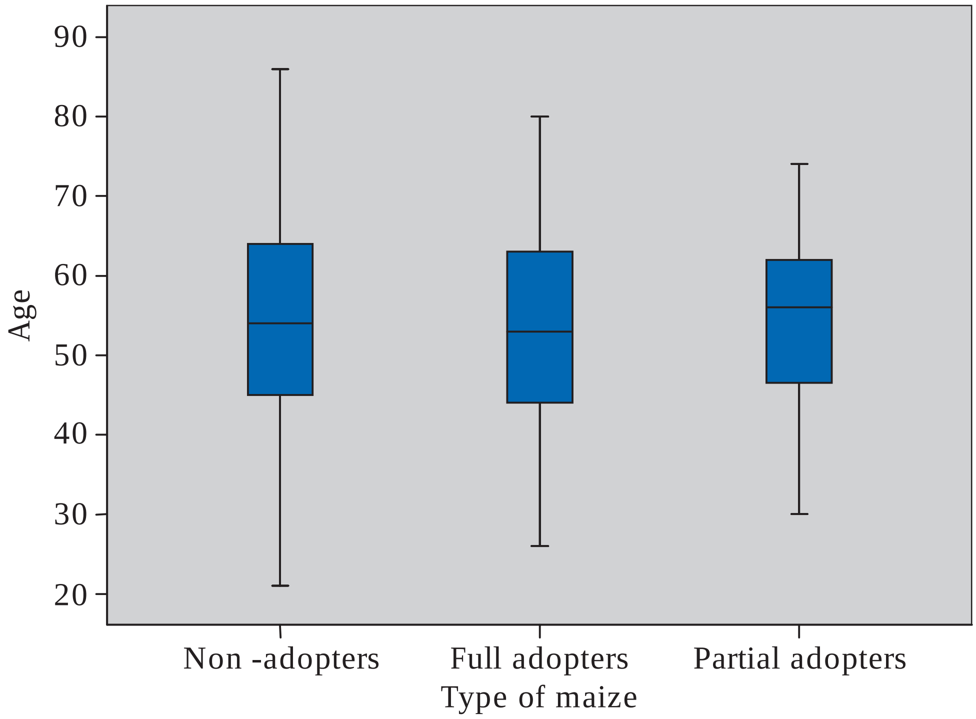


Table B3: Farmers' age

Type of farmer	Mean	Number of farmers	Standard deviation
Non-adopter	54.17	184	13.151
Full adopter	53.28	194	12.527
Partial adopter	53.87	23	11.478
Total	53.72	401	12.738

Table B4: ANOVA of farmers' age by type of maize

	Sum of squares	Df	Maen squares	F	Sig.
Between groups	75.363	2	37.682	0.231	0.794
Within groups	64831.355	398	162.893		
Total	64906.718	400			

Table B5: Level of education for whole sample of farms

Education	Cases	Percentage
Without studies	28	7.0%
Primary school unfinished	129	32.1%
Primary school finished	142	35.3%
Secondary	55	13.7%
Vocational studies (non-agricultural)	13	3.2%
Other non-agricultural studies	1	0.2%
Agricultural training	19	4.7%
Veterinary	1	0.2%
Agricultural engineer (medium degree)	5	1.2%
Agricultural engineer (higher degree)	3	0.7%
Other university degree	2	0.5%
Total	398	99.0%
NA	4	1.0%
Total	402	100.0%

Table B6: Contingency table for farmers' education by type of maize

Education	Non-adopters	Full adopters	Partial adopters	Total
Without studies	15 (8%)	13 (7%)	0 (0%)	28 (7%)
Primary unfinished	66 (36%)	59 (30%)	4 (17%)	129 (32%)
Primary finished	63 (35%)	70 (36%)	9 (39%)	142 (36%)
Secondary, vocational (non-agricultural) and other non-agricultural studies	26 (14%)	35 (18%)	8 (35%)	69 (17%)
Agricultural training	8 (4%)	9 (5%)	2 (9%)	19 (5%)
Higher education	3 (2%)	8 (4%)	0 (0%)	11 (3%)
Total	181 (100%)	194 (100%)	23 (100%)	398 (100%)

Table B7: Chi-square test farmers' education and types of maize

	Value	Degrees of freedom	Asymptotic significance (2-sided)
Pearson Chi-square	13.481	10	0.198026714
Likelihood ratio	14.961	10	0.133498207
Linear-by-linear association	7.2286	1	0.007174996
Number of valid cases	398		

