Fachhochschule Weihenstephan
University of Applied Sciences

Wissenschafts Zentrum STRAUBING

Economic assessment of co-existence schemes and measures

This study has been carried out within the framework of the study "New case studies on the co-existence of GM and non-GM crops in European agriculture" commissioned by the European Commission.

Klaus Menrad, Daniela Reitmeier

University of Applied Sciences of Weihenstephan
Science Centre Straubing
Straubing, Germany
May 2nd, 2006

Partner Institutions:

EUROPEAN COMMISSION DIRECTORATE-GENERAL Joint Research Centre | European Science and Technology Observatory | ipts Institute for Prospective Technological Studies | INRA

Table of content

List of figures

List of tables

Foreword

In 2003, the European Commission's Joint Research Centre (JRC) agreed with several Commission services (DGs for Agriculture, Health and Consumer Protection, Environment and Legal Service) to undertake new case studies on the agronomic and economic issues of co-existence between genetically modified (GM) crops and non-GM crops in European agriculture. The studies were designed and coordinated by Manuel Gomez-Babero, Karine Lheureux (currently at EFSA, Parma) and Emilio Rodriguez-Cerezo, from the SAFH Unit of the Institute for Prospective Technology Studies (IPTS) of JRC and a consortium of additional project partners was formed within the European Science and Technology Observatory (ESTO) framework.

The objective of this project was to analyse new case studies on how different production systems (GMO, conventional and organic) can co-exist in the same region through minimising the potential risk of adventitious presence by adapting farming practices. Seed and crop production of maize, sugar beet and cotton are considered in this project.

The project analysed (i) the sources of adventitious GM presence in conventional crops, (ii) the levels of admixture (expressed as the proportion of seeds, grains or roots containing GM material) estimated with current and additional farming practices and (iii) the economic costs of adapting farming practices.

This report summarizes results on economic assessment of co-existence schemes and measures. This part of the study has been carried out by a research team of the University of Applied Sciences of Weihenstephan consisting of Klaus Menrad and Daniela Reitmeier. The findings of this research are included in the final report of the project "New Case studies of GM and non-GM crops in European agriculture" which was published by JRC IPTS in spring 2006 (Messéan, A., F. Angevin, et al. 2006). Our part of the project needs to refer to results of a work package that dealt with landscape simulations in order to quantify pollen dispersal carried out by Institute National de la Recherche Agronomique (INRA)

for rapeseed and maize and for cotton by Empresa Pública de Desarrollo Agrario y Pesquero (DAP). We are thankful for the contribution of INRA and DAP that provided economic data from France and Spain as well as for the financial support of the project provided by the European Commission.

Executive summary

The economic impacts of the suggested co-existence measures as well as their effectiveness in economic terms are analysed in this report. In this context it has to be considered that according to the Recommendations of the European Commission of 2003, GM farmers will bear the responsibility of implementing the changed farm management practices and the relevant additional costs**.** Insurance cost and co-existence in the same farm are not included in the analyses. In addition, costs borne by the GM farmers to put in place practices due to GM production (e.g. refuge areas for Bt crop production) are excluded from the scope of the study. In a first step the economic performance of the different crops is investigated as background information necessary to analyse the costs of co-existence measures by reviewing literature, collecting publicly available statistical information and searching databases, as well as contacting and interviewing regional farm advisers, farmers unions, industry companies (such as seed producers, chemical industry) and public institutions. The costs of co-existence measures for the different crops, farm types and regions as suggested by INRA in a appropriate work package are calculated in a second step of the analyses. For this purpose publicly available data sources of costs of agronomic practices are used in order to identify the specific cost level of the suggested measure. When calculating the costs of co-existence measures labour costs as well as opportunity costs of an alternative use have been taken into account. If necessary, available data are modified according to the situation in the defined farm type and region. In order to check these modifications additional experts have been consulted in rarely cases. The outcome of this part of the analysis are absolute costs of adopting new farming practices at individual farms or in a region in order to achieve a defined level of adventitious presence of GM material. The costs of the different practices are put into proportion to total production costs and gross margins in order to evaluate the influence of

costs of co-existence measures on total income of farming in the analysed regions.

Maize seed production

For estimating the costs of the suggested co-existence measures, it is assumed that a yield of 3.5 t maize seed per hectare results in a total income of 3,365 €/ha in maize seed production in France. Taking into account variable production costs of 2,177 €/ha and compensation payments, a gross margin of 1,488 €/ha (for the years 2003 and 2004) forms the baseline for the cost calculations in maize seed production. The first step was to quantify the costs of the different additional measures assuming a 5 ha squared GM maize seed field. The costs of increasing isolation distances have been calculated in a kind of worst case scenario in which the farmer producing GM maize seed has to reduce his seed producing area and to plant alternatively the most economic crop (i.e. wheat). This results in opportunity costs of almost 22 % of the gross margin of maize seed production in the case of an additional 100 m isolation distance and almost one third of the gross margin if an additional 150 m isolation distance is required (Table I). Planting additional male parent rows on the non-GM seed field, results in yield reductions on this field, which have to be compensated by the farmer producing GM maize seed. For this measure substantial opportunity costs of around 16 % of the gross margin have to be calculated, in particular if 18 additional male rows have to be cultivated (Table I). Changing the flowering time of the cultivated seed maize varieties also has negative yield effects which are quite substantial in the case of changing from very late to late varieties (30°days) resulting in farmers' income losses of this measure of around 30 % of the gross margin of maize seed production. The income losses are significantly lower in the case of changing the flowering time from late to mid early (Table I).

Table I: Opportunity costs of singular co-existence measures in maize seed production in France

Additional co-existence measure	**Opportunity costs in €/ha**	**% of variable production costs**	**% of gross margin**
Increasing isolation distance by			
100 m (Wheat as alternative crop)	322	14.8	21.6
150 m (Wheat as alternative crop)	483	22.2	32.5
Planting additional male rows on non-GM seed maize field			
6 additional male rows	80.85	3.7	5.4
18 additional male rows	242.5	11.1	16.3
Changing flowering time of cultivated maize varieties from			
Very late to late (30°days)	446.8	20.5	30.0
Late to mid early (60°days)	114.0	5.2	7.6

In the second step the economic effects of combined co-existence measures are calculated as simulated by INRA in the worst case of the "in wind situation[1]. Firstly the project team estimated the economic effects of co-existence measures between GM and non-GM seed plots (seed-seed scenario) but the given restrictions of the methodology, in particular concerning quantification of the costs of increasing isolation distances, should be considered when interpreting the results. If the opportunity costs of increasing isolation distances are taken into account, the income losses of farmers due to these co-existence measures can reach significant levels often exceeding 40 % of the gross margin of maize seed production in France. This relates in particular to small non-GM seed production plots and low thresholds of adventitious presence of GM material. The lowest per-hectare-costs of combined co-existence measures necessary to meet a defined threshold highly differ with respect to sizes of neighbouring non-GM seed production plots. In order to meet a threshold of 0.5 % in maize seed production opportunity costs of around 410 €/ha have to be calculated (representing almost 28 % of the gross margin) in the case of non-GM seed plots of 0.5 ha, while this threshold already can be met without any opportunity costs in the case of a neighbouring 5 ha non-GM seed plots. The same picture emerges

[1] By talking about the "in wind situation" the non-GM field is placed downwind in front of the GM field.

if a 0.3 % threshold has to be met: In the case of 0.5 ha non-GM seed plots, opportunity costs of around 650 €/ha (representing around 44 % of the gross margin) have to be calculated, which decrease to around 114 €/ha in the case of non-GM seed plot sizes of 5 ha. The opportunity costs of additional measures to meet a 0.1 % threshold already amount to more than 650 €/ha in the “best case” of 5 ha non-GM seed plots. In a further step we calculated the costs of additional co-existence measures without opportunity costs of isolation distances. These opportunity costs were not taken into consideration because they are very variable depending on the organisational measures seed breeding companies and seed producing farmers might implement in order to avoid a strong reduction of the economically interesting production of maize seeds. In this case, the opportunity costs of co-existence measures rarely exceed the level of 20 % of the gross margin of maize seed production.

Secondly the costs of co-existence measures are calculated for the crop-seed situation (i. e. a GM crop producing field is in the neighbourhood of non-GM maize seed fields). By increasing isolation distances or planting 20 additional male parent rows, a significant reduction of the levels of adventitious presence of GM material can be achieved in all simulated non-GM seed field sizes. Substantial opportunity costs in the range of up to 20 % of the gross margin of maize crop production can be expected in case of planting high numbers of additional male parent rows, while increasing isolation distances do not cause high opportunity costs in the crop-seed situation. The opportunity costs of increasing isolation distances are estimated to up to 5 % the gross margin of maize crop production in case a non-GM maize variety is planted on the “isolation strip” of the GM maize crop field. If alternatively wheat is planted on this strip the opportunity costs will range up to 2 % of the gross margin of maize crop production. It can be concluded that in contrast to the seed-seed situation increasing isolation distances between GM crop and non-GM seed maize fields is a very cost-effective measure in order to meet defined thresholds of 0.5 % or 0.3 % adventitious presence of GM material in maize seeds in the crop-seed situation.

In case isolation distances will be increased in maize seed production a re-organisation of fields used for maize seed production is required in regions in which GM varieties will be multiplied if maize seed production is organised according to a centralised plan[2]. This process will lead to a reduction of the total area used for maize seed production in a specific region. In particular in regions with small scaled field sizes significant absolute and relative reductions of the maize seed producing area can be expected. The loss of the maize seed producing area will result in a significant decline of the amount of certified maize seed produced in a specific region which might be followed by a loss of potential turnover with seeds as well as declining market shares of the respective company. Furthermore, there are additional time requirements and management costs for re-organising the seed producing area in a region due to increasing isolation distances with the consequence of rising fixed costs and declining profit margins of certified seed production both for seed breeding and multiplying companies as well as for farmers co-operating with them. Besides, additional conflicts among seed producing farmers can be expected during the decision-making process which farmers can participate in the economically interesting multiplying of seeds.

An argument which is highly stressed by the seed industry is a potential re-allocation of certified seed production to regions outside the EU. Due to significant cost effects it was regarded as almost impossible to realise higher isolation distances in small-scaled production areas like e. g. many maize seed producing regions in France or Germany. Major factors for the allocation of seed producing areas are the production costs in a specific region as well as the security and quality of production. Countries like France or Germany were regarded as being competitive in maize seed production despite relatively high production costs, but this picture might change in future due to significantly increasing costs in case of higher isolation distance requirements in case of multiplying GM seeds. In this case it was seen as “realistic option” that certified maize seed production will be transferred step-by-step to regions outside the EU. In addition to generally lower costs (e. g. for labour, agricultural land) specific advantages were seen in large-scaled fields in interesting regions outside the EU and legal requirements which are comparable to those currently existing in the EU.

[2] It is assumed that multiplying of GM seeds offers a benefit compared to the current situation and that there is a demand for GM seeds in the EU.

Maize crop production

Variable production costs of 687 €/ha and an income of 950 €/ha in the year 2004 form the baseline for the calculation of costs of co-existence measures in maize crop production in France resulting in a gross margin of 743 €/ha if compensation payments were taken into consideration. The costs of several co-existence measures differ depending on the potential economic performance of the cultivated GM maize (i.e. insect resistant Bt maize) for which no empirically sound data are available for France so far. Therefore, two different cases were used in order to quantify the potential cost range: In a first case it is assumed that Bt maize has the same gross margin as non-GM maize, while an economic advantage of 43 €/ha of Bt maize compared to non-GM varieties is considered in a second case.

In contrast to maize seed production there are moderate opportunity costs of increasing isolation distances in maize crop production due to the small differences in the gross margins of alternative crops[3] whereas the changing of flowering times causes substantial income losses for farmers active in maize crop production. The opportunity costs of discard widths on the non-GM field (which is separately harvested) significantly differ depending on the width of the discard width as well as the size of the non-GM field (table II). High differences in the per-hectare costs can also be observed for non-GM buffer zones around GM fields mainly depending on the GM adoption rate in a region and the estimated economic performance of GM maize.

[3] The costs of respecting isolation distances only occur in those cases that farmers may not able to cultivate GM crops (due to respecting a certain isolation distance). For fields which are already located outside the isolation distance area, there are no additional costs due to this measure.

Table II: Additional costs or gross margin losses of farmers of singular co-existence measures in maize crop production in France

Additional measure	Costs or gross margin losses of singular measures
Clean the machines a) single seed driller b) harvest - combine c) transport - trailer or truck	Costs of shared machinery[1)] 38.38 56.84 1.48
Isolation distance	GMA[2)] of Bt maize = GMA[2)] of non-GM maize: 0 €/ha GMA[2)] of Bt maize > GMA[2)] of non-GM maize: 2.19 €/ha
Time isolation	Change from very late to late (30°days): 201 €/ha Change from late to mid early (60°days): 46 €/ha
Discard width on the non-GM-field - extra harvest	6 m wide discard width: 1.27 – 2.85 €/ha[3)] 12 m wide discard width: 2.55 – 5.70 €/ha[3)] 24 m wide discard width: 5.10 – 11.40 €/ha[3)]
Non-GM buffer zones around the GM field - extra sowing	GMA[2)] of Bt maize = GMA[2)] of non-GM maize: 17.54 – 35.07 €/ha[4)] GMA[2)] of Bt maize > GMA[2)] of non-GM maize: 60.54 – 78.07 €/ha[4)]

1) Renting fees for collectively used machinery were used for calculating the costs of shared machinery.
2) GMA = Gross margin
3) The first figure refers to a neighbouring non-GM field of 5 ha, and the second to a non-GM field of 1 ha.
4) The first figure refers to a 50 % GM adoption rate in the region with clustered fields, while the second figure refers to a 10 % GM adoption rate with dispersed fields.

In addition to the (opportunity) costs of singular co-existence measures the costs of non-GM buffer zones have been analysed in a landscape. Based on the simulations of the level of adventitious presence of GM pollen in different fields, big variations in the additional costs of non-GM buffer zones can be observed depending on the sizes of the GM fields, the width of the buffer zones as well as the underlying assumptions concerning the economic performance of Bt maize in France: In the case of a 10% GM adoption rate in the region, the per-hectare costs of non-GM buffer zones range between around 4 €/ha and 17 €/ha for a 9 m wide buffer zone or between around 7 €/ha and 30 €/ha in the case of a 18 m wide buffer zone respectively. If we assume a 50% GM adoption rate in crop maize production in Poitou-Charentes and the location of the non-GM buffer zones around each GM field the additional per-hectare costs vary between 1.1 €/ha and 60 €/ha, representing 0.1 % or 8.1 % of the current gross margin of crop maize production in France. In particular, in very small GM fields with field sizes below 1 ha, substantial additional costs emerge when non-GM buffer zones have to be established around each field.

In a final step the additional costs were calculated for a non-GM buffer zone around a cluster of eight GM fields representing a 50 % adoption of GM maize in the region. Compared to the additional costs of establishing buffer zones around each GM field, significant cost reductions can be realized by non-GM buffer zones around a cluster of GM fields. This holds true for all field sizes and assumptions concerning the potential economic performance of planting GM maize in France. If we take the 18 m wide buffer zone, which is necessary to meet the threshold of 0.9 % in the neighbouring non-GM fields, the additional per-hectare costs of a “clustered” buffer zone range between 1.4 €/ha and 4.8 €/ha, which equal from 0.2 % up to 0.6 % of the current gross margin of crop maize production. Compared to the lowest per-hectare costs of non-GM buffer zones which are established around each of the GM fields, cost savings of around 29 % can be observed with “clustered” non-GM buffer zones. These cost savings of ”clustered” buffer zones are substantially higher in the case of smaller GM fields.

Currently it is not possible to give any sound results concerning the overall economic net effects of cultivating Bt maize in France. This is basically due to the missing practical experience with planting this crop in the case study region. Therefore additional research is required in order to quantify the net economic benefits which farmers might have if they cultivate Bt maize and have to implement additional co-existence measures in France.

A combined analysis of the effects on additional costs of co-existence measures in maize crop production in case that the thresholds for GM adventitious presence are changed in maize seed production is another field of research which should follow this current study. A combined approach simulating the agronomic measures necessary in maize seed production (in order to meet defined thresholds of 0.5 %, 0.3 % and 0.1 % GM adventitious presence in maize seeds) and the corresponding effects on the agronomic measures to be taken in maize crop production has to be applied for this purpose, followed by the calculation of additional costs or gross margin losses of farmers in both fields. The ongoing research activities on co-existence (like e. g. SIGMEA project) represent an excellent opportunity to carry out such analyses for defined crops and regions.

