Bt maize in Germany

Experience with cultivation from 1998 to 2002

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The European corn borer is a pest that causes yield losses worldwide in the billions. This pest is responsible also in Europe for regional decreases in yield quantity and quality. Genetically modified crops represent a safe method for the control of the European corn borer. Although in Germany planting of genetically modified crops is currently only possible on a small scale, the efficiency of Bt technology could be shown in a multi-year study comparing different methods of pest control.

The European corn borer is continuously spreading. Originally found south of the Main-river line and in certain favourable locations in Eastern Germany (for example the Oderbruch region), a noticeable increase in infestation has been registered recently in areas such as North-Rhine-Westphalia, Thuringia, Saxony, Saxony-Anhalt and Brandenburg. Today almost 300,000 hectares of agricultural land are affected (Figure 2).

The financial damage caused by the European corn borer differs from region to region and from year to year. For a surface of 100,000 hectares of grain maize, a 5% yield decrease, the equivalent of 40,000 tons of dry goods, would imply an economic loss of 4,400,000€. A 20% decrease would bring about a loss of 17,600,00 €. Yield losses are also to be expected in silage maize; these are however more difficult to quantify as the exact yield of silage maize is seldom recorded at the farm level. In all cases, because of the physiological stress it causes, the European corn borer affects the yield of the maize plants, thus reducing their value as feed. Furthermore, mould fungus (*Fusarium*) can develop in those areas where pests feed on the plants and produce toxic compounds known as mycotoxins. High-level control of the European corn borer therefore offers an additional advantage, since it allows to reduce the amount of fungus contaminating the crop.

Commercial Bt maize cultivation

Although over 20 million hectares of Bt maize have been cultivated worldwide since the first commercialisation of this crop, the amounts planted in Germany have so far remained comparatively modest. In this country, a few hundred hectares of Bt maize have been grown every year between 1998 and 2002. The resulting harvest was used as fodder.

Over the same time period, comparative large plot studies were conducted in Baden Wuerttemberg (Rhine Valley) and Brandenburg (Oderbruch region), as a joint project between the companies Syngenta seeds, Pioneer Hi-Bred Northern Europe GmbH and Monsanto Agrar Deutschland GmbH, and partly in cooperation with the official extension service. The plots were planted with Bt maize and the corresponding conventional variety. Including *Trichogramma* and insecticide treatments into the test set-up made it possible to evaluate and assess different methods of European corn borer control under identical environmental conditions.

The Bt maize hybrids used in the study were approved for cultivation in the EU. Commercial cultivation in Germany was conducted with varieties currently undergoing the official German variety testing or were already approved for cultivation in other EU countries.

Study setup

- Contiguous large plots of at least 0.5 hectares per treatment.

- Treatments: Bt maize / untreated control / registered insecticides (applied once) / commercially available *Trichogramma* (applied twice manually).

- Sampling by official extension service in charge of plant protection.

- Determination of European corn borer infestation in each treatment conducted by slicing a representative amount of maize stalks (50 or 100 per region)

- Determination of yield and grain moisture

- Economic assessment of each treatment

DAMAGE

- The European corn borer larvae can produce tunnels in the maize stalks from the tassel to the roots, thus damaging xylem and phloem. In the worst cases, this can lead to massive crop lodging.

TREATMENTS

A) Conventional insecticide treatment

- The *Lepidoptera* infestation of the maize crops depends on weather conditions, thus differs from year to year. As a result, the optimal date for insecticide treatment is difficult to determine

- Limited long-term efficacy of the insecticides, registered only for a single application per vegetation period

- Complicated application technique

- Registrations due to expire, thus probably no insecticide available in 2004

B) Biological control with *Trichogramma*

- Well established system, but high costs and complex handling

- Highly dependant on weather conditions

C) *Bacillus thuringiensis* (Bt) maize

- Insect-resistance through the production of a protein originally isolated from Bt

- Bt proteins were discovered in 1901 and Bt sprays have been used since 1927 also in organic agriculture

- Protection throughout complete growth period

- Independent of weather conditions

- In the EU, Bt176 (1997) and MON810 (1998) approved for planting

Level of infestation and efficacy of the treatments

In the untreated control of the Rhine Valley, infestation with the European corn borer in the individual years ranged from 0.11 to 0.42 larvae per maize plant. Pest occurrence was consistently higher in the Oderbruch region in plots without European corn borer protection where 0.68 and even 1.18 (!) larvae per plant were recorded.