Table B8: Contingency table for further farming-related training and type of farmer

Further courses	Non-adopters	Full adopters	Partial adopters	Total
Yes	83 (46%)	90 (47%)	11 (48%)	184 (46%)
No	99 (54%)	103 (53%)	12 (52%)	214 (54%)
Total	182 (100%)	193 (100%)	23 (100%)	398 (100%)

Table B9: Chi-square test for further farming-related training and type of farmer

	Value	Degrees of freedom	Asymptotic significance (2-sided)
Pearson Chi-square	0.0648	2	0.968128518
Likelihood ratio	0.0648	2	0.968138095
Linear-by-linear association	0.0645	1	0.799582256
Number of valid cases	398		

Figure B2: Experience as farmer (years)

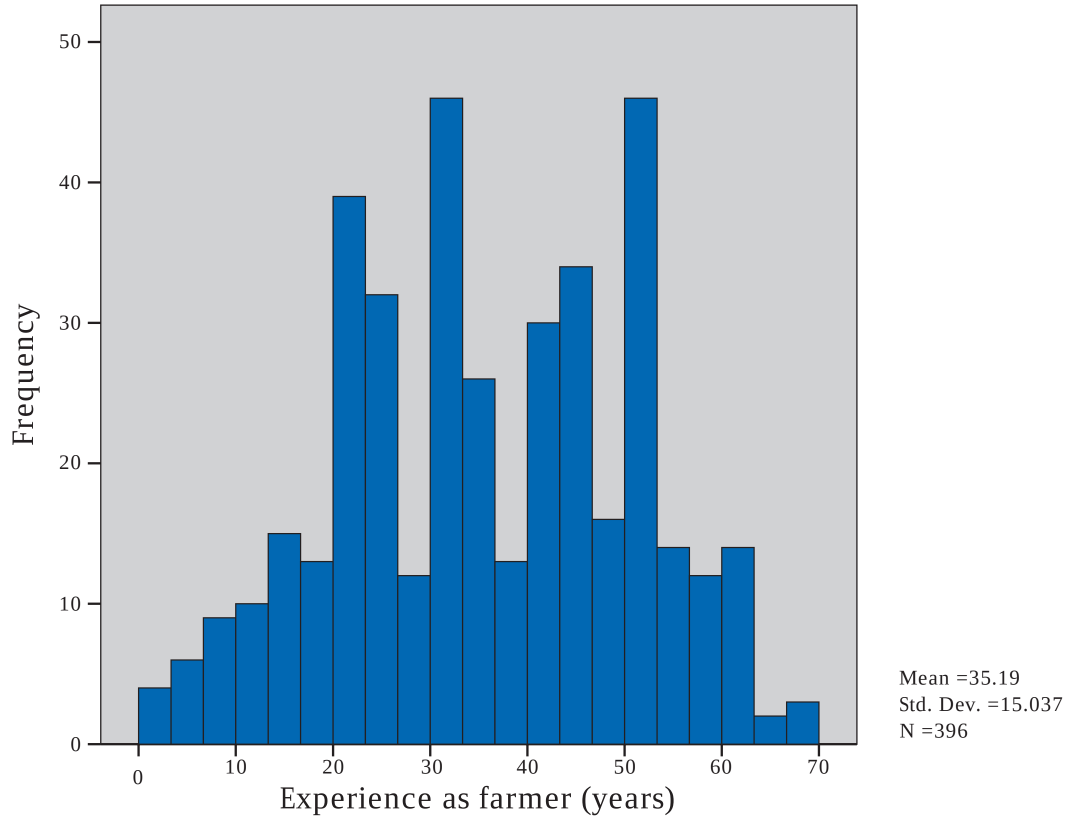


Table B10: Experience as farmer and on the farm where currently working (years)

Types of farmer		Experience as farmer (years)	Experience on current farm
Non-adopters	Mean	36.06111111	32.44751381
	No	180	181
	Standard deviation	15.08825578	14.90875048
Full adopters	Mean	33.98963731	31.515625
	No	193	192
	Standard deviation	15.11035435	14.71722165
Partial adopters	Mean	38.47826087	36.34782609
	No	23	23
	Standard deviation	13.5976922	13.64021026
Total	Mean	35.19191919	32.22222222
	No	396	396
	Standard deviation	15.03745654	14.75268218