Sugar beet seed production

For estimating the economic effects of additional co-existence measures, we assume a total income of 6,240 €/ha in sugar beet seed production in France resulting form a yield of 1.95 t/ha and prices of 3,200 €/t. Taking into account variable production costs of 3,060 €/ha a gross margin of 3,180 €/ha in the year 2004 forms the baseline for cost calculations in sugar beet seed production in France. For a threshold of 0.5 % the total costs of additional co-existence measures amount to almost 197 €/ha which equals to 6.2 % of the gross margin of sugar beet seed production. These costs are strongly influenced by cleaning the harvester with water after each plot (63 %) as well as the general management and supervision of an increased area for sugar beet seed production (19 %). In order to achieve a threshold of 0.3 % in sugar beet seed production, additional measures are required which cost around 246 €/ha (7.7 % of the gross margin). High influence on these costs have cleaning of the harvester with water after each plot (50 %) and the general management and supervision of an increased production area (31 %). When changing to a threshold of 0.1 %, almost a doubling of the costs of co-existence measures can be expected compared to the 0.3 % threshold: Around 15 % of the variable production costs are necessary in order to meet the threshold of 0.1 % of which almost half of the additional costs are caused by the supervision and global management of an increased production area. When changing from a 0.5 % to a 0.1 % threshold, a strong increase in costs can be expected for measures required at the final production field while the costs of measures carried out at the nursery field are below 40 €/ha in all threshold levels.

Sugar beet crop production

The effects of different co-existence measures are simulated in sugar beet crop production in Picardie (France) and Lower Bavaria (Germany). In France variable production costs of 720 €/ha and a gross margin of 2,569 €/ha form the baseline of the economic analysis in sugar beet crop production. With variable production costs of 1,090 €/ha and a gross margin of 3,505 €/ha, the respective figures are slightly higher in Lower Bavaria compared to Picardie[4]. To control critical points in sugar beet crop production, additional cleaning of a (rented) drilling machine and two-times hand pulling of weed beets are required in both regions. The total costs of these measures are calculated to 39.22 €/ha in France and 47.89 € in Germany what equals to 1.5 % or 1.4 % of the gross margin respectively.

The impact of different measures on the content of GM seeds in the seed bank of the GM field as well as neighbouring non-GM fields has been simulated in a further step of the project, as well as the related costs of these measures. In this context a high efficiency of the first hand pulling of weed beets on GM fields can be observed in particular in connection with neighbouring non-GM fields without hand pulling. In this situation the relative costs of the first hand pulling of weed beets on GM fields are often below 2 €/1,000 seeds. In case the base adventitious presence of GM seeds is relatively low, the relative costs of the first hand pulling of weed beets on the GM field might exceed 5 €/1,000 seeds. However, this measure still can be recommended as "precautionary activity" since the absolute costs of two times hand pulling are around 2 % of the total variable production costs of sugar beet crop production in France and Germany.

Cotton seed production

Typical farmers earn a total income of 3,178 €/ha in cotton seed production in Andalusia with total variable production costs amounting to 2,107 €/ha. This results in a gross margin of 1,071 €/ha for seed producing cotton farmers in 2004. In order to respect a threshold of 0.5% GM adventitious presence in cotton seed production, no additional measures are required besides those already in place for certified seed production in this crop. Thus, no additional costs have to be carried by GM cotton seed producing farmers.

Cotton fibre production

In cotton fibre production the economic performance differs between small and large farms in Andalusia. While in both farm types a total income of 3,001 €/ha

[4] Both for Picardie and Lower Bavaria these are average figures from 2001 to 2003.

can be earned with this crop, the variable production costs are slightly higher with 2,059 €/ha in small farms resulting in a gross margin of 943 €/ha in small farms compared to 1,007 €/ha in large cotton-producing farms in 2004. The additional costs of cleaning machinery range between 10.35 €/ha and 12.48 €/ha for the drilling machine, 17.15 €/ha and 20.86 €/ha for the harvester, as well as 6.60 €/ha for the trailer. The additional planting of a non-GM buffer zone of 3.8 m width (which is not separately treated with insecticides) causes costs of 54.40 €/ha.

The combined costs of additional measures in cotton fibre production are calculated for different farm types in Andalusia. The additional costs for a small farm, which is not producing GM cotton itself but shares machinery with neighbouring farms, amount to around 40 €/ha per year for cleaning of the equipment. For another small farm which produces GM cotton on 50 % of the total cotton area of the farm, additional costs amount to around 50 €/ha GM cotton which equals to almost 5.4 % of the gross margin. On a large cotton farm the costs of additional co-existence measures highly depend on the adoption rate of GM cotton: In case only 10 % of the total cotton area is cultivated with GM varieties, the additional co-existence costs result in 4.3 % of the gross margin. If the farmer decides to cultivate GM cotton on 50 % of his total cotton area on the farm only 2.2 % of the gross margin has to be calculated for the suggested co-existence measures.

1 Introduction and methodology

The dispersal of GM material to non-GM crops can occur through seed impurity, seed and pollen dispersal, outcrossing, volunteers, the use of shared machinery or transport equipment and other routes. Due to the multiple sources of dispersal of GM material, a broad variety of measures can be adopted in the growing and handling of crops in order to ensure co-existence between GM, conventional and organic plants. These measures are described in detail for the analysed crops, regions and farm types in Messéan, A., F. Angevin, et al. (2006) . The economic effects of the suggested co-existence schemes and measures as well as their effectiveness in economic terms are analysed in the following chapter in order to identify the most cost-effective alternative of the different measures.

In this context it has to be considered that according to the Recommendations of July 23rd, 2003 of the European Commission (European Commission 2003), the farmers who introduce a new production type will bear the responsibility of implementing the changed farm management practices and the relevant additional costs**.** In this study we generally regard the farmer who introduces a GM variety as the "newcomer" who is responsible for changing practices. In the rare cases that a non-GM farmer has to take additional measures (e. g. due to biological or agronomic reasons), it is assumed that they are compensated by the GM farmer. In this context it has to be considered that insurance costs (e. g. to cover a potential liability of the GM farmer) are not included in the cost analyses performed in this study. In addition, costs borne by the GM farmers to order to implement the cultivation of GM varieties on his farm (e.g. refuge areas for Bt crop production which are necessary in order to prevent the development of insect resistances against the Bt toxin) are excluded from the scope of the study.

Within the project we identified, calculated and evaluated economic impacts, on the side of the GM farmers, due to the introduction of changed farming practices for the different farm types and regions but we did not include the costs of implementing GM practices on the respective farms. In a first step the economic performance of the different crops is investigated as background information necessary to analyse the monetary impact of additional co-existence measures. This has been done by reviewing literature, collecting publicly available statistical information and searching databases, as well as contacting and interviewing regional farm advisers, farmers unions, industry companies (such as seed producers, chemical industry) and public institutions. In case economic performance data of several years are available, it was the target to use average values of 3 years in order to smooth annual variations. However, this target could not be achieved in all analyses due to high differences in data availability. If economic performance data are not available for the specific crop, farm type and region, information on differing farm types and/or regions are used and adopted to the specific situation as defined in this project.

The economic assessment of co-existence measures for the different crops, farm types and regions are calculated in a second step of the analyses. For this purpose publicy available data sources of costs of agronomic practices (such as handbooks for farm management, databases of different sources etc.) are used in order to identify the specific cost level of the suggested measure. When calculating the costs of co-existence measures labour costs as well as opportunity costs of an alternative use (e. g. higher rent prices of shared machinery) have been taken into account. If necessary, available data are modified according to the situation in the defined farm type and region. In order to check these modifications additional experts have been consulted in rarely cases. The outcome of this part of the analysis are absolute figures assessing the economic impact of adopting new farming practices at individual farm level in order to achieve co-existence between GM and non-GM farming systems.

In a final part of the analyses the costs of the different measures are compared with each other in order to determine the cost-effectiveness of the measures proposed. In this sense, the suggested farming practices are compared with each other in relation to its costs and efficiency in reducing levels of admixture. Finally, the most efficient farming practice is defined and identified that allow respecting the targeted threshold with less additional costs. Furthermore the costs of the different practices are put into proportion to total production costs and gross margins in order to evaluate the influence of costs of co-existence measures on total profitability of farming in the analysed regions.

2 Economic performance of analysed crops

In a first step of the project, data on production costs as well as the profitability of the analysed crops were collected by the project team. These data form the basis for the calculation of additional measures. The economic performance data both for seed and crop production of the analysed crops in the different regions are presented in the following chapter.

2.1 Maize

In France, 50 % of maize seed are produced in the south-western part of the country. With Pyrénées-Atlantique one of the two major maize seed-producing departments of France has been selected as case study region within this project by INRA in which almost 500 farmers produce certified maize seed on a total area of around 5,500 ha. Due to the high acreage grown with grain maize as well as the presence of weeds and pest (for which GM maize varieties might be a good alternative for farmers), Poitou-Charantes region has been selected as case study region for maize crop production in France.

The economic performance of maize certified seed production is shown in table 2.1.1. In this context the data in the federal state of Baden-Württemberg (Germany) were used as starting point for the analysis due to lack of corresponding figures for France. According to consulted experts there are differences in the labour costs between Baden-Württemberg and France which are considered in calculating the costs of maize seed production while the other cost positions are comparable between the two regions (table 2.1.1). Since the yields of seed maize fluctuate highly between the different years, cost calculations were performed for a yield range of 3.5 t/ha to 4.5 t/ha. Taking the figures of a yield of 3.5 t/ha as base for the following calculations of co-existence measures, a high income of more than 3,300 €/ha can be earned by farmers if we consider the same price for conventional and GM maize seed varieties. This income coincides with variable production costs of more than 2,000 €/ha (table I), resulting in a gross margin of 1,488 €/ha for maize certified seed production in France.

Table 2.1.1: Economic performance of maize seed production in France in 2004

Parameter		**Baden-Württemberg**	**France**		
Yield	t/ha	3.5	3.5	4.0	4.5
Price	€/t	950	950	950	950
Fodder maize	t/ha	0.4	0.4	0.4	0.4
Price	€/t	100	100	100	100
Total income	**€/ha**	**3,365**	**3,365**	**3,840**	**4,315**
Costs of basic seed	€/ha	272	272	272	272
Plant protection	€/ha	285	285	285	285
Machinery costs	€/ha	50	50	50	50
Machinery renting costs	€/ha	300	300	300	300
Castration (labour costs)	€/ha	530	647	647	647
Irrigation	€/ha	375	375	375	375
Charge for acceptation	€/ha	32	32	32	32
Fertilizer	€/ha	146	146	146	146
Insurance	€/ha	70	70	70	70
Variable costs	**€/ha**	**2,060**	**2,177**	**2,177**	**2,177**
Compensation payments total	€/ha	450	300	300	300
Gross margin	**€/ha**	**1,755**	**1,488**	**1,963**	**2,438**

Source: Modified according to Hugger 2004

In contrast to certified seed production, the economic performance of maize crop production is considerably lower in France (table 2.1.2). With a total income of 950 €/ha and variable production costs of almost 690 €/ha, it is mainly the area compensation payment which significantly influences the maize gross margin of 743 €/ha in 2004.

Table 2.1.2: Economic performance of maize crop production in France in 2004

Gross margin maize crop production		**France 2004**
Yield	t/ha	9.5
Price	€/t	100
Total income	**€/ha**	**950**
Costs of seed	€/ha	170
Herbicide	€/ha	50
Insecticide	€/ha	12
Harvest	€/ha	105
Irrigation (1000 m^3 water per annum)	€/ha	220
Fertilizer	€/ha	120
Hail insurance	€/ha	10
Variable costs	**€/ha**	**687**
Compensation payments	€/ha	480
Gross margin	**€/ha**	**743**

Source: Teyssier 2004

2.2 Sugar beet

France and Italy are the main sugar beet seed-producing countries in Europe. In France this production is concentrated on around 2,200 ha in the south-western part of the country which has been selected as case study region within this project. For sugar beet crop production the region of Santerre in France (within the Picardie area) and Lower Bavaria in Germany have been selected as case study regions, which are both among the most important beet producing areas in the two countries.

The economic performance of sugar beet seed production is shown in table 2.2.1 according to data provided by the French seed producer association (Fédération Nationale des Agriculteurs Multiplicateurs de Semences (FNAMS)). Mainly due to high prices of 3,200 €/t for sugar beet seeds a total income of more than 6,200 €/ha can be earned by producing certified seeds of sugar beets. This high income coincides with variable production costs exceeding 3,000 € partly due to high expenditures for seedlings, plant protection, use of specific machinery and harvesting as well as insurance costs (table 2.2.1). However, French farmers producing sugar beet seeds achieve a significant income with this crop what is illustrated in the gross margin of 3,180 €/ha.

Table 2.2.1: Economic performance of sugar beet seed production in France in 2003

Sugar beet seed production		**France 2003**
Yield	t/ha	1,95
Price	€/t	3,200
Total income	€/ha	**6,240**
Seedlings	€/ha	600
Plant protection		520
Fertilizer		320
Irrigation		250
Border management		70
Cutting		230
Harvest		250
Storage, drying, delivery costs		150
Fee[1]		50
Hail insurance		320
Depreciation sum for specific machinery[2)]		300
Variable costs	€/ha	**3,060**
Gross margin	€/ha	**3,180**
[1)] This fee includes costs for field control, costs for contract registration and syndicate fees [2)] This machinery is only used in sugar beet seed production		

Source: Modified according to Fédération Nationale des Agriculteurs Multiplicateurs de Semences (FNAMS) 2004

The high economic performance of sugar beets does not only hold true for producing certified seeds but relates to crop production as well. As outlined in table 2.2.2 a high gross margin of 3,505 €/ha can be earned by farmers producing sugar beet (within their A-quota sugar beet contingent) in Lower Bavaria compared to 2,569 €/ha in Picardie. If farmers produce sugar beets within their B-quota[5] sugar contingent they earn more than 1,000 €/ha less compared to the A-quota figures (table 2.2.2). The differences in the economic performance of sugar beet crop production between Lower Bavaria and Picardie can be explained mainly by differing producer prices for sugar beets.

5 Within the A-quota (which represents approximately the consumption of sugar in the EU) the EU gives a full sales quantity guarantee and a restricted price guarantee to sugar beet growers. For the B-quota the price guarantee of the EU is much more limited so that there might be higher price fluctuations in producer prices between different years.

Table 2.2.2: Economic performance of sugar beet crop production in France and Germany

Parameter		Regions (years)					
		Lower Bavaria [1] (2001-2003)		Picardie [2] (2001-2003)		France [3] (2003)	
		A-quota	B-quota	A-quota	B-quota	A-quota	B-quota
Yield	t/ha	72.91	72.91	70.40	70.40	75	75
Price	€/t	63.07	41.57	46.72	30.35	46.72	32.42
Total income	**€/ha**	**4,598**	**3,030**	**3,289**	**2,137**	**3,504**	**2,432**
Seed	€/ha	193	193	160	160	160	160
Crop protection	€/ha	238	238	165	165	165	165
Machinery costs	€/ha	102	102				
Harvesting	€/ha	322	322	210	210	210	210
Fertilizer	€/ha	230	230	160	160	160	160
Assurance	€/ha	8	5	25	25	25	25
Variable costs	**€/ha**	1,093	1,090	720	720	720	720
Gross margin	**€/ha**	**3,505**	**1,940**	**2,569**	**1,417**	**2,784**	**1,712**

1) Bavarian State Research Centre for Agriculture and Association of Bavarian sugar beet planter Ratisbon, 2004
2) Confédération Générale des planteurs de Betteraves (CGB) and Service central des Enquêtes et Ètudes statistiques du Ministère de l'Agriculture, de l'Alimentation, de la Pêche et des Affaires rurales (SCEES), 2004
3) Teyssier, 2003

Sources: Bavarian State Research Centre for Agriculture 2004, CGB 2004, Teyssier 2003

2.3 Cotton

Andalusia was selected as a case study for cotton production within this project since around 98 % of the Spanish cotton production is located in Andalusia. Table 2.3.1 summarizes some fundamental data of cotton production for fibre and seeds in Andalusia which form the baseline for the following economic calculations.

Table 2.3.1: Fundamental data of cotton production in Andalusia in 2002/2003

Criteria		Seed production	Fibre production
Cultivated area	ha	2,084	92,475
Average yields	kg/ha[1)]	3,531	
Prices	€/kg	0.90	0.85
Number of cotton producers		n. a.	10,000
[1)] 1,000 kg are equivalent to 1 tonne. Common harvest technique in both, cotton fibre and seed production, is the spindle harvester which harvest unginned cotton consisting of fibre, seed and plant impurities.			

Source: University of Applied Sciences of Weihenstephan based on working report of DAP 2004

The costs of co-existence measures in cotton production are calculated for representative farm types of the Andalusia region. Around 80 % of the farms are small-scaled with an average cropping area of 16 ha, of which 29 % are cultivated with cotton. The average sizes of the cotton fields of these farms are around 2.77 ha (table 2.3.2). In Andalusia, large farms have a total cropping area of around 160 ha in average with 20 % cotton production in the farm's rotation. The average field size of these farms is around 10 ha (table 2.3.2).