Treatments with insecticide resulted in a noticeable reduction of the infestation (Figure 3). Because pest pressure was high, insecticide application in the Oderbruch region reduced the average infestation only to that seen in the untreated control group of the Rhine Valley. The use of *Trichogramma* merely achieved satisfactory results in the Rhine Valley. In the Oderbruch region, in spite of having been treated with the ichneumon fly, an average of 70% of the maize remained infested. Practically no European corn borer larvae were found in any of the Bt maize plots, with a few exceptions resulting from the fact that the seed mixtures used contained a small number of plants not bearing the resistance gene. The results of the biological efficacy of the treatments are unequivocal, as shown in Figure 4 where 0% efficacy corresponds to levels in untreated control fields.

The use of insecticide resulted in over 80% reduction of the borer in the respective plots of both test regions. Given the relatively high number of remaining larvae in the *Trichogramma* plots, efficiency was rated at only 59% (Rhine Valley) and 29% (Oderbruch), respectively. In contrast, Bt maize resulted in complete pest control.

Yield results

Yield results obtained for the individual maize hybrids over the study period showed the expected variations in the different environments. However, the average trend was clear: the higher the efficiency of the chosen control method, the higher the grain maize yield. For both test regions, the difference between the untreated control group and the Bt maize group corresponded to approximately 1 ton of grain maize (Table 1). In the Rhine Valley, the maize showed lower moisture at harvest compared to that from the Oderbruch region. Contrary to early assumptions, Bt maize - which due to complete corn borer protection is physiologically active for a longer period of time – showed hardly more moisture at the time of harvest than maize from the untreated control group. The largest variation in average water content between extreme values was approximately 1%. Relative yield results (untreated controls represent 100%) indicate an increase of 2% or 3% for the groups treated with *Trichogramma* (Figure 5). With application of insecticides, an average increase compared to controls of 7% was achieved for the Rhine Valley and 10% for the Oderbruch region. In accordance with the excellent corn borer efficiency explained earlier, the highest yield increase was observed in the Bt maize groups (14% and 15% increase relative to untreated controls, respectively).

Profitability calculations

The insights obtained allow an economic evaluation of the individual treatments, assuming:

- Farmers will receive approximately 110 € per ton of grain maize (dry goods)

- For *Trichogramma*, the cost per hectare is approximately 60 €. The application by hand, twice, has to be calculated at 15 €

- The insecticide alternative (product plus single application) amounts to around 40 € per hectare

- The price for Bt maize seed is around 35 € per hectare higher than for conventional seed.

Not taking into account regional subsidies (e.g. for *Trichogramma* application in Baden-Württemberg), and considering that the costs incurred for drying are irrelevant as shown in Table 1, the different treatments can be compared and evaluated (Figure 6).

There was no direct amortisation of the costs for *Trichogramma* application in any of the years considered. Because of the limited efficacy against corn borer and the relatively high costs, this treatment resulted in a financial loss in comparison to the untreated control group amounting to an average of -52 € per hectare for the Rhine Valley and -57 € per hectare for the Oderbruch region.

The application of insecticides, however, increased the harvest profit by 18 € per hectare for the Rhine Valley and 55 € per hectare for the Oderbruch region.

Due to moderate product costs and high biological efficacy against the European corn borer, the use of Bt maize resulted in an average increase in profit for the farmer of 84 € and 93€ per hectare, respectively.