Figure B3: Experience as farmer and types of maize

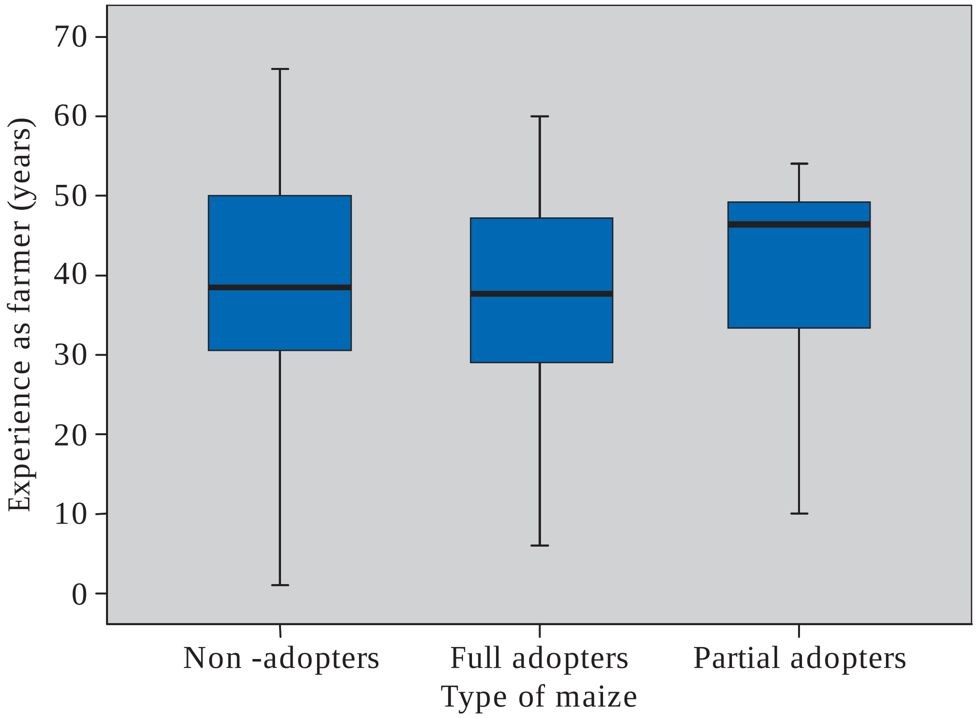


Table B11: Non-parametric one-way analysis of variance of experience as farmer and on the farm where currently working

Experience as farmer (years)					
	Sum of squares	Df	Mean square	F	Sig.
Between groups	663	2	331	1.47030924	0.23111595
Within groups	88656	393	225		
Total	89319	395			
	Sum of squares	Df	Mean square	F	Sig.
Experience on current farm (years)					
Between groups	496	2	248	1.14150563	0.32039431
Within groups	85471	393	217		
Total	85968	395			

Table B12: Chi-square test for dedication to farming and type of maize

	Value	Degrees of freedom	Asymptotic significance (2-sided)
Pearson Chi-square	1.282960937	2	0.52651236
Likelihood ratio	1.494330218	2	0.47370756
Linear-by-linear association	0.628972566	1	0.42773243
Number of valid cases	400		

Table B13: Other occupations and types of maize

	Non-adopters	Full adopters	Partial adopters	Total
Paid labour on other farms 2 (6%)	7 (21%)	0 (0%)	9 (14%)	
Paid labour in a non-agricultural activity	13 (39%)	9 (27%)	0 (0%)	22 (33%)
Owns a business, bar, restaurant, shop	3 (9%)	4 (12%)	0 (0%)	7 (11%)
Owns an office or professional consultancy	8 (24%)	8 (24%)	1 (100%)	16 (24%)
Works freelance/alone occasionally or erratically in another activity	3 (9%)	4 (12%)	0 (0%)	7 (11%)
Other sources of income	4 (12%)	1 (3%)	0 (0%)	5 (8%)
Total	33 (100%)	33 (100%)	1 (100%)	66 (100%

Table B14: Chi-square test for other occupations and types of maize

	Value	Degrees of freedom	Asymptotic significance (2-sided)
Pearson Chi-square	8.342893218	10	0.595382
Likelihood ratio	8.27222751	10	0.602265
Linear-by-linear association	1.028213233	1	0.310578
Number of valid cases	66		

Table B15: Contingency table for farmers' participation in cooperatives and other associations