Table 2.3.2: Farm types in cotton production in Andalusia

Farm type	Criteria	Average area (ha)	Proportion of farms	Total cotton crop area (ha)	% of cotton area
Small farms	Total crop area	16	80 %	36,364	39
	Total cotton	5			
	Size of cotton fields	2.77			
Large farms	Total crop area	160	20 %	56,090	61
	Total cotton	30			
	Size of cotton fields	10			

Source: University of Applied Sciences of Weihenstephan based on working report of DAP 2004

Cotton production in Andalusia can be classified into two types depending on the sowing and on the irrigation system as shown in table 2.3.3. Currently there are around 29,699 ha of cotton sown in the open air with an average yield of 3,310 kg/ha. With almost 55,000 ha plastic mulching is much more widespread in cotton production in Andalusia which might be due the higher average yield of 3,747 kg/ha according to 2002/2003 data as well. In Andalusia, cotton has to be irrigated during the summer months as the period of greatest water shortage. The most common irrigation system is surface or gravity irrigation, followed by drip irrigation and sprinklers (table 2.3.3). Dry-farmed cotton is limited to only 2,308 ha and thus has only minor relevance.

Table 2.3.3: Cultivation techniques in cotton production in Andalusia in 2002/2003

Cultivation technique	**Cropping area**	**Yields**
Sowing	ha	kg/ha
Plastic mulching	54,720	3,747
Open air	29,699	3,310
Irrigation		
Surface or gravity irrigation	44,916	4,043[1)]
Drip irrigation	21,080	
Sprinklers	15,388	3,163[2)]
Dry-farmed	2,308	
1) With plastic mulching 2) Plants are cultivated in the open air		

Source: University of Applied Sciences of Weihenstephan based on working report of DAP 2004

The economic performance of cotton seed and fibre production in Andalusia is shown in table 2.3.4 taking into account average yields, prices and costs of a production system including plastic mulching and irrigation in 2004. In all analysed farm types a total income between 3,000 and almost 3,200 €/ha coincides with variable production costs of around 2,000 to 2,100 €/ha, thus resulting in a gross margin of around 1,000 €/ha for cotton seed production and fibre production on large farms while producers of cotton fibre on small farms achieve a lower gross margin of 943 €/ha (table 2.3.4).

Table 2.3.4: Economic performance of cotton production in Andalusia in 2004 (with plastic mulching and irrigation)

Parameter		Seed production / small farms	Fibre production / small farms	Fibre production / large farms
Farm types[1)]		**1, 1', 2, 2'**	**3, 3', 5, 5'**	**4, 4', 6, 6'**
Yields	kg/ha [2)]	3,531	3,531	3,531
Price	€/kg	0.90	0.85	0.85
Total income	**€/ha**	**3,178**	**3,001**	**3,001**
Sowing	€/ha	171	126	126
Crop protection	€/ha	616	616	616
Fertilizer	€/ha	195	195	195
Machinery costs	€/ha	495	493	476
Harvester	€/ha	436	435	387
Irrigation	€/ha	193	193	193
Total variable costs	**€/ha**	**2,107**	**2,059**	**1,994**
Gross margin	**€/ha**	**1,071**	**943**	**1,007**

1) The number of the different farm types refer to those defined detailed in Messéan, A., F. Angevin, et al. (2006). Small farms are characterize for average farm sizes of 16 ha whereas large farms have average farm sizes of 160 ha. Farm types without inverted comma stands for 10 % adoption of GM cotton in the region, farm types with inverted comma for a 50 % adoption rate

1000 kg are equivalent to 1 tonne. Common harvest technique in both, cotton fibre and seed production, is the spindle harvester which harvest unginned cotton consisting of fibre, seed and plant impurities

Source: University of Applied Sciences of Weihenstephan based on working report and additional information of DAP 2004

3 Economic impact of maize, sugar beet and cotton

3.1 Economic impact of co-existence measures in maize

The analyses of biology and agronomic practices of maize production identified a number of critical points for admixture both in seed and crop production. These critical points as well as the suggested measures for both production schemes are shown in table 3.1.1 In maize seed production in particular the problem of cross pollination was identified as critical point since certified seed-producing farmers already are obliged to carefully clean their equipment. Suggestions for reducing cross pollination in maize seed production refer to increasing the spatial isolation distances between GM maize seed fields and adjacent maize fields, planting of additional male parent rows at the end of a non-GM seed field as well as changing the flowering time of the grown maize varieties (table 3.1.1). Admixture of GM and non-GM material during sowing, harvesting and transport were identified as critical points in maize crop production in addition to the cross pollination problem. Therefore cleaning of the used equipment, spatial isolation between GM and non-GM fields, changing of the flowering time of GM and non-GM varieties, buffer zones of non-GM varieties around a GM field as well as a non-GM discard width with extra harvest are suggested as potential co-existence measures (table 3.1.1).

Table 3.1.1: Critical points in maize seed and crop production

Critical points	Considered co-existence measures in the study	
	Seed production	**Crop production**
A - sowing		Clean the sower
B- harvest		Clean the combine
C - transport		Clean the trailer or truck
D - cross pollination	Isolation distance - spatial isolation	Isolation distance - time isolation
	Plant extra male parent rows	Isolation distance - spatial isolation
	Isolation distance – time isolation (flowering lag)	Discard width around the non-GM field - extra harvest
		Non-GM buffer zone around the GM field - extra sowing

Sources: University of Applied Sciences of Weihenstephan based on working report of INRA 2004

3.1.1 Seed production

When performing the analysis of economic effects of the suggested co-existence measures in maize seed production, the singular costs of the suggested measures will be estimated in a first step. Afterwards the costs of combined measures will be calculated according to the simulations carried out by INRA. Finally some additional consequences will be analysed qualitatively which might emerge from changing isolation distances in maize seed production in order to fulfil defined co-existence thresholds.

Singular cost effects of selected co-existence measures

The issue of changing isolation distances between fields will be firstly handled when analysing the costs of additional co-existence measures in maize seed production. In this context methodological questions emerge since the distribution of seed-producing fields in a region generally is organised by seed breeding companies (or other companies engaged to organise multiplying of base seed varieties on behalf of seed breeding companies) in co-operation with the farmers who actually do the multiplying of base seed varieties. In this context crop-specific isolation distances between seed-producing and other fields of the same species have to be taken into account which is regulated by international and national regulations. Changing of these isolation distances between seed- and seed/crop-producing fields of the same species therefore firstly causes organisational efforts and costs which are distributed between seed breeding companies and the farmers who produce certified seeds. Secondly, the number of farmers who can produce certified seeds as well as the amount of such seeds produced in a specific region will decrease in case the isolation distances between fields are increased in order to reduce cross pollination between GM and non-GM fields. Another effect of increasing isolation distances between seed- and seed/crop-producing fields of the same species might be the question whether certified seeds of a specific variety are still produced in the same region or whether the seed breeding company decides to move to another region, which might be located outside the EU if GM seed varieties are concerned. The quantitative calculation of these effects is extremely difficult since no publicly available data exist concerning the time requirements and other organisational efforts required organising certified seed production of maize in a specific region.

In order to give an insight in the potential range of costs which might be caused by changing isolation distances between maize seed and/or maize crop producing fields in the case study region of south western France, a hypothetical model was calculated which can be regarded as a kind of worst case scenario. In analogy to the simulations carried out by INRA, we assumed a squared GM-seed field of 5 ha in this model with adjacent non-GM seed or crop fields of different size. On the one hand, the farmer producing GM seed on this field could be made responsible to change the isolation distance. In this case it is assumed that the GM farmer plants another alternative crop in the increased isolation distance (on the GM field). The same effect can be achieved by planting extra male parent rows on the non-GM field. In the latter case it is assumed that the costs of these extra male parent rows are compensated by the GM farmer (figure 3.1.1).

Figure 3.1.1: Methodology to calculate costs of changing isolation distances in maize seed production

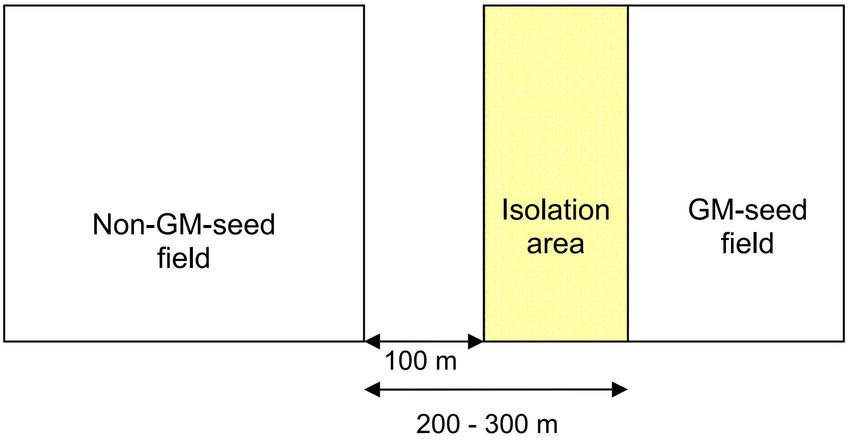
Isolation distance

Case A: Planting another crop on the isolation area	**Case B: Planting extra male parent rows on the non-GM field**
Effects: Loss of profit respectively difference of the gross margins of seed maize and the alternative crop	Effects: Loss of income due to loss of yield on the additional male parent rows + Additional work and expenses - Labour savings by displacing female parent rows by male parent rows

Source: University of Applied Sciences of Weihenstephan 2004

When using the first option of planting an alternative crop on the increased isolation distance (which might be increased from 100 m between fields – which is the current practice in south west France – to 200 m), the farmer might have to reduce the field size of the GM-seed-producing field by 100 m in order to achieve the new isolation distance of 200 m, as shown in figure 3.1.2. On this additional isolation area, the farmer will cultivate the most economic alternative crop taking into account the rules of crop rotation and good farming practice. A number of alternative crops as well as their gross margin and labour requirements are shown in table 3.1.2 As outlined above, this assumption represents a worst case scenario but it seems to be useful in order to quantify the potential range of opportunity costs for seed-producing farmers which might be caused by such a measure.

Figure 3.1.2: Methodology to calculate opportunity costs of planting alternative crop for changing isolation distances in maize seed production



Source: University of Applied Sciences of Weihenstephan 2004

Table 3.1.2: Economics of alternative crops to seed maize production in France 2003

Alternative crops	Yield (t/ha) [1)]	Gross margin (€/ha) [1)]	Labour time (hours/ha) [2)]
Oilseed rape	3.8	779	6
Maize (fodder)	9.5	743	8
Barley	7.0	691	6
Soy bean	3.4	644	n. a.
Sunflower	3.0	746	5
Winter wheat	8.0	769	6
Seed maize	**3.5**	**1,488**	**85**

Sources: 1) Teyssier 2004, 2) Kuratorium für Technik und Bauwesen in der Landwirtschaft e.V. (KTBL) 2002

The potential impact of increasing the isolation distances in maize seed production and planting another crop on the increased isolation area are shown in the tables 3.1.3 and 3.1.4 In the first case it is assumed that the isolation distance is increased by additional 100 m - thus resulting in a total isolation distance of 200 m – and that the farmer plants another cereal[6] on the increased isolation area instead of seed maize. The reduction of gross margin of planting alternatively wheat and barley are calculated for this purpose - thus representing always a worst case scenario by using the lowest gross margin. Due to the high differences in the gross margins between seed maize and wheat or barley respectively, substantial gross margin losses for the concerned farmers are emerging in this scenario. In case of planting wheat the gross margin losses of

6 Due to crop rotation reasons the planting of oilseed rape, which is the most economic alternative crop (table 3.1.2), is regarded as being unrealistic and therefore is not considered in the cost calculation.

this measure amount to 322 €/ha which equals to almost 15 % of the variable production costs of seed maize (assuming a yield of 3.5 t/ha seed maize in south west France) or 22 % of the original gross margin (table 3.1.3). If barley is planted instead of wheat on the increased isolation area, the opportunity costs will further rise (table 3.1.3) due to the lower gross margin of barley compared to wheat.

Table 3.1.3: Opportunity costs of increasing isolation distance in maize seed production and cultivating alternative crop

Parameter	**Specification**	
Size of GM seed-producing field	5 ha (224 x 224 m)	
Additional isolation distance	100 m	
Reduction of area of GM seed field	2.24 ha	
Remaining area of GM seed field	2.76 ha	
Opportunity costs of increasing isolation distance (for 5 ha GM seed field)		
Alternative crop	**Wheat**	**Barley**
Gross margin seed maize current practice	7,440 €	7,440 €
Gross margin remaining seed maize	4,107 €	4,107 €
Gross margin alternative crop	1,725 €	1,548 €
Gross margin of adapted practice	5,832 €	5,655 €
Opportunity costs of co-existence measures	1,608 €	1,785 €
Opportunity costs in relation to economic parameters		
Opportunity costs of increased isolation distance	322 €/ha	357 €/ha
% of variable production costs	14.8 %	16.4 %
% of gross margin	21.6 %	24.0 %

Source: Calculations of University of Applied Sciences of Weihenstephan 2004

However, a significant rise in the opportunity costs for farmers can be expected in case the isolation distances in maize seed production are further increased. As shown in table 3.1.4 changing of the additional isolation distance from 100 m to 150 m and planting of wheat as alternative crop on the increased isolation area will result in opportunity costs of 483 €/ha which equal to almost one third of the gross margin of seed production in south west France (table 3.1.4). If the isolation distances in maize seed production would be further increased, this would have even more significant effects on farmer’s opportunity costs assuming the general framework of this scenario.

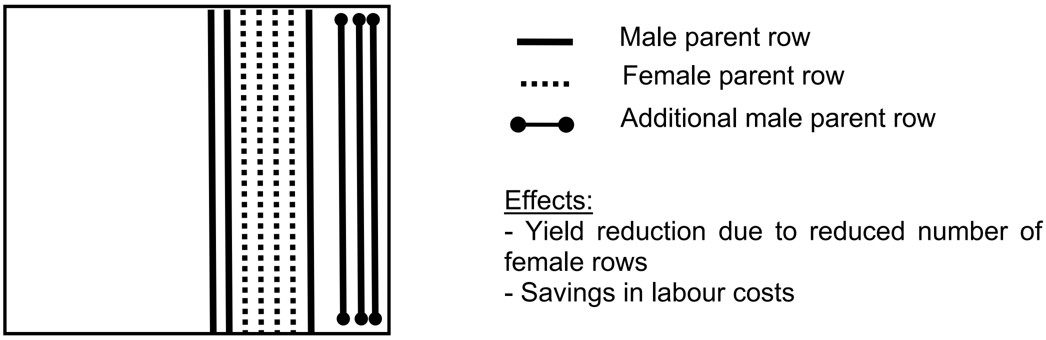
Table 3.1.4: Opportunity costs of differing isolation distances in maize seed production and cultivating wheat as alternative crop

Alternative crop: wheat (for 5 ha GM seed field)	**Additional isolation distance**	
	100 m	**150 m**
Gross margin seed maize current practice	7,440 €	7,440 €
Gross margin remaining seed maize	4,107 €	2,440 €
Gross margin alternative crop	1,725 €	2,584 €
Gross margin of adapted practice	5,832 €	5,024 €
Opportunity costs of co-existence measures	1,608 €	2,416 €
Opportunity costs in relation to economic parameters		
Opportunity costs of increased isolation distance	322 €/ha	483 €/ha
% of variable production costs	14.8 %	22,2 %
% of gross margin	21.6 %	32.5 %

Source: Calculations of University of Applied Sciences of Weihenstephan 2004

Instead of cultivating an alternative crop (like wheat) on an increased isolation area, farmers have the option of planting additional male parent rows around a non-GM seed field which have similar effects in terms of reducing cross pollination between GM and non-GM varieties by rising the non-GM pollen amount in competition to GM pollen. In this case the non-GM seed-producing farmer looses yield in seed production if he replaces (seed-producing) female parent rows by pollen-producing male rows, but additionally he does not have to castrate parts of the female rows, thus resulting in labour cost savings (figure 3.1.3). Since the GM farmer who introduces a new GM variety in a region is regarded as being responsible for ensuring co-existence, the non-GM farmer will ask for compensation of his additional costs so that these costs have to be assigned to the GM farmer who will be asked to pay compensation.