A further advantage of Bt maize is that only the target pest is affected, while other beneficial arthropods are not harmed. Bt maize offers efficient protection against the European corn borer throughout the complete cultivation period, regardless of the weather conditions. It is easy to handle; the time-consuming tasks of monitoring infestation and spraying the crop are no longer necessary. Bt maize crops may grow undisturbed, thus fully exploiting their yield potential at the selected location.

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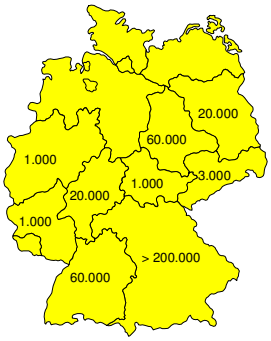
Figure 2: Distribution of the European corn borer in Germany. Estimated infestation areas per hectare for each Federal State



(Photo) High degree of European corn borer infestation may lead to the complete loss of crops.

Figure 3: Average European corn borer infestation of the four test groups in the Rhine Valley (1998 – 2002) and the Oderbruch region (2000 – 2002) - (larvae per plant)

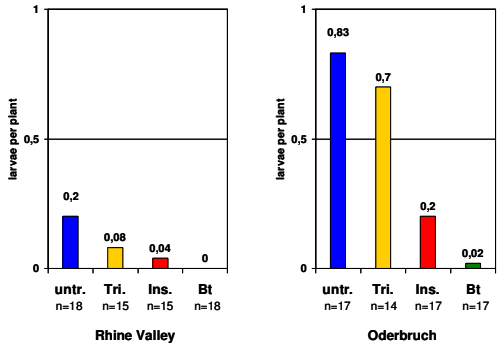
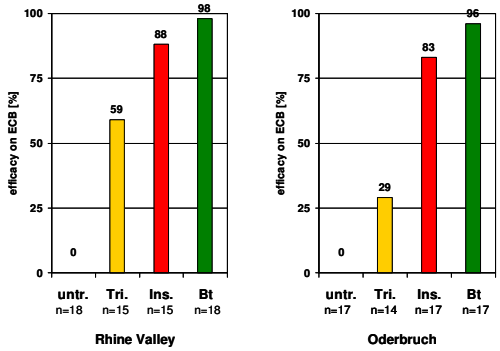


Figure 4: Average efficacy of the treatments on corn borer activity (the results for the untreated control group mark 0% efficacy)



(Photo) Appearance of typical borer damage: broken stalk.

Table 1: Average grain yield (15% moisture) for each treatment group in the Rhine Valley (1998 – 2002) and the Oderbruch region (2000 – 2002)

	Rhine Valley		Oderbruch region	
	grain moisture (%)	yield (t/ha)	grain moisture (%)	yield (t/ha)
untreated	27,1	8,63	32,3	8,88
Trichogramma	25,5	9,01	32,5	9,04
Insecticide	25,7	9,34	32,9	9,75
Bt maize	28,2	9,71	33,4	10,04

Figure 5: Relative grain yield (results for the untreated control groups marks 100 %) in the Rhine Valley (1998 – 2002) and the Oderbruch region (2000 – 2002)

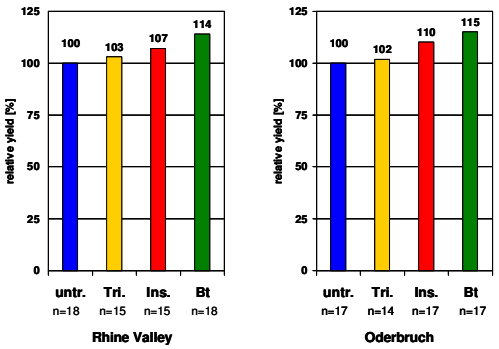


Figure 6: Economic evaluation of the treatments against European corn borer control (in € per hectare) in the Rhine Valley (1998 – 2002) and the Oderbruch region (2000 – 2002)