Institution	Non-adopters	Full adopters	Partial adopters	Total
Cooperative	125 (68%)	145 (74%)	19 (83%)	289 (72%)
Agricultural processing company	25 (14%)	21 (11%)	1 (4%)	47 (12%)
Farmers' association or union	3 (2%)	4 (2%)	1 (4%)	8 (2%)
Other	1 (1%)	0 (0%)	0 (0%)	1 (0%)
None	30 (16%)	25 (13%)	2 (9%)	57 (14%)
Total	184 (100%)	195 (100%)	23 (100%)	402 (100%)

Table B16: Chi-square test for farmers' memberships by type of maize

	Value	Degrees of freedom	Asymptotic significance (2-sided)
Pearson Chi-square	5.979742728	8	0.649501114
Likelihood ratio	6.565035137	8	0.584203288
Linear-by-linear association	2.010061098	1	0.156259025
Number of valid cases	402		

Table B17: ANOVA for cultivated area by type of maize

ANOVA	Sum of squares	Df	Mean square	F	Sig.
Between groups	2 172.94	2	1 086.47	0.289174	0.7490387
Within groups	1 499 104.65	399	3 757.15		
Total	1 501 277.59	401			

Table B18: ANOVA for maize-growing area in 2004 and type of maize

ANOVA	Sum of squares	Df	Mean square	F	Sig.
Between groups	686.1482	2	343.1	1.216298	0.2975
Within groups	103235.5	366	282.1		
Total	103921.6	368			

Table B19: Chi-square test for land tenure and type of farmer (three groups of farmer)

	Value	Degrees of freedom	Asymptotic significance (2-sided)
Pearson Chi-square	13.94	4	0.007488523
Likelihood ratio	13.63	4	0.008556893
Number of valid cases	401		

Table B20: Chi-square test for land tenure and type of farmer (full adopters and non-adopters)

	Value	Degrees of freedom	Asymptotic significance (2-sided)
Pearson Chi-square	3.055772	2	0.216994
Likelihood ratio	3.089226	2	0.213394
Linear-by-linear association	0.325296	1	0.568442
Number of valid cases	378		

Table B21: ANOVA for farm area owned (hectares) and types of maize

	Sum of squares	Df	Mean square	F	Sig.
Inter-group	1 401.82	2	700.91	1.16280	0.31549
Intra-group	88 005.59	146	602.78		
Total	89 407.41	148			

Table B22: Paid employed farm labour in maize farms surveyed in Spain

		Number of permanent workers (non-family)	Number of paid workers from the family	Number of workers in peak periods	Seasonal workers hired in peak periods (number of days worked)
Non-adopters	Mean	0.12	0.09	1.27	7.37
	NO	184	184	183	174
	Stand. Dev.	0.58	0.36	3.58	17.69
Full adopters	Mean	0.16	0.11	1.72	13.18
	NO	194	194	194	178
	Stand. Dev.	0.64	0.44	5.29	40.77
Partial adopters	Mean	0.00	0.09	1.74	8.91
	NO	23	23	23	22
	Stand. Dev.	0.00	0.29	6.24	22.72
Total	Mean	0.13	0.10	1.52	10.23
	NO	401	401	400	374
	Stand. Dev.	0.60	0.39	4.65	31.16

Table B23: ANOVA table for paid employed farm labour

ANOVA		Sum	Df	Mean square	F	Sig.
Number of permanent workers	Inter-group	0.58	2	0.29	0.81484	0.44345
	Intra-group	141.42	398	0.36		
	Total	142.00	400			
Number of workers from the family registered as wage-earners	Inter-group	0.03	2	0.01	0.08905	0.91482
	Intra-group	61.98	398	0.16		
	Total	62.01	400			
Number of workers in peak periods	Inter-group	19.73	2	9.86	0.45590	0.63421
	Intra-group	8 590.18	397	21.64		
	Total	8 609.91	399			
Number of days worked	Inter-group	3 006.90	2	1 503.45	1.55260	0.21307
	Intra-group	359 254.78	371	968.34		
	Total	362 261.68	373			

Table B24: Family help on the farm by type of maize grower

	Type of farmer			
Help from family members	Non-adopters	Full adopters	Partial adopters	Total
Always	24 (13%)	25 (13%)	5 (22%)	54 (14%)
Fixed plus seasonal	8 (4%)	15 (8%)	0 (0%)	23 (6%)
Seasonal	70 (39%)	72 (38%)	6 (26%)	148 (38%)
NO help	78 (43%)	79 (41%)	12 (52%)	169 (43%)
Total	180 (100%)	191 (100%)	23 (100%)	394 (100%)