Figure 3.1.3: Methodology to calculate effects of planting additional male parent rows in maize seed production



Source: University of Applied Sciences of Weihenstephan 2004

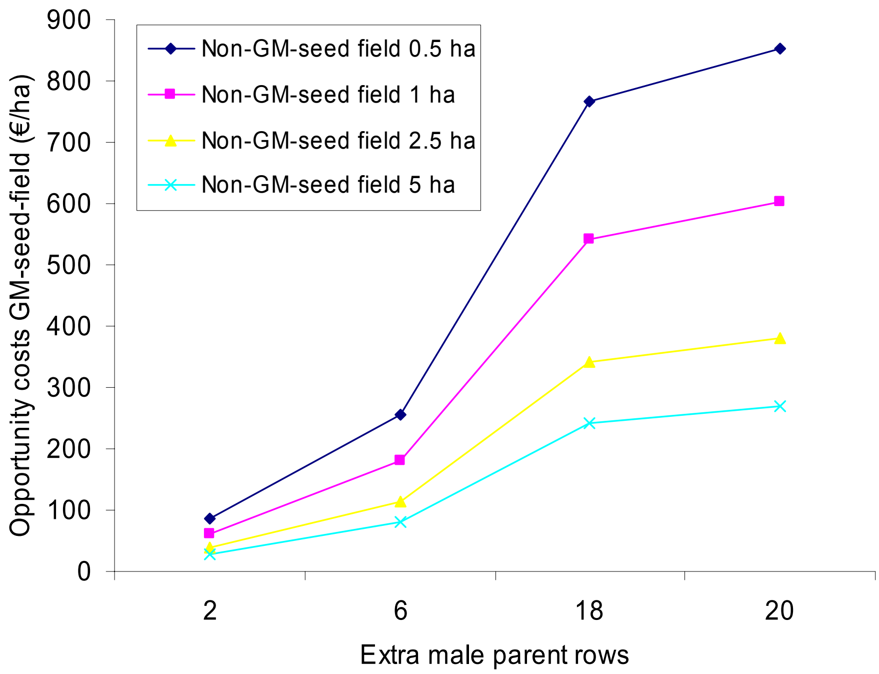
Using the above described calculation scheme, the opportunity costs of planting additional male rows on a 5 ha squared GM seed-producing field are shown in table 3.1.5 (considering the same gross margin for GM and non-GM certified seed production). In case six additional male parent rows are planted on a neighbouring non-GM field (as suggested by INRA as one potential co-existence measure), this will result in opportunity costs of almost 81 €/ha which equal to 3.7 % of the variable production costs or 5.4 % of the gross margin of seed maize production in south west France (table 3.1.5). If 18 male parent rows have to be planted in order to achieve a certain threshold of GM adventitious presence, the opportunity costs of this measure will increase by factor 3 compared to the planting of six additional male parent rows (table 3.1.5). The opportunity cost effects of planting additional male parent rows on varying field sizes of the non-GM field are illustrated in figure 3.1.4. The opportunity costs per hectare strongly increase with a higher number of additional male parent rows in all four simulated field sizes. However, if the opportunity costs of this measure are related to the 5 ha GM seed field, they amount for six additional male parent rows to more than 250 €/ha in case of neighbouring non-GM seed fields sized 0.5 ha. These opportunity costs decrease to around one third if the GM seed producing farmer is surrounded by farms with 5 ha non-GM fields. The same relationship can be observed in case of planting 18 or 20 additional male parent rows on the non-GM field (figure 3.1.4).

Table 3.1.5: Opportunity costs of planting additional male parent rows in maize seed production

Parameter	Specification	
Size of GM seed-producing field	5 ha (224 x 224 m)	
Additional number of male rows	6	18
Savings in labour input for male rows	85 hours/ha	
Opportunity costs of planting extra male rows (for 5 ha non-GM field)		
Gross margin seed maize current practice	7,440 €	7,440 €
Income loss due to reduction of yields	502 €	1,505 €
Labour savings (castration)	98 €	293 €
Total opportunity costs of co-existence measures	404 €	1,212 €
Opportunity costs in relation to economic parameters		
Opportunity costs of additional male rows	80.85 €/ha	242.53 €/ha
% of variable production costs	3.7 %	11.1 %
% of gross margin	5.4 %	16.3 %

Source: Calculations of University of Applied Sciences of Weihenstephan 2004

Figure 3.1.4: Opportunity costs of planting male parent rows in differently sized non-GM fields (€/ha)



Source: Calculations of University of Applied Sciences of Weihenstephan 2004

In order to reduce cross pollination between GM and adjacent non-GM fields, modifying of the flowering times (by cultivating varieties with differing flowering sequences) is suggested as an additional co-existence measure in maize seed production (table 3.1.1). This measure has to be carried out by the GM seed producing farmer. In order to calculate the opportunity costs of this measure, it has to be taken into account that farmers face yield losses if they change to a maize variety with later flowering time. According to published data of Bock et al. 2002 these yield losses amount to more than 13 % in case of changing from a very late to late variety (30°days) and almost 3.5 % in case of changing from a late to a mid early variety (60°days) (table 3.1.6). For changing from a late to very early variety (90°days) the effect on yield reduction could not be quantified, but this can be regarded as a rather unrealistic option for the south west part of France anyhow. Taking into account the differing yield losses in case of changing flowering times of maize varieties, an income loss amounting to almost 450 €/ha has to be expected in case of changing from a very late to a late variety. This equal to around 20 % of the variable production costs or 30 % of the gross margin of seed production in south west France (table 3.1.6). In case flowering time is changed from a late to a mid early variety, an income loss of around 114 €/ha can be expected which equal to around 5 % of the variable production costs or almost 8 % of the gross margin of maize seed production (table 3.1.6).

Table 3.1.6: Income loss of changing flowering times in maize seed production (seed-seed situation)

Changing flowering time from	**Very late to late**	**Late to mid early**	**Late to very early**
Difference in flowering time (°days)	30	60	90
Yield loss (t/ha) [1)]	0.47	0.12	Not available
Yield decrease (%)	13.44	3.43	n.a.
Price of maize (€/t)	950.0		
Income loss due to change of flowering time (€/ha)	446.77	114.00	n.a.
.....% of variable production costs	20.5 %	5.2 %	n.a.
.....% of gross margin	30.0 %	7.6 %	n.a.
1) Data of Bock et al. 2002			

Sources: Calculations of University of Applied Sciences of Weihenstephan 2004 based on data of Bock et al. 2002

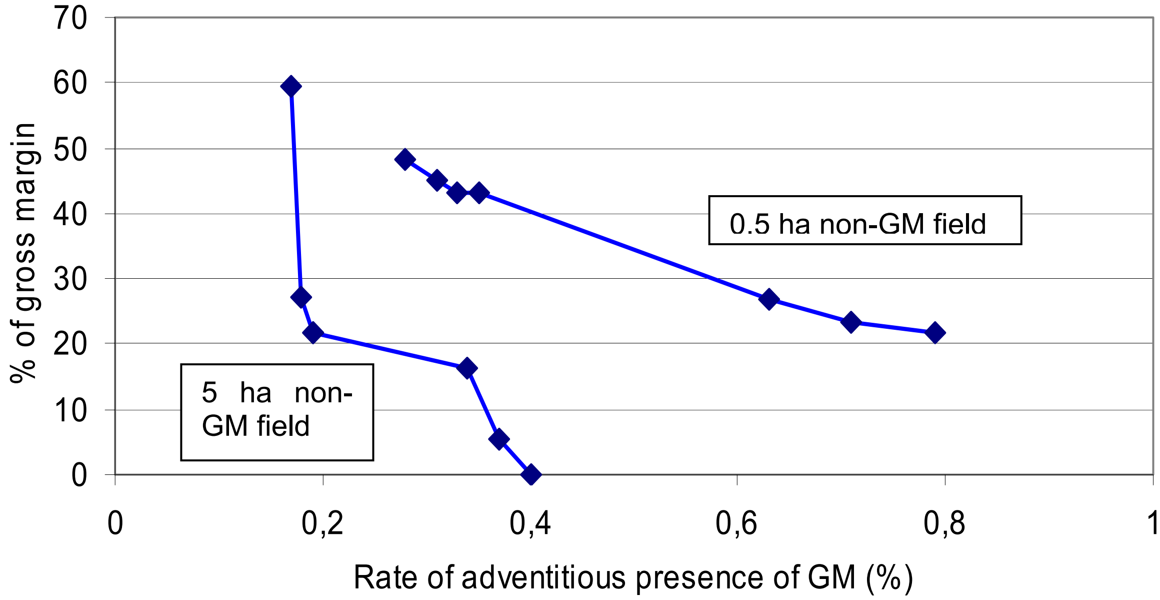
Cost effects of combined co-existence measures: seed-seed situation

Using the cost calculation methodologies described in the figures 3.1.2 and 3.1.3, the costs of differing combinations of increased isolation distances and planting of additional male parent rows are calculated in the following paragraph. For this purpose it is assumed that a squared 5 ha-GM maize seed-producing field is adjacent to other non-GM maize seed-producing fields with differing field sizes (seed-seed situation).

The estimated opportunity costs of increasing isolation distances and planting additional male parent rows on the non-GM field are shown in table 3.1.7. For this purpose the opportunity costs of the different suggested co-existence measures have been calculated for the entire 5 ha GM field and put into relation to the gross margin originally resulting from this field (table 3.1.7). The opportunity costs of additional isolation distances exceeding 200 m cannot be calculated with the approach described in figure 3.1.2, so that no estimations have been carried out for these cases. As shown in table 3.1.7, threshold levels of 0.3 % GM adventitious presence can be achieved in all adjacent non-GM seed fields irrespectively of their field size. Despite some exceptions from this rule, it can be observed that the opportunity costs of co-existence measures (calculated in % of the gross margin) increase with a decreasing field size of the neighbouring non-GM seed field. In case of a 0.5 ha non-GM field these opportunity costs are estimated up to 50 % of the gross margin of maize seed production, while the corresponding figure for the 2.5 ha field is calculated up to 20 % of the gross margin. However, in the 5 ha-case of an adjacent non-GM seed field the co-existence opportunity costs may amount to more than 40 % of the gross margin of maize seed production in south west France in case thresholds below 0.2 % have to be considered (table 3.1.7).

The GM adventitious presence/co-existence-cost-graphs of measures suggested for the 0.5 ha or 5 ha non-GM fields (as the extreme cases of field sizes simulated by INRA in the seed-seed situation) are shown in figure 3.1.5. With co-existence costs of a maximum of 30 % of the gross margin of maize seed production, a threshold of 0.63 % GM adventitious presence can be reached on the 0.5 ha non-GM field in contrast to 0.18 % on the 5 ha field. In order to reach thresholds below 0.3 % costs are significantly rising on the 0.5 ha field and are exceeding 50 % of the gross margin of maize seed production, while threshold levels of below 0.2 % GM adventitious presence can be achieved with the same cost range on the 5 ha non-GM field (figure 3.1.5).

Figure 3.1.5: Interrelationships of opportunity costs of co-existence measures[1] and GM adventitious presence rates in maize seed production



1: The co-existence measures used in this figure are a combination of increasing isolation distances and planting extra male parent rows on a neighbouring non-GM field.

Sources: Simulations of INRA and calculations of University of Applied Sciences of Weihenstephan 2004

Table 3.1.7: Opportunity costs of increasing isolation distances and planting additional male rows in maize seed production (seed-seed situation)

Field size		Additional measures		Rate of GM adventitious presence with additional measure	Opportunity costs of additional measures			
GM seed field	Non-GM-seed field	Isolation distance	Extra male rows[2]		Extra male rows	Wheat as alter-native crop[1]	Total oppor-tunity costs	% of gross margin
ha		m	number	%	€ / 5 ha GM field			%
			2	**0.77**				
		100	0	0.79	0	1608.1	1608.1	21.6
		100	6	0.71	127.8	1608.1	1735.9	23.3
		100	18	0.63	383.5	1608.1	1991.6	26.8
		200	0	0.35	0	3216.1	3216.1	43.2
		200	0	0.33	0	3216.1	3216.1	43.2
	0.5	200	6	0.31	127.8	3216.1	3344.0	44.9
		200	18	0.28	383.5	3216.1	3599.6	48.4
		300	0	0.2		Not possible on a 5 ha GM field	Not possible on a 5 ha GM field	
		400	0	0.13		Not possible on a 5 ha GM field	Not possible on a 5 ha GM field	
		100	**2**	**0.66**				
		100	0	0.31	0	1608.1	1608.1	21.6
	1	200	0	0.18	0	3216.1	3216.1	43.2
5		300	0	0.12		Not possible on a 5 ha GM field	Not possible on a 5 ha GM field	
		100	**2**	**0.52**				
		100	0	0.25	0	1608.1	1608.1	21.6
	2.5	200	0	0.15	0	3216.1	3216.1	43.2
		300	0	0.1		Not possible on a 5 ha GM field	Not possible on a 5 ha GM field	
		100	**2**	**0.4**				
		0	0	0.4	0	0.0	0.0	0.0
		0	6	0.37	404.2	0.0	404.2	5.4
		0	18	0.34	1212.7	0.0	1212.7	16.3
		100	0	0.19	0	1608.1	1608.1	21.6
	5	100	0	0.19	0	1608.1	1608.1	21.6
		100	6	0.18	404.2	1608.1	2012.3	27.0
		100	18	0.17	1212.7	3216.1	4428.8	59.5
		200	0	0.12	0	3216.1	3216.1	43.2
		300	0	0.08	0	Not possible on a 5 ha GM field	Not possible on a 5 ha GM field	

1) Gross margin of seed maize: 1,488 €/ha; Gross margin of wheat: 769 €/ha
2) If "0 extra male rows" are mentioned in this column, there are no additional male parent rows planted on the non-GM seed field.
The blue figures in the table represent the current situation.

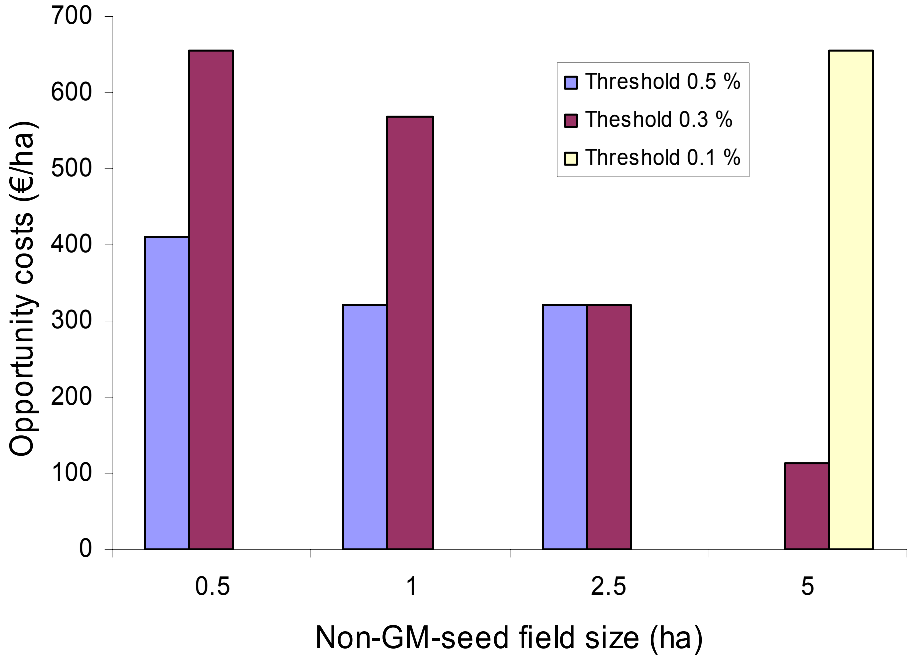
Sources: Simulations of INRA and calculations of University of Applied Sciences of Weihenstephan 2004

In a further step of the analysis the opportunity costs of flowering time lags are taken into account in the simulated seed-seed situation. The results of these calculations are shown in table 3.1.8 in which the opportunity costs are related to the 5 ha GM-seed producing field. Depending on the simulated isolation distance and additional male rows, there are differing flowering time lags necessary between the seed-producing varieties in order to achieve the differing thresholds. As a general trend it can be observed that with increasing isolation distances and non-GM field sizes lags in the flowering time are only necessary for threshold levels below 0.3 % thus resulting in opportunity costs of 2,234 €/5ha or 570 €/5ha respectively (table 3.1.8). In order to meet a threshold of 0.5 % opportunity costs for flowering lags between the seed varieties of 570 €/5ha only occur in case of a small non-GM field with 0.5 ha and an additional isolation distance of 100 m (table 3.1.8). In contrast, it seems that a threshold of 0.1 % in maize seed production cannot be met without strongly increasing isolation distances and additionally use seed varieties with different flowering times. In most cases the opportunity costs of the second measure could not be quantified due to lack of data for the 0.1 % threshold level, but this should not be interpreted in the sense that this measure will not cause substantial income losses for farmers.

The opportunity costs of the combined co-existence measures are shown in table 3.1.9. In a first part the increased isolation distances are taken into account in order to show the maximum level of co-existence costs in maize seed production. In this case the opportunity costs can reach significant levels often exceeding 40 % of the gross margin of maize seed production in France. This relates in particular to small neighbouring fields with non-GM seed production and low thresholds of adventitious presence of GM material (table 3.1.9).

In order to get insight in the most effective combination of co-existence measures in maize seed production, the simulated combinations were screened with respect to the lowest per-hectare-costs (taking into account the calculated opportunity costs of isolation distances, planting of additional male rows and changing flowering time of the seed varieties) for the three simulated threshold levels of 0.5 %, 0.3 % and 0.1 %. The results of this screening process are shown in figure 3.1.6. It can be observed that the opportunity cost levels of co-existence measures necessary to meet a defined threshold highly differ depending on the field sizes of neighbouring non-GM seed producing fields. In order to meet a threshold of 0.5 % in maize seed production, opportunity costs of around 410 €/ha have to be calculated (representing almost 28 % of the gross margin) in case of adjacent non-GM fields of 0.5 ha, while this threshold already can be met without additional measures (and thus no costs) in case the GM seed producing farmer is adjacent to neighbours with 5 ha fields (figure 3.1.6). The same picture emerges if a 0.3 % threshold has to be met: In case of 0.5 ha non-GM adjacent fields opportunity costs of around 650 €/ha (representing 44 % of the current gross margin) has to be calculated, which decrease to around 114 €/ha in case of non-GM field sizes of 5 ha. The opportunity costs of additional measures to meet a 0.1 % threshold could only be quantified for the 5 ha non-GM field with the used methodology (for calculating opportunity costs of isolation distances) and the available data (related to effects of changing flowering time of seed varieties). As shown in figure 3.1.6, there will be substantial opportunity costs to meet the threshold level of 0.1 % (if ever possible from an agronomic point of view) since they amount to more than 650 €/ha already in the "best case" of 5 ha non-GM fields.

Figure 3.1.6: Gross margin losses due to the most effective co-existence measures (isolation distances, flowering lag, extra male parent rows) for different thresholds and field sizes of non-GM neighbouring fields in maize seed production situated downwind



Note: This figure combines all the measures identified.

Sources: Simulations of INRA and calculations of University of Applied Sciences of Weihenstephan 2004

As explained above it is very difficult from a methodological point of view to quantify the costs of increasing isolation distances in maize seed production and thus the calculated costs should be regarded as a maximum level of costs for this measure. In addition, costs of increasing isolation distances might be reduced by organisational measures of seed breeding companies and seed-producing farmers in order to avoid a strong reduction of the economically interesting production of maize seeds. In order to show the minimum cost range of additional measures in maize seed production. The opportunity costs of the suggested measures are calculated without taking into account the effect of increased isolation distances. In this case the opportunity costs of co-existence measures rarely exceed the level of 20 % of the gross margin of maize seed production (table 3.1.9). This again indicates the high relevance of increasing isolation distances in maize seed production - both for meeting thresholds below 0.5 % and as a dominant part of the farmers' income losses due to co-existence measures in this field.

Table 3.1.8: Opportunity costs of flowering lags in maize seed production in France (seed-seed situation)

<table>
<tr><th colspan="2">Field size</th><th colspan="2">Additional measures</th><th rowspan="2">Rate of GM adventitious presence with additional measure</th><th colspan="3">Flowering time lag necessary to achieve GM adventitious presence rate below ......</th><th colspan="3">Opportunity costs of flowering lag</th></tr>
<tr><th>GM seed field</th><th>Non-GM-seed</th><th>Isolation distance</th><th>Extra male rows</th><th>0.5 %</th><th>0.3 %</th><th>0.1 %</th><th>0.5 %</th><th>0.3 %</th><th>0.1 %</th></tr>
<tr><th colspan="2">ha</th><th>m</th><th>number</th><th>%</th><th>°days</th><th>°days</th><th>°days</th><th>€/5 ha GM field</th><th>€/5 ha GM field</th><th>€/5 ha GM field</th></tr>
<tr><td rowspan="29">5</td><td rowspan="11">0,5</td><td>100</td><td>2</td><td>0.77</td><td colspan="3">Basic</td><td colspan="3">Basic</td></tr>
<tr><td>100</td><td>0</td><td>0.79</td><td>90</td><td rowspan="3">90</td><td rowspan="3">120</td><td>n.a.</td><td rowspan="3">n.a.</td><td rowspan="3">n.a.</td></tr>
<tr><td>100</td><td>6</td><td>0.71</td><td rowspan="2">60</td><td rowspan="2">570</td></tr>
<tr><td>100</td><td>18</td><td>0.63</td></tr>
<tr><td>200</td><td>0</td><td>0.35</td><td rowspan="6">0</td><td>60</td><td rowspan="5">90</td><td rowspan="6">0</td><td>570</td><td rowspan="5">n.a.</td></tr>
<tr><td>200</td><td>0</td><td>0.33</td><td rowspan="2">30</td><td rowspan="2">2,234</td></tr>
<tr><td>200</td><td>6</td><td>0.31</td></tr>
<tr><td>200</td><td>18</td><td>0.28</td><td rowspan="3">0</td><td rowspan="3">0</td></tr>
<tr><td>300</td><td>0</td><td>0.2</td></tr>
<tr><td>400</td><td>0</td><td>0.13</td><td>60</td><td>570</td></tr>
<tr><td colspan="3"></td><td colspan="6"></td></tr>
<tr><td rowspan="4">1</td><td>100</td><td>2</td><td>0.66</td><td colspan="3">Basic</td><td colspan="3">Basic</td></tr>
<tr><td>100</td><td>0</td><td>0.31</td><td rowspan="3">0</td><td>30</td><td rowspan="2">90</td><td rowspan="3">0</td><td>2,234</td><td rowspan="2">n.a.</td></tr>
<tr><td>200</td><td>0</td><td>0.18</td><td rowspan="2">0</td><td rowspan="2">0</td></tr>
<tr><td>300</td><td>0</td><td>0.12</td><td>60</td><td>570</td></tr>
<tr><td rowspan="4">2,5</td><td>100</td><td>2</td><td>0.52</td><td colspan="3">Basic</td><td colspan="3">Basic</td></tr>
<tr><td>100</td><td>0</td><td>0.25</td><td rowspan="3">0</td><td rowspan="3">0</td><td rowspan="2">90</td><td rowspan="3">0</td><td rowspan="3">0</td><td rowspan="2">n.a.</td></tr>
<tr><td>200</td><td>0</td><td>0.15</td></tr>
<tr><td>300</td><td>0</td><td>0.1</td><td>60</td><td>570</td></tr>
<tr><td rowspan="10">5</td><td>100</td><td>2</td><td>0.4</td><td colspan="3">Basic</td><td colspan="3">Basic</td></tr>
<tr><td>0</td><td>0</td><td>0.4</td><td rowspan="9">0</td><td rowspan="3">60</td><td rowspan="3">120</td><td rowspan="9">0</td><td rowspan="3">570</td><td rowspan="3">n.a.</td></tr>
<tr><td>0</td><td>6</td><td>0.37</td></tr>
<tr><td>0</td><td>18</td><td>0.34</td></tr>
<tr><td>100</td><td>0</td><td>0.19</td><td rowspan="6">0</td><td rowspan="4">90</td><td rowspan="6">0</td><td rowspan="4">n.a.</td></tr>
<tr><td>100</td><td>0</td><td>0.19</td></tr>
<tr><td>100</td><td>6</td><td>0.18</td></tr>
<tr><td>100</td><td>18</td><td>0.17</td></tr>
<tr><td>200</td><td>0</td><td>0.12</td><td>60</td><td>570</td></tr>
<tr><td>300</td><td>0</td><td>0.08</td><td>0</td><td>0</td></tr>
</table>

Sources: Simulations of INRA and calculations of University of Applied Sciences of Weihenstephan 2004

Table 3.1.9: Opportunity costs of combining different co-existence measures in maize seed production in France

Field size		**Additional measures**		**Rate of GM adventitious presence with additional measure**	**Flowering time lag necessary to achieve GM adventitious presence rate below...**			**Total opportunity costs of additional measures (including isolation distances)**			**Proportion of gross margin**			**Total opportunity costs of additional measures (excluding isolation distances)**			**Proportion of gross margin**		
GM seed field	**Non-GM-seed**	**Isolation distance**	**Extra male rows**		**0.5 %**	**0.3 %**	**0.1 %**	**€/ha**			%			**€/ha**			%		
ha		**m**	**number**		**°days**	**°days**	**°days**	**0.5 %**	**0.3 %**	**0.1 %**	**0.5 %**	**0.3 %**	**0.1 %**	**0.5 %**	**0.3 %**	**0.1 %**	**0.5 %**	**0.3 %**	**0.1 %**
		100	**2**	**0.77**	Basic			Basic			Basic			Basic			Basic		
		100	0	0.79	90			n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	n. a.	0	0	0
		100	6	0.71	60	90	120	410	n. a.	n. a.	28	0	0	140	n. a.	n. a.	9	0	0
		100	18	0.63				461	n. a.	n. a.	31	0	0	191	n. a.	n. a.	13	0	0
	0,5	*200*	*0*	*0.35*		*60*		*643*	*655*	*n. a.*	*43*	*44*	*0*	*0*	*114*	*n. a.*	*0*	*8*	*0*
		200	0	0.33		30		643	691	n. a.	43	46	0	0	447	n. a.	0	30	0
		200	6	0.31	*0*		*90*	669	716	n. a.	45	48	0	140	575	n. a.	9	39	0
		200	18	0.28				720	720	n. a.	48	48	0	191	128	n. a.	13	9	0
		300	0	0.2		0		0	0	n. a.	0	0	0	0	0	n. a.	0	0	0
		400	0	0.13			60	0	0	n. a.	0	0	0	0	0	114	0	0	8
		100	**2**	**0.66**	Basic			Basic			Basic			Basic			Basic		
	1	100	0	0.31		30	90	322	568	n. a.	22	38	0	0	447	n. a.	0	30	0
		200	0	0.18	0			643	643	n. a.	43	43	0	0	0	n. a.	0	0	0
5		300	0	0.12		0	60	0	0	n. a.	n. a.	n. a.	0	0	0	114	0	0	8
		100	**2**	**0.52**	Basic			Basic			Basic			Basic			Basic		
	2,5	100	0	0.25			90	322	322	n. a.	22	22	0	0	0	n. a.	0	0	0
		200	0	0.15	0	0		643	643	n. a.	43	43	0	0	0	n. a.	0	0	0
		300	0	0.1			60	0	0	n. a.	n. a.	n. a.	0	0	0	114	0	0	8
		100	**2**	**0.4**	Basic			Basic			Basic			Basic			Basic		
		0	0	0.4				0	114	n. a.	0	8	0	0	114	n. a.	0	8	0
		0	6	0.37		60	120	81	195	n. a.	5	13	0	81	195	n. a.	5	13	0
		0	18	0.34				243	357	n. a.	16	24	0	243	357	n. a.	16	24	0
	5	100	0	0.19				322	322	n. a.	22	22	0	0	0	n. a.	0	0	0
		100	0	0.19	0		90	322	322	n. a.	22	22	0	0	0	n. a.	0	0	0
		100	6	0.18				402	402	n. a.	27	27	0	81	81	n. a.	5	5	0
		100	18	0.17		0		886	886	n. a.	60	60	0	243	243	n. a.	16	16	0
		200	0	0.12			60	643	643	655	43	43	44	0	0	114	0	0	8
		300	0	0.08			0	0	0	n. a.	0	0	0	0	0	0	0	0	0

The blue figures in the table represent the current situation

Example for interpretation of the table (in italic format): For a GM seed field of 5 ha and a neighbouring non-GM seed field of 0.5 ha, it is suggested to increase the isolation distance by 200 m in order to achieve a level of 0.35 % of GM adventitious presence. In case a threshold of 0.3 % has to be met, it is necessary to additionally plant maize seed varieties with a flowering lag of 60°days, in case of a 0.1 % threshold with 90°days. If the opportunity costs of increasing isolation distances are taken into account, the opportunity costs of additional measures amount to 643 €/ha (which equals to 43 % of the gross margin of maize seed production) for the 0.5 % threshold, and to 655 €/ha for the 0.3 % threshold (equivalent to 44 % of the gross margin). If opportunity costs of increasing isolation distances are not included in the cost analysis, there are no additional costs in case of a 0.5 % threshold, and opportunity costs of 114 €/ha in case of a 0.3 % threshold (representing 8 % of the gross margin). For the 0.1 % threshold the opportunity costs of the suggested measures cannot be quantified due to lack of information on the yield losses in case of flowering time lags of 90°days.

Sources: Simulations of INRA and calculations of University of Applied Sciences of Weihenstephan 2004

Cost effects of combined co-existence measures: crop-seed situation

In a final step of the quantitative cost analysis in maize seed production, the costs of increasing isolation distances and planting additional male parent rows are estimated for the so-called crop-seed situation, i. e. a GM-crop-producing field is adjacent to non-GM seed fields. The results of such a simulation are shown in table 3.1.10.. Due to the assumption of a squared 10 ha GM-crop-producing field only opportunity costs of increasing isolation distances up to 300 m can be calculated with the approach described in figure 3.1.2. This measure has to be taken by the GM crop producing farmer. By increasing isolation distances or planting 20 additional male parent rows[7], a significant reduction of the levels of adventitious presence of GM material can be achieved in all simulated non-GM seed field sizes. Substantial opportunity costs can be expected in case of planting high numbers of additional male parent rows (table 3.1.10.), while increasing isolation distances do not cause high income losses of farmers in the crop-seed situation. Due to agronomic reasons (i.e. similar cultivation procedures and placement of the plant in the crop rotation plan of the farm) it is assumed that the GM maize producing farmer is planting a non-GM maize variety on the strip of the GM maize field which is necessary to increase the isolation distance between the GM crop and the non-GM seed field (in analogy to figure 3.1.2.)[8]. For quantifying the costs of increasing isolation distances in the crop-seed situation, we assumed a gross margin of 786 €/ha for the GM maize variety and 743 €/ha for the non-GM maize variety (for further details see table 3.1.16.)[9]. By increasing the additional isolation distance up to 300 m, a significant reduction in the GM adventitious presence below the 0.5 % threshold can be achieved in all field sizes. However, this causes opportunity costs in the range of up to approximately 20 % of the gross margin of GM maize crop production in case it is necessary to plant 20 additional male parent rows. The farmers' income losses can be reduced below around 5 % the gross margin

[7] The extra male parent rows have to be planted on the non-GM seed field. It is assumed that the GM crop producing farmer compensates the opportunity costs of this measure.

[8] In order to minimize a potential contamination of the non-GM certified seed with pollen of other varieties, the GM maize producing farmer should plant the same non-GM variety on the "isolation strip" which is multiplied on the corresponding non-GM seed field.

[9] The analysis of the potential economic performance of Bt maize cultivation in France is included in chapter 4.3.2 since this issue deals with maize crop production and not with maize seed production.

in case of avoiding planting high numbers of additional male parent rows (table 3.1.10.).

In a second option of the crop-seed situation we assumed that the GM maize producing farmer is cultivating wheat as alternative crop on the “isolation strip” of the GM maize crop field instead of non-GM maize. Although the gross margin of wheat (769 €/ha) is higher than the corresponding figure of non-GM maize (743 €/ha), the cultivating of wheat is regarded as being less realistic due to crop rotation[10] and agronomic reasons (i. e. higher organisational efforts of the farmer compared to planting a non-GM maize variety). Cultivating of wheat on the “isolation strip” of the GM maize crop field and the non-GM maize seed field would prevent pollen flow and thus a potential cross pollination between two differing non-GM varieties which might cause problems in the first scenario. Due to the higher gross margin of wheat compared to non-GM maize, the opportunity costs of meeting the threshold of 0.5 % will range up to around 18 % of the gross margin of maize crop production in case high numbers of additional male parent rows have to be planted (table A5). If this can be avoided, the opportunity costs are significantly lower and range up to 2 % of the gross margin of maize crop production if wheat is planted as alternative crop on the “isolation strip”. Taken all together, it can be concluded that in contrast to the seed-seed situation increasing isolation distances between GM crop and non-GM seed maize fields is a very cost-effective measure in order to meet defined thresholds of 0.5 % or 0.3 % adventitious presence of GM material in the crop-seed situation.

[10] The cultivation of wheat in monoculture is regarded as being unrealistic under the conditions in Pyrénées-Atlantique due to climate conditions, weed and pest pressure.

Table 3.1.10.: Opportunity costs of increasing isolation distances and planting additional male rows in maize seed production (crop-seed situation)

Field size		Additional measures		Rate of GM adventitious presence with additional measure	Opportunity costs of additional measures			
GM crop field	Non-GM-seed field	Isolation distance	Extra male rows		Extra male rows	Non-GM maize as alternative crop	Total opportunity costs	% of gross margin
ha		m	number	%	€/10ha GM field			%
10	1		**20**	**1.42**				
		300		**1.05**				
		100	0	0.73	0	136.0	136.0	1.7
		200	0	0.53	0	272.0	272.0	3.5
		300	0	0.4	0	407.9	407.9	5.2
		400	0	0.31	0	Not possible on a 10 ha GM field	Not possible on a 10 ha GM field	Not possible on a 10 ha GM field
		500	0	0.24	0			
		600	0	0.19	0			
		700	0	0.15	0			
	5	**300**		**0.77**				
			20	**1.07**				
		100	20	0.54	1347.4	136.0	1483.4	18.9
		200	20	0.4	1347.4	272.0	1619.4	20.6
		300	20	0.3	1347.4	407.9	1755.4	22.3
		400	20	0.23	1347.4	Not possible on a 10 ha GM field	Not possible on a 10 ha GM field	Not possible on a 10 ha GM field
		500	20	0.18	1347.4			
		600	20	0.15	1347.4			
		700	20	0.12	1347.4			
	10		**20**	**1.49**				
		200		**0.94**				
		100	0	0.61	0	136.0	136.0	1.7
		200	0	0.43	0	272.0	272.0	3.5
		300	0	0.32	0	407.9	407.9	5.2
		400	0	0.24	0	Not possible on a 10 ha GM field	Not possible on a 10 ha GM field	Not possible on a 10 ha GM field
		500	0	0.19	0			
		600	0	0.15	0			
		700	0	0.12	0			
		800	0	0.1	0			

1) Gross margin of Bt maize: 786 €/ha (for details see table 3.1.16.)
Gross margin of non-GM maize: 743 €/ha (for details see table 3.1.16.)
The blue figures in the table represent the current situation.

Sources: Simulations of INRA and calculations of University of Applied Sciences of Weihenstephan 2004

Organisational effects of increasing isolation distances

Increasing isolation distances in maize seed production can be regarded as one efficient option in order to meet a threshold of 0.5 % or 0.3 % adventitious presence of GM material in certified maize seed. However, the quantification of costs of such a measure is restricted due to methodological reasons as well as e. g. the heterogeneity of farming systems, landscape patterns, specific behaviour of farmers as well as strategies of seed breeding and multiplying companies. Nevertheless it can be assumed that seed breeding companies will try to re-arrange field locations used for certified seed production in order to meet modified isolation distances and produce certified seeds under the new regulatory framework in the most efficient way.

In order to analyse the organisational effects of such activities, seed breeding companies, companies organising the production of certified seeds on behalf of seed breeding companies, plant breeders associations as well as farmers associations related to certified seed production in France and Germany were contacted for personal or telephone interviews. Although there was a high general interest of the companies in the analysed question, they often hesitated to give detailed information not least due to the secrecy character of the requested data. In this context the companies often gave the hint that they already participate in another study of the European Commission which partly deals with this question. A specific initiative of the German Plant Breeding Association (BDP) to collect the views of their member companies to increasing isolation distances in maize seed production also failed due to lack of time as well as a limited willingness of the companies to co-operate. Therefore only a small number of telephone and personal interviews could be arranged in order to discuss organisational and other effects of increasing isolation distances in maize seed production. A meeting with plant breeding companies in France which took place on February 11, 2005 in the building of Groupement National Interprofessionnel des Semences (GNIS) in Paris was used to discuss the preliminary findings of the interviews with the participating representatives of more than ten seed breeding companies or institutions involved in production or control of certified maize seed. The outcome of this meeting is included in the results of the analyses.

In the following firstly a case study on certified maize seed production in Germany is presented in order to show the organisational consequences of increasing isolation distances in a small-scaled farming region. This case study is mainly based on data provided by a company which organise certified maize seed production on behalf of seed breeding companies. In a second step the general consequences will be outlined as they could be extracted from the information collected during the interviews and the meeting in Paris.

Case study: Certified maize seed production in Germany

In the following paragraph the impacts of changing isolation distances are analysed for a company which organises certified maize seed production in Germany on behalf of several seed breeding companies. As shown in table 3.1.11. only a very limited amount of base and certified maize seeds are produced in Germany mainly due to climatic reasons which allow maize grain production only in few regions of Germany.

Table 3.1.11: Level of maize seed production in Germany (base and certified seeds)

Year	**Level of maize seed production (ha)**
2000	1,860
2001	2,549
2002	2,742
2003	3,108

Source: Bundesministerium für Verbraucherschutz, Ernährung und Landwirtschaft 2003

The analysed company is part of one of the most important trade and Service Company in the agricultural sector in Germany. Besides animal food, plant protection, fertilizers, energy and farming equipment the company deals with producing and trading of seeds. The company organises the regional production and cultivation of certified maize seed varieties on behalf of important international and German seed breeding companies like e. g. Pioneer, Advanta, KWS and Saaten-Union. In total the company produces – in collaboration with regional farmers - around 40 fodder and grain maize varieties with FAO-Numbers between 190 and 250 (table 3.1.12).

Table 3.1.12: Statistical information related to maize production of the case study company

Cultivated area with certified maize seeds	Around 2,500 ha
Average size of isolations	2 to 200 ha
Average field size in the region	1.6 ha
Number of farmers who produce certified maize seeds/Number of farmers who produce maize (fodder or grain)	210/150
Number of conflicts among farmers	2-3 per year
Number of produced grain and fodder maize varieties	40
Degree of purity of certified seed maize seeds	99 %
Average isolation distance between certified seed maize and conventional maize fields	200 m to-500 m

Source: Information of the company provided in 2005

The legal requirements concerning the production of certified maize seed are clarified in the German seed regulation law called „Saatgutverordnung“ (Verordnung über den Verkehr mit Saatgut landwirtschaftlicher Arten und von Gemüsearten) which entered into force in May 1999. In order to ensure varietals purity of the produced maize seed variety, isolation distances of 200 m are required between maize seed fields in the region. However, there are some possibilities to reduce these distances if additional measures are taken by the certified seed producing farmers (table 3.1.13).

Table 3.1.13: Possibilities to reduce isolation distances in maize seed production

Possibilities to reduce required minimum isolation distance	Reduction of the isolation distance by …..
A: Planting of additional male rows closely to female rows directly on the seed producing fields	10 m/male row maximum of 10 rows or 100 m
B: Recognition of natural constraints for pollen flow like woods, hedges or dams. Depending on the heights of the constraints the following reductions are valid:	
< 3 m	No reduction
3 m	20 m
4 m	40 m
5 m	60 m
6 m	80 m
7 m	100 m
C: Activities on neighbouring maize fields a) Pure seeding of male plants of maize variety which should be propagated b) Seeding of a pollen-sterile maize variety together with the paternal variety of the maize variety to be propagated [1), 2)]	5 m/male row in the neighbouring field maximum of 20 rows or 100 m
D: Relation female/male plants in two propagation fields In case there are less than 10 % of non castrated plants of the maternal variety in a neighbouring propagation field of the same variety and category, the minimum isolation distance equals to the ten-fold proportion of non-castrated plants (e. g. for 5.7 % non-castrated maternal plants a minimum isolation distance of 57 m is required).	
1) The rows will only be acknowledged if they are planted parallel to the rows of the plants to be propagated. 2) A maximum of 2 % of pollen-producing plants is allowed for the pollen-steril maize variety as tested in all field investigations.	

Source: Information of the company 2005

The company has contracts with seed breeding companies as well as farmers in specific regions in order to organize the propagation of certified maize of a specific variety. The farmers inform the company which fields should be used for this purpose. Based on this information the company forms so-called “isolations” (i. e. specific parts of the region in which a specific maize variety is propagated) which fulfil the regulatory requirements concerning isolation distances. During this process there are conflicts with around 1 % of the seed producing farmers, who cannot fulfil the required isolation distances mostly due to the cultivation of other maize varieties for feeding or human consumption purposes. The company tries to arrange a solution with the farmer in conflicting cases in the following ways:

- All possibilities to reduce the required minimum isolation distance (table 3.1.13) have to be checked whether they can be realised in the specific case.
- Cultivation of the non-seed maize variety outside the “isolations” mainly due to exchange of fields with other farmers.
- Propagation of a maize seed variety with differing flowering time.

In most cases conflicts among farmers are solved without intervention of the company. Thus the company does not have to calculate high additional efforts for such cases. This is mainly due to the fact that the propagation of certified maize seed has a long tradition in the region so that the distribution of seed producing fields follows a certain routine which is facilitated by the specific knowledge of farmers concerning the legal and agronomic requirements related to seed production.

When discussing a potential increase of the required isolation distances in order to meet a specific threshold of adventitious presence of GM material in certified maize seeds, the company explained that a 200 m isolation distance is regarded as the highest isolation distance which can be economically realised in the region. The main reason for this statement forms the small-scaled farm and field structure in the region which is underlined by an average field size of 1.6 ha. In case of increasing isolation distances of around 100 m, 20 % of the seed producing fields cannot be used for this purpose since they will not fulfill the new legal requirements. Another effect would be a significant reduction of the diversity of propagated maize varieties as well as the amount of seeds produced in the region. Although the company was not able to quantify this effect due to lack of data and recent experiences, they put specific emphasis on the fact that this will limit the market opportunities as well as the future turnover of the company. Altogether increasing isolation distances significantly will decrease the value added both for the farmers in the region and the service company organising production of certified maize seed.

General consequences of increasing isolation distances in maize seed production

In case isolation distances will be increased in maize seed production in order to meet threshold levels of 0.5 % or 0.3 % adventitious presence of GM material in non-GM certified maize seeds, a re-organisation of fields used for maize seed production is required in regions in which GM varieties will be multiplied[11]. This process will lead to a reduction of the total area used for maize seed production in a specific region if maize seed production is organised according to a centralised plan[12]. The absolute and relative level of reduction mainly depends on the additional isolation distance and the landscape pattern of the region. If we assume an additional isolation distance of 100 m and an average field size of 1 ha in a region, the proportion of seed producing fields might be reduced from 21 % of the agriculturally used area (AUA) to around 11 % of the AUA, thus resulting in a reduction of almost 50 % of the originally used seed producing area. In case there is an average field size of 4 ha in the region, the proportion of fields used for seed production may fall from 36 % of the AUA to 26 % of the AUA – which equals to a reduction of around one third - if the isolation distance is increased by 100 m. The lowest absolute and relative reduction of the seed producing area can be expected in case of large field sizes like it can be shown if we have an average field size of 9 ha in a region. In this case the maize seed producing area might be decreased from around 45 % of the AUA to 38 % of the AUA which means a minus of around 14 % of the area originally used for certified maize seed production. The reduction of the maize seed producing area will result in a significant decline of the amount of certified maize seed produced in a specific region which might followed by a loss of potential turnover with seeds as well as declining market shares of the respective company.

In addition to the described consequences on the production and market side, there are additional time requirements and management costs for re-organising the seed producing area in a region due to increasing isolation distances. Currently there are hardly any data publicly available which analyse the time requirements and management costs of organising seed producing fields in a

[11] It is assumed that multiplying of GM seeds offers a benefit compared to the current situation and that there is a demand for GM seeds in the EU.
[12] If a specific maize seed variety is multiplied on a defined field it is theoretically possible to grow the same maize variety in the isolation area. However, in order to ensure varietals purity many seed multiplying companies ask their co-operating farmers to grow an alternative crop on the isolation area.

region. In this context one specific problem represents the fact that these time requirements and the resulting costs are scattered between different actors (e. g. seed breeding companies, companies organising the multiplying of seeds, farmers, control and administrative institutions). In the case study on maize seed production in Germany it is estimated that around five minutes per hectare are required for the organisation and management of the seed producing area in the region. However, the company was not able to quantify the additional time requirements resulting from a potential increase of the isolation distance required for maize seed production. Nevertheless, there is an agreement among all interviewed experts that the fixed costs of certified seed production will increase both for seed breeding and multiplying companies as well as for farmers co-operating with them. These higher fixed costs will result in increasing total production costs and declining profit margins of seed-producing farmers and seed breeders if only part of the additional costs can be transferred to fodder or grain maize producing farmers.

Besides cost effects there are additional impacts of increasing isolation distances in maize seed production. Due to the decreasing area used for maize seed production, the diversity of seed varieties multiplied in a specific region may decline not least in order to limit the additional costs of increasing isolation distances. Another indirect impact of this co-existence measure refers to additional conflicts among seed producing farmers. In principle there are two strategies of seed multiplying companies to re-organize the seed production area in a region:

- Significant reduction of the number of farmers who multiply maize seed and constant cultivation area per farmer
- Constant number of farmers who produce maize seed and a significant decrease of the average seed multiplying area per farmer

The first strategy might result in stronger conflicts among farmers who can participate in the economically interesting production of certified seeds, but it has advantages on the cost side since the additional costs might be lower compared to the second strategy due to the fact that time-consuming interactions (like e. g. advice, control activities) are limited to a lower numbers of farmers. On the other hand, conflicts among farmers will be significantly lower when applying the second strategy since “the burden” is shared by all participating farmers.

An argument which was strongly stressed during the interviews and in the meeting in Paris was a potential re-allocation of certified seed production to regions outside the EU. Due to significant cost effects it was seen as almost impossible to realise higher isolation distances in small-scaled production areas like e. g. many maize seed producing regions in France or Germany. Major factors for the allocation of seed producing areas are on the one hand the production costs in a specific region and on the other hand the security and quality of production. Countries like France or Germany were regarded as being competitive in maize seed production despite relatively high production costs, but this picture might change in future due to significantly increasing costs in case of higher isolation distance requirements. In this case it was seen as “realistic option” that certified maize seed production will be transferred step-by-step to regions outside the EU. In addition to generally lower costs (e. g. for labour, agricultural land) specific advantages were seen in large-scaled fields in interesting regions outside the EU and legal requirements which are comparable to those currently existing in the EU.

3.1.2 Crop production

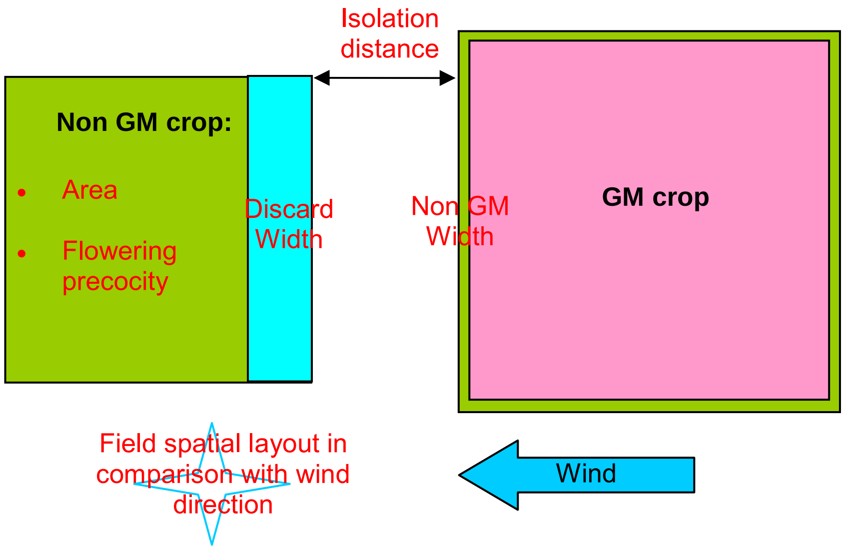
The critical points of maize crop production are a potential admixture of GM and non-GM material during sowing, harvest and transport as well as cross pollination due to pollen flow (table 3.1.1). In order to avoid admixture farmers have to clean the respective machinery (seeding machine, combine, trailer or truck) thereby taking into account whether the farmers own these machines or whether he shares them with other farmers, who could possibly produce GM maize. This kind of machinery sharing is generals organised by special companies. In the latter case opportunity costs for not using the machinery while the cleaning process have to be taken into account when calculating cleaning costs (table 3.1.14). Four different additional measures have been suggested in order to reduce cross pollination (figure 3.1.7). In case of increasing isolation distances between GM and non-GM maize crop fields, the potential costs of this measure can be estimated with the same methodology used for increasing isolation distances in maize seed production (for illustration see figure 3.1.2). In case of time isolation, i. e. differing flowering times between the cultivated maize varieties, the additional costs result from yield losses (table 3.1.14). If a non-GM farmer does not harvest this part of his field which is closely located to neighbouring GM maize field due to a potential cross pollination, the GM farmer has to compensate price differences between GM and non-GM maize to his neighbour, i.e. this measure only causes additional costs in case of higher prices of non-GM maize varieties compared to GM varieties. In case of a non-GM buffer zone around a GM maize field additional costs arise from differences in the gross margins between GM and non-GM maize, additional efforts for land use management as well as extra machinery costs (table 3.1.14).

Table 3.1.14: Details to additional measures in maize crop production

Additional measures	**Details**
Clean the machines a) single seed driller b) harvest - combine c) transport - trailer or truck	There are two possibilities: a) Farmer owns his machineries b) Farmer shares his machineries with neighbours (incl. opportunity costs)
Isolation distance	Plant an alternative crop on the GM field to keep the isolation distance (worst case – only required if there is a lower isolation distance between a GM and a non-GM field).
Time isolation	Difference in flowering time of maize varieties might result in yield losses.
Discard width on the non-GM field - extra harvest	The non-GM farmer does not harvest those part of the field which is closely located to a neighbouring GM maize field. The GM farmer pays the non-GM farmer the price of non-GM maize. Thus the GM farmer only has additional costs if the non-GM price is higher than the GM price.
Non-GM buffer zones around the GM field - extra sowing	GM farmer has to sow a non-GM buffer around his GM field. The additional costs result from differences in the gross margins between GM and non-GM maize, additional efforts for land use management as well as extra machinery costs.

Sources: University of Applied Sciences of Weihenstephan based on working report of INRA 2004

Figure 3.1.7: Illustration of different measures to avoid cross pollination in maize crop production



Sources: University of Applied Sciences of Weihenstephan based on working report of INRA 2004

Potential economic performance of Bt maize

In order to quantify the costs of the suggested co-existence measures in maize crop production, it is necessary to make assumptions concerning the potential economics of GM maize production in France. Since no Bt maize is planted for commercial purposes in France so far, the existing experiences with cultivating Bt maize in other countries (mainly Spain and USA) as well as their economic effects, which are reported in scientific literature, have been collected and used to modify the gross margin of non-GM conventional crop maize in France. Table 4.3.15 gives an overview of the literature findings. According to the reported experiences, it can be assumed that the yields of Bt maize might increase in particular in regions with a high infestation level to the European Corn Borer. Due to the resistance of Bt maize against this insect, insecticide use is often reported to decrease when cultivating Bt maize. In contrast, the seed costs of Bt maize will increase due to the technology fee which farmers have to pay to the seed breeding companies (table 3.1.15). However, there is no final conclusion possible concerning positive or negative changes in gross margins of GM maize in comparison to non-GM varieties.

Table 3.1.15: Change of economic parameters of conventional maize compared to Bt maize

Economic Parameter	Trait[1,2]	Reported changes of parameter in GM-maize	Source	Country
Gross margin	IR	↑	Marra et al. (1998)	USA
	IR	↑ (if infestation is high)	Rice and Pilcher (1998)	USA
	IR	↓	Fernandez-Cornejo and McBride (2002)	USA
	HT	↑	Fernandez-Cornejo and McBride (2002)	USA
	IR	↓ (1998-1999)	Carpenter and Gianessi (2001)	USA
	IR	↑ (1997)	Carpenter and Gianessi (2001)	USA
	IR	↑ (if area with high infestation levels)	Hyde et al. (1999)	?
	IR	↔ (if area with low to medium infestation levels)	Hyde et al. (1999)	?
Yield	IR	1.8 % - 2.5 % ↑	Brookes (2002)	Spain
	IR	5 % ↑	Brookes (2002)	Spain
	IR	↑ (if infestation is high)	Rice and Pilcher (1998)	USA
	IR	↑	Carpenter and Gianessi (2001)	USA
	IR	↑	Hyde et al. (1999)	?
	HT	↓ (1996-2001) ↑ (2002-2003)	Benbrook (2003)	USA
Herbicide	IR	0 % -100 % ↓	Brookes (2002)	Spain
Insecticide	IR+HT	↓ (1996-2001) ↑ (2002-2003)	Benbrook (2003)	USA
Herbicide + Insecticide	IR + HT	↓	Fernandez-Cornejo and McBride (2002)	USA
	IR	↔	Carpenter and Gianessi (2001)	USA
	IR	30 % -35 % ↑	Benbrook (2001)	USA, Canada
Costs of seeds	IR	12 % -19 %↑	Brookes (2002)	Spain
	IR	12 % -19 %↑	Brookes (2002)	Spain
IR: Insect resistance (mostly resistance due to *Bacillus thuringiensis* (Bt) toxin) HT: Herbicide tolerance				

Source: Investigations of University of Applied Sciences of Weihenstephan 2005

Due to the differing results of scientific studies referring to experiences with cultivation of Bt maize and difficulties to transfer e. g. US experiences to Europe, it is currently not possible to define a empirically sound gross margin for a potential growing of Bt maize in France. Therefore two different options are considered in the analysis of economic effects of co-existence measures within this project:

- In the first case it is assumed that the gross margin of Bt maize is equivalent to that of non-GM maize, i.e. it is assumed that a potential increase in yields of Bt maize is balanced by a reduction in the price of Bt maize. Higher seed costs of Bt maize might be balanced by savings in insecticide use.
- In a second optimistic case it is assumed that the gross margin of Bt maize is higher than that of a conventional non-GM maize variety mainly due to yield increases and savings in insecticide use if planting Bt maize[13].

In order to quantify the second optimistic case, the gross margin of conventional non-GM crop maize production in France has been modified based on the reported changes of economic parameters when planting Bt maize. The estimated gross margin of a potential growing of Bt maize in France is shown in table 3.1.16. We assumed 5 % lower prices of Bt maize since it seems most probable that high proportions of this maize might be used in animal feeding – a sector which is very price sensitive. In addition, Bt maize does not offer a specific quality for human or animal feeding which might justify higher prices. Based on literature findings we assumed 10 % higher yields of Bt maize (table 3.1.16) which is at the upper limit of the results reported in literature. The seed costs were estimated to be 30 €/ha higher for Bt maize (an increase of around 18 % compared to the non-GM variety) which are partly compensated by 25 €/ha lower plant protection costs (table 3.1.16). Altogether, these changes result in a potential gross margin of Bt maize of 786 €/ha which is 43 €/ha or 5.8 % higher than the corresponding figure of the non-GM crop maize variety in France. This estimation should be interpreted as an upper limit of potential gross margins which is used in order to show the range of potential cost effects of co-existence measures.

[13] A case study in which Bt maize has lower gross margins than non-GM maize is not considered within the study since EU farmers most probably will not adopt genetically engineered crops without having an economic advantage.

Table 3.1.16: Economics of conventional (non-GM) maize and Bt maize

Parameter		Non-GM maize	Bt maize
Yield	t/ha	9.5	10.5
Price	€/t	100	95
Total income	**€/ha**	**950**	**998**
Costs of seed	€/ha	170	200
Plant protection	€/ha	62	37
Harvest	€/ha	105	105
Irrigation 1000m³	€/ha	220	220
Fertilizer	€/ha	120	120
Hail insurance	€/ha	10	10
Variable costs	**€/ha**	**687**	**692**
Gross margin I	**€/ha**	**263**	**306**
Compensation payments	€/ha	480	480
Gross margin II	**€/ha**	**743**	**786**
Differences in economic parameters between conventional and Bt maize			
Difference in prices	€/t	-5 €/t	
Higher yields	%	+10 %	
Higher seed costs due to technology fee	%	+18 %	
Savings in plant protection due to insect resistance of Bt maize	€/ha	- 25 €/ha	
Economic benefit of Bt-maize	**€/ha**	**+ 43 €/ha**	

Sources: Teyssier 2004 and estimations of University of Applied Sciences of Weihenstephan 2005

Costs of singular measures

The costs of cleaning machinery in maize crop production are shown in table 3.1.17. Due to opportunity costs of renting machinery, the cleaning costs of shared machinery by far outreach those of own equipment of the farm (table 3.1.17).[14]

[14] Opportunity costs for the rented machinery occur due to the fact that farmers have to pay a renting fee for the machinery which is higher in case the machinery has to be cleaned after e. g. seeding or harvesting.

Table 3.1.17: Costs of cleaning machinery in maize crop production

Measures crop production	Own machinery	Shared and rented machinery 1)
	€ / cleaning	
Clean single seed drilling machine	7.61	38.38
Clean combine	3.81	56.84
Clean trailer	0.63	1.48
1) Renting fees for collectively used machinery were used for calculating the costs of shared machinery.		

Source: Calculations of University of Applied Sciences of Weihenstephan 2005

The approach of analysing costs of increasing isolation distances in maize crop production is illustrated in figure 3.1.8. In accordance to the simulations carried out by INRA it is assumed that a squared 15 ha GM maize crop field is in the neighbourhood of a 2 ha non-GM field. In case the GM farmer has to increase the isolation distance between GM and non-GM maize plots in order to meet a defined threshold of GM adventitious presence, it is assumed that the GM farmer reduces part of the area originally cultivated with GM maize and plant an alternative crop instead of maize. According to table 3.1.2 wheat can be regarded as the most economic alternative crop to maize with a gross margin of 769 €/ha compared to a gross margin of 743 €/ha for non-GM crop maize[15]. The costs of increasing isolation distances between GM and non-GM maize fields depends on the estimated gross margins of planting of Bt maize in France. If we consider the first case (i.e. the gross margin of Bt maize is equivalent to the gross margin of the non-GM variety) the GM farmer, who has to cultivate wheat instead of Bt maize on the GM field in order to meet an increased isolation distance, has no additional costs for this measure due to the higher gross margin of wheat compared to the GM maize.

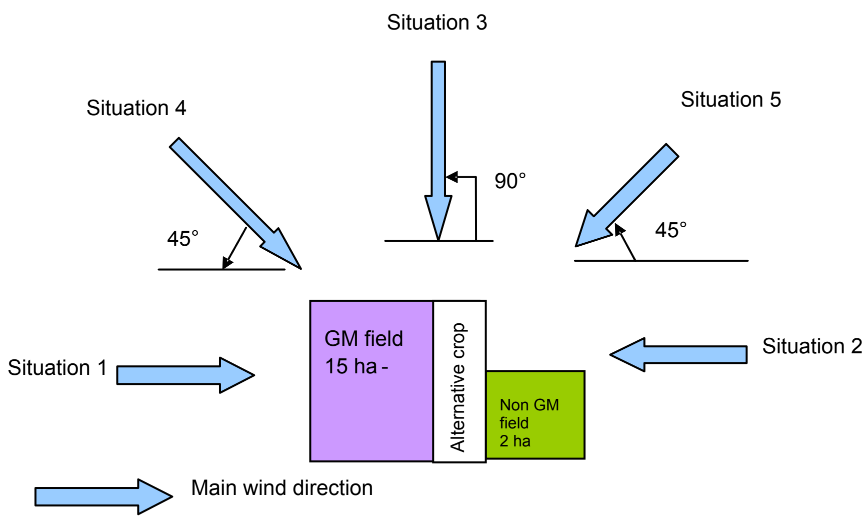
However, if we take into account the second (optimistic) scenario that planting of Bt maize is more economic than cultivating a non-GM maize variety in France, increasing of isolation distances between GM and non-GM crop maize fields causes opportunity costs which are quantified in table 3.1.18[16]. In case of a

[15] According to expert opinions cultivating rapeseed (which has the highest gross margin in accordance with table 3.1.2.) cannot be regarded as an realistic option in the region under investigation due to agronomic reasons.

[16] The costs of respecting isolation distances only occur in those cases that farmers may not able to cultivate GM crops (due to respecting a certain isolation distance). For fields which are already located outside the isolation distance area, there are no additional costs due to this measure.

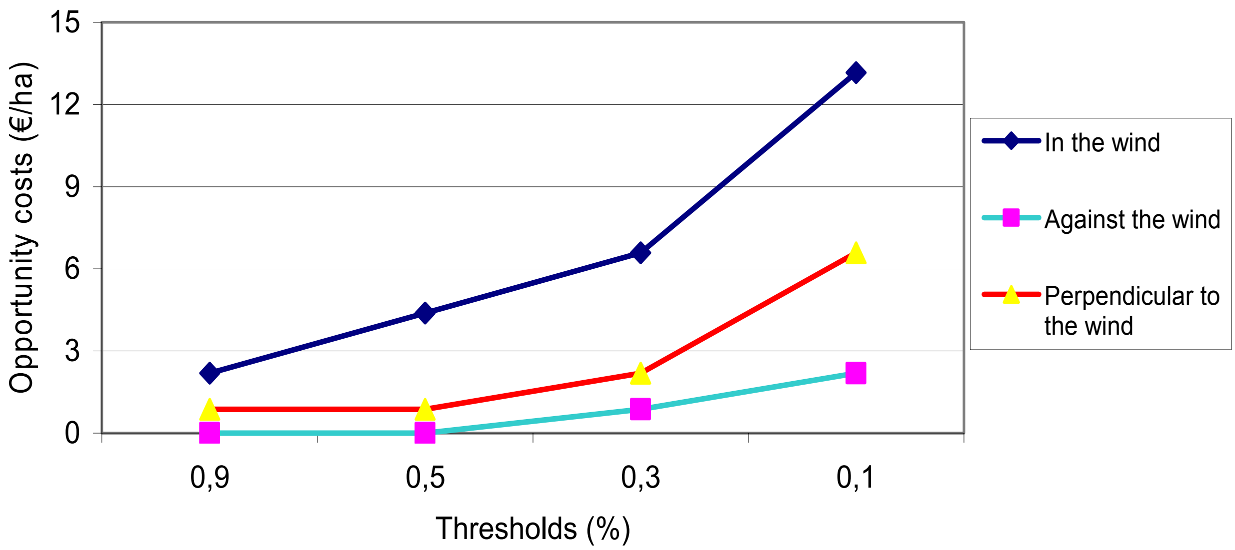
squared 15 ha GM maize field and an isolation distance of 50 m, the isolation area amounts to 1.94 ha, on which wheat (with a gross margin of 769 €/ha is planted instead of Bt maize (with a gross margin of 786 €/ha). This measure results in opportunity costs of 32.92 €/15 ha, what equals to opportunity costs of 2.19 €/ha (table 3.1.18). These opportunity costs are highly influenced by the requested threshold level and the wind situation as shown in figure 3.1.9 Independently from the threshold of GM adventitious presence, the highest opportunity costs of increasing isolation distances are found “in the wind”-situation, followed by the situation “perpendicular to the wind” while the opportunity costs only rise marginally in the “against the wind”-situation. Furthermore, a sharp increase in opportunity costs of increasing isolation distances can be observed when changing from the 0.3 % to the 0.1 % threshold (figure 3.1.9). If we consider the current threshold of 0.9 % adventitious presence with GM material, only moderate opportunity costs of 2.19 €/ha have to be calculated for increasing isolation distances in the “in the wind” situation which equals to 0.3 % of the gross margin of crop maize production in France. These costs rise up to 1.7 % of the gross margin in case of a threshold of 0.1 % (table 3.1.18). If the main wind direction is changed in the landscape only very low opportunity costs of a maximum of 0.1 % of the gross margin have to be calculated for increasing isolation distances between GM and non-GM crop maize fields as long as thresholds of a minimum of 0.5 % have to be met (table 3.1.18).

Figure 3.1.8: Illustration of increased isolation distances in maize crop production depending on the wind situation



Sources: University of Applied Sciences of Weihenstephan based on working report of INRA 2004

Figure 3.1.9: Opportunity costs of changing isolation distances in maize crop production depending on differing thresholds and wind situations (squared GM field of 15 ha, non-GM field of 2 ha)



Sources: Simulations of INRA and calculations of University of Applied Sciences of Weihenstephan 2004

Table 3.1.18: Opportunity costs of increasing isolation distances between GM and non-GM maize crop varieties depending on the wind situation[1)]

Wind situation	In the wind	Against the wind	Perpendicular to the wind
Threshold (%)	**Isolation distance (m)**		
0.9	50	0	20
0.5	100	0	20
0.3	150	20	50
0.1	300	50	150
	Opportunity costs per field (€/15 ha GM field)		
0.9	32.92	0.00	13.17
0.5	65.84	0.00	13.17
0.3	98.76	13.17	32.92
0.1	197.52	32.92	98.76
	Opportunity costs per hectare (€/ha GM field)		
0.9	2.19	0.00	0.88
0.5	4.39	0.00	0.88
0.3	6.58	0.88	2.19
0.1	13.17	2.19	6.58
	Opportunity costs in % of gross margin		
0.9	0.3	0.0	0.1
0.5	0.6	0.0	0.1
0.3	0.8	0.1	0.3
0.1	1.7	0.3	0.8
1) Alternative crop: wheat Gross margin of Bt maize 786 €/ha compared to gross margin of 743 €/ha for non-GM variety.			

Sources: Simulations of INRA and calculations of University of Applied Sciences of Weihenstephan 2005

The farmers' income losses of changing flowering time of cultivated maize varieties are shown in table 3.1.19. In case flowering time of the GM variety is changed from very late to late (30°days), an income loss of around 201 €/ha has to be taken into account which equals to 27 % of the gross margin. Income losses of around 6 % of the gross margin occur if the flowering time of the GM variety is changed from late to mid early (table 3.1.19). Due to lack of data concerning the yield decrease when changing the flowering time by 90°days, the income loss of this measure cannot be quantified within this project.

Table 3.1.19: Income losses of changing flowering time in maize crop production

	Change of flowering time of GM maize from ...		
	Very late to late	**Late to mid early**	**Late to very early**
°days	30	60	90
Yield loss (t/ha) 1)	2.08	0.46	n.a.
Yield decrease (%) 2)	13.44	3.43	n.a.
Income loss (€/ha) 3)	201	46	n.a.
Income loss in % of gross margin	27.0 %	6.2 %	n.a.

1) According to Bock et al. 2002, pp.64
2) Assuming a yield of 9.5 t/ha
3) Assuming prices of 100 €/t

Source: Calculations of University of Applied Sciences of Weihenstephan 2005

Another measure which is suggested as outcome of the agronomic analyses in order to meet the 0.9 % threshold of GM adventitious presence are discard width on the part of the non-GM field which are closely located to the neighbouring GM crop maize field. It is assumed that the non-GM farmer does not harvest the crop on the discard width but sells it to the GM farmer who pays the price of non-GM crop maize to the non-GM farmer. On the other hand it is assumed that the GM farmer can sell the harvest of the discard strip to prices of GM maize. Therefore this measure causes additional costs if the price for non-GM maize is higher than those of GM varieties (table 3.1.14). For calculating the additional costs of this measure we assumed a price difference of 5 % between non-GM and GM maize, i.e. a price of 95 €/t is estimated for the GM variety (in accordance to table 3.1.16). Taking into account a yield of 9.5 t/ha for non-GM maize, the costs of a non-GM discard width differ depending on the size of the non-GM field and the width of the discard strip as shown in table 3.1.20. Due to the small price difference between GM and non-GM prices there are only low income losses for farmers due to this measure. They range from around 1.27 €/ha for a 5 ha non-GM field up to 2.85 €/ha for the 1 ha non-GM field in case of separately harvesting a 6 m wide strip (table 3.1.20). These income losses are increased by factor 4 if a 24 m strip is separately harvested but in almost all cases the income losses are below 1.5 % of the current gross margin of maize production in France. However, the farmers' income losses caused by this measure might rise significantly if there are higher price differences between GM and non-GM maize than considered in this study.

Table 3.1.20: Farmers' income losses of a non-GM discard width with separate harvesting of the crop

GM field *)	Non-GM field *)	Income loss per non-GM field (€/field)			Income loss per hectare GM field (€/ha)		
		Width of discard width					
ha	ha	6 m	12 m	24 m	6 m	12 m	24 m
15	1	2.85	5.70	11.40	0.19	0.38	0.76
	2	4.03	8.06	16.12	0.27	0.54	1.07
	3	4.94	9.87	19.75	0.33	0.66	1.32
	4	5.70	11.40	22.80	0.38	0.76	1.52
	5	6.37	12.75	25.49	0.42	0.85	1.70
*) It is assumed that all fields are squared. Gross margin of Bt-maize 786 €/ha, Gross margin of non-GM maize is 743 €/ha.							

Source: Calculations of University of Applied Sciences of Weihenstephan 2005

Finally, a non-GM buffer zone around a GM field is suggested by INRA in order to reduce cross pollination in maize crop production (table 3.1.14). The additional costs of this measure result from potential differences in the gross margin of GM and non-GM maize, additional labour requirements for land use management as well as extra machinery costs due to double ways. The additional costs of non-GM buffer zones are quantified in table 3.1.21 for the different situations considered in the project. There are substantial differences in the per-hectare costs of non-GM buffer zones mainly depending on the potential difference in the economic performance of GM maize compared to non-GM maize while the other cost positions do not differ significantly between the simulated cases. If we assume a 10 % GM adoption rate per-hectare, costs of non-GM buffer zones range between 35 €/ha and 78 €/ha. They are reduced to a range of around 18 €/ha to 60 €/ha if a 50 % GM adoption rate is considered in the region (table 3.1.21). The total additional costs of a non-GM buffer zone are quantified for a 15 ha GM field - which is the standard GM field size in the simulations of INRA – taking into account an economic advantage of GM maize. Additional costs of 5.46 €/ha have to be calculated for a 9 m wide buffer zone which equal to 0.7 % of the current gross margin of maize crop production in France. In case of doubling the width of the non-GM buffer zone the additional costs rise almost proportionally resulting in costs of 1.4 % for a 18 m wide non-GM buffer zone (table 3.1.22).

Table 3.1.21: Costs of non-GM buffer zones in maize crop production (€/ha)

Cost positions		Gross margin GM maize > gross margin non-GM maize		Gross margin GM maize = gross margin non-GM maize	
		Dispersed fields 10% GM adoption	**Clustered fields 50 % GM adoption**	**Dispersed fields 10% GM adoption**	**Clustered fields 50 % GM adoption**
Difference in gross margin	€/ha	43		0	
Additional labour for land use management	€/ha	7.61	3.81	7.61	3.81
Extra machinery costs due to double ways (e. g. extra fuel, extra labour costs)	€/ha	27.46	13.73	27.46	13.73
Total costs	**€/ha**	**78.07**	**60.54**	**35.07**	**17.54**

Source: Calculations of University of Applied Sciences of Weihenstephan 2005

Table 3.1.22: Costs of non-GM buffer zones in maize crop production for clustered GM fields and differing width of buffer zones (50 % GM adoption in region)

Cost positions for 15 ha squared GM field	Gross margin GM maize > gross margin non-GM maize					
	Costs per field (€/field)			**Costs per hectare GM field (€/ha)**		
Width of non-GM buffer zone	**9 m**	**12 m**	**18 m**	**9 m**	**12 m**	**18 m**
Difference in gross margin	58.06	76.80	113.36	0.35	5.12	7.56
Additional labour for land use management	5.18	6.85	10.12	1.25	0.46	0.67
Extra machinery costs due to double ways (e. g. extra fuel, extra labour costs)	18.70	24.73	36.51	2.43	1.65	2.43
Total costs	**81.94**	**108.39**	**159.98**	**5.46**	**7.23**	**10.67**

Source: Calculations of University of Applied Sciences of Weihenstephan 2005

In order to show the effect of the different assumptions of the potential economic performance of Bt maize cultivation in France, a sensitivity analysis is carried out estimating the level of additional costs of non-GM buffer zones in maize crop production in France thereby taking into account the influence of factors such as the size of the GM field and the width of the non-GM buffer zone (table 3.1.23). In all cases simulated in the sensitivity analysis, a strong decrease in the additional costs of non-GM buffer zones can be observed with increasing sizes of the GM field, in particular if a higher gross margin of the GM maize (786 €/ha) is assumed compared to the non-GM variety (743 €/ha) (figure 3.1.10). If we regard a 15 ha GM field – which is the standard field size in the simulations of

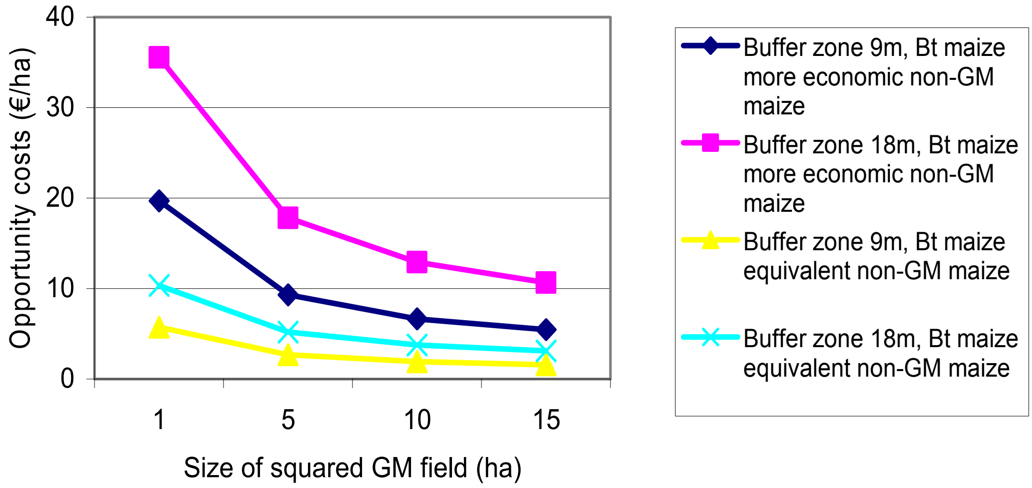
INRA for cultivating GM maize in France – additional costs of a maximum of around 10 €/ha (for a 18 m wide buffer zone) have to be calculated for this measure (figure 3.1.10) which equal to 1.4 % of the current gross margin of crop maize production in this country. These costs can rise up to more than 35 €/ha if a non-GM buffer zone of 18 m has to be realized in a 1 ha GM field (table 3.1.23) and economic advantages of Bt maize in comparison to non-GM maize. If the gross margin of Bt maize is equivalent to the one of non-GM maize, the additional costs of a non-GM buffer zone are substantially lower and range for the 18 m wide buffer zone from 3.11 €/ha for the 15 ha GM field (which equal to 0.4 % of the gross margin of crop maize) to 10.36 €/ha in case of a 1 ha GM field (or 1.4 % of the gross margin) (table 4.3.23). In case of a 9 m wide buffer zone the respective additional costs account for around half of those of buffer zones of 18 m.

Table 3.1.23: Sensitivity analysis of costs of buffer zones in maize crop production

Squared GM field		**Area non-GM buffer zone (ha)**		**Gross margin GM maize higher than non-GM maize**				**Gross margin GM maize equivalent to non-GM maize**			
Size	**Width of field**			**Costs in €/field**		**Costs in €/ha**		**Costs in €/field**		**Costs in €/ha**	
		Width of non-GM buffer zone (m)									
ha	**m**	**9**	**18**	**9**	**18**	**9**	**18**	**9**	**18**	**9**	**18**
1	100.0	0.33	0.59	19.71	35.52	19.71	35.52	5.75	10.36	5.75	10.36
5	223.6	0.77	1.48	46.48	89.07	9.30	17.81	13.55	25.97	2.71	5.19
10	316.2	1.11	2.15	66.55	129.2	6.65	12.92	19.40	37.66	1.94	3.77
15	387.3	1.36	2.66	81.94	160.0	5.46	10.67	23.89	46.64	1.59	3.11

Source: University of Applied Sciences of Weihenstephan 2005

Figure 3.1.10: Costs of non-GM buffer zones in maize crop production in France (assuming a squared GM field)



Source: University of Applied Sciences of Weihenstephan 2005

Currently it is not possible to give any sound results concerning the overall economic net effects of cultivating Bt maize in France. This is basically due to the missing practival experience with planting this crop in the case study region. Therefore additional research is required in order to quantify the net economic benefits which farmers might have if they cultivate Bt maize and have to implement additional co-existence measures.

Co-existence costs of planting GM crop maize in landscape

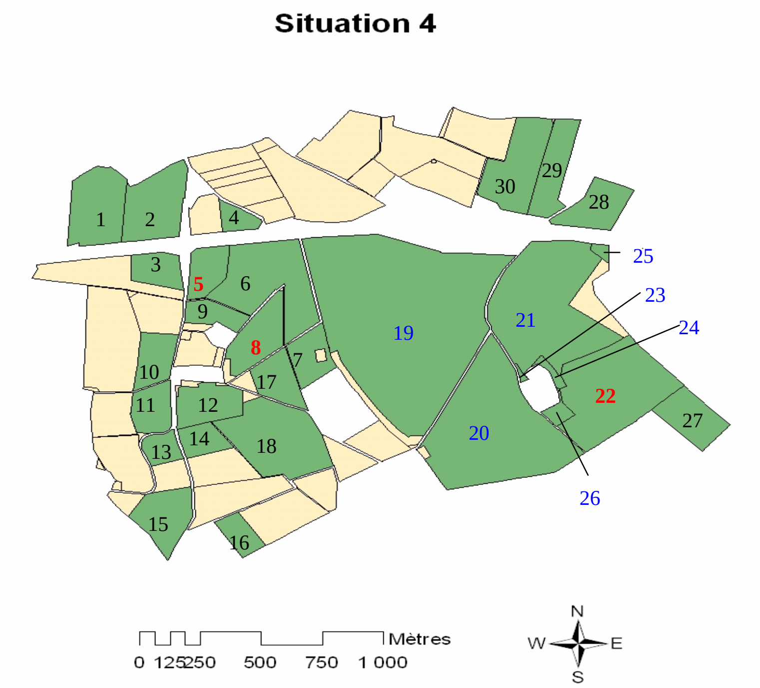
In order to identify the effects of different co-existence measures in a landscape, INRA simulated several scenarios of GM adoption in Poitou-Charantes. During the project it has been agreed that cost effects of buffer zones should be calculated for a farm in an existing landscape situation since buffer zones seem to be a cost-effective measure in order to meet the required threshold of 0.9 % in maize crop production. In this context the effects of non-GM buffer zones on the level of GM adventitious presence in neighbouring fields have been simulated for differing locations of GM maize fields:

- The GM fields are scattered among the non-GM fields (“dispersed fields”)
- The GM fields are concentrated in one part of the farm (“clustered fields”)

In addition, a specific focus has been put on the fact that large and small fields are planted with GM maize in order to show the effect of differing field sizes. An additional element was the main wind direction which has a strong impact on the level of GM adventitious presence in neighbouring fields. This simulated landscape situation is illustrated in figure 3.1.11 and refers to a so-called situation "situation 4" of the simulations carried out by INRA. In case of an adoption rate of 10 % GM crop maize in the region, it is estimated that “dispersed” fields are cultivated with Bt maize, namely the fields with the numbers 5, 8 and 22. If 50 % of the maize production area of the region is cultivated with GM maize, a “cluster” of fields consisting of fields with the numbers 19, 20, 21, 22, 23,24, 25 and 26 is planted with this variety (figure 3.1.11). When calculating the cost effects of buffer zones the two differing situations concerning the potential economic performance of planting Bt maize in France have to be taken into account (table 3.1.16). Thus the respective additional costs have been estimated assuming firstly that the gross margin of GM maize is equivalent to the one of non-GM maize, and secondly that the gross margin of GM maize is 43 €/ha higher than the gross margin of non-GM crop maize (table 3.1.16). Another differentiation has to be made concerning the location of the buffer zones in case of a 50 % adoption rate of GM maize in Poitou-Charantes: In a first alternative the additional costs are estimated under the assumption that the buffer zone is located around the cluster of the eight GM maize fields[17]. In a second alternative it is assumed that a buffer zone is located around each of the eight fields which are cultivated with GM maize.

[17] Since all considered fields of the GM maize cluster belong to one farm in the simulated "situation 4", there are no difficulties in distributing the additional costs of the non-GM buffer. In case the respective fields belong to different farms, the additional costs of the non-GM buffer zone around a "GM cluster" might be distributed among the farmers according to the proportion of fields belonging to the single farms. However, other arrangements between the farmers can be foreseen in such cases as well.

Figure 3.1.11: Cultivation of GM and non-GM crop maize in landscape in France



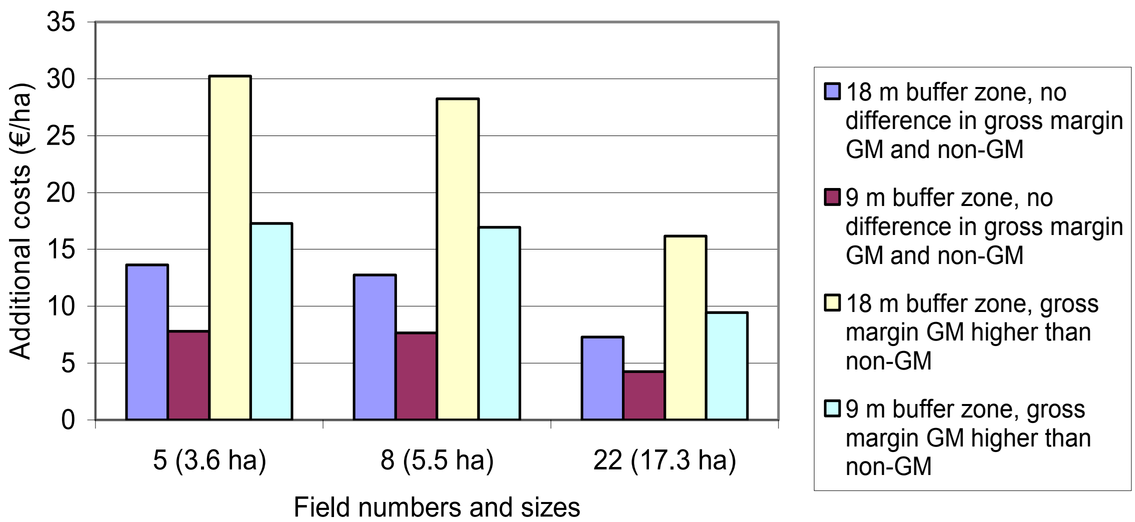
Source: Working report of INRA 2004

The additional costs of buffer zones for differing adoption rates of GM maize in the simulated "situation 4" in Poitou-Charantes are shown in the tables 3.1.24 (under the assumption that there are no differences in the gross margins between GM and non-GM maize) and 3.1.25 (assuming that the gross margin of GM maize is 43 €/ha higher than the one of non-GM maize). For calculating the costs of this measure the surface area of the non-GM buffer zone has been quantified for each GM maize field using GIS (= Geographical Information System