Table B25: Chi-square test for family help

	Value	Degrees of freedom	Asymptotic significance (2-sided)
Chi-square	5.89089	6	0.43552
Number of valid cases	394		

Table B26: Contingency table for number of tractors and types of maize

	Type of farmer			
Tractors	Non-adopters	Full adopters	Partial adopters	Total
1	109 (65%)	103 (57%)	7 (32%)	219 (59%)
2	34 (20%)	54 (30%)	13 (59%)	101 (27%)
3	18 (11%)	18 (10%)	0 (0%)	36 (10%)
4	3 (2%)	4 (2%)	2 (9%)	9 (2%)
5	2 (1%)	0 (0%)	0 (0%)	2 (1%)
>6	1 (1%)	1 (1%)	0 (0%)	1 (0%)
Total	167	180	22	369

Table B27: Chi-square test for number of tractors and types of maize

	Value	Degrees of freedom	Asymptotic significance (2-sided)
Three groups of farmer	26.7979	12	0.00826
Main groups (without partial adopters)	8.38286	6	0.21137

Table B28: *Number of combine harvesters/seed drills*

	Type of farmer			
Harvesters/seed drills	Non-adopters	Full adopters	Partial adopters	Total
1	54	60	6	120
%	76%	80%	67%	77%
2	9	11	2	22
%	13%	15%	22%	14%
3	6	4	0	10
%	8%	5%	0%	6%
4	2	0	0	2
%	3%	0%	0%	1%
5	0	0	1	1
%	0%	0%	11%	1%
Total	71	75	9	155
0	100%	100%	100%	100%

Table B29: *Chi-square test for number of combine harvesters/combiners*

	Value	Degrees of freedom	Asymptotic significance (2-sided)
Three groups of farmer	20.506	8	0.00858
Main groups (without partial adopters)	2.80831	3	0.42213

Table B30: *Chi-square test for CB damage by type of maize*

	Value	Degrees of freedom	Asymptotic significance (2-sided)
Pearson Chi-square	79.315	16	0.000

European Commission

EUR 22778 EN - Joint Research Centre - Institute for Prospective Technological Studies

Title: **Adoption and impact of the first GM crop introduced in EU agriculture : Bt maize in Spain**

Authors: Manuel Gómez-Barbero, Julio Berbel, Emilio Rodríguez-Cerezo

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Abstract

This report analyses the process of adoption by farmers of the only GM crop cultivated in Europe. Bt maize is a transgenic crop resistant to an important group of pests (the maize borers). The study also provides the first large-scale empirical evidence on the agronomic and economic performance of this crop in the EU. The research was carried out in Spain, the EU member state with highest adoption rate of Bt maize in agriculture (reaching 60% in some regions) since it was first introduced in 1998. The report used data from a survey carried out among 402 commercial maize farms, including both adopters and non adopters of Bt maize during three growing seasons (2002-2004). Farmers were based in three Spanish provinces (Zaragoza, Lleida and Albacete) situated in leading Bt maize growing areas of Spain. All farmers were producing maize for feed manufacturing.

The survey found that Bt maize, like other pest-control technologies, produced variable impacts on maize yields in different provinces, ranging from neutral to 11.8% yield increase. The regional variability depends mainly on local variations of pest pressure and damage. Yield gains for growers of Bt maize were translated into revenue increase since no differences were found in the price paid to farmers for Bt or conventional maize. Regarding production costs, Bt maize growers paid more for the seeds than conventional growers, but had reduced insecticide use and costs. On average, growers of conventional maize applied 0.86 insecticide treatments/year to control borers versus 0.32 treatments/year applied by Bt maize growers. All things considered, the impact of Bt maize adoption on gross margin obtained by farmers in different provinces ranged from neutral to ¤ 122/ha and year. In the survey, the reason most quoted by farmers for adopting Bt maize was "lowering the risk of maize borer damage" followed by "obtaining higher yields".

Finally, the report compared the socio-economic profiles of farmers adopting or not Bt maize varieties. No differences were found for the two groups of farmers for variables such as land ownership, farm size, experience as maize grower, education or training. The report concludes that the differences in yields and gross margin are therefore attributable to the adoption of Bt maize varieties.

The mission of the JRC is to provide customer-driven scientific and technical support for the conception, development, implementation and monitoring of EU policies. As a service of the European Commission, the JRC functions as a reference centre of science and technology for the Union. Close to the policy-making process, it serves the common interest of the Member States, while being independent of special interests, whether private or national.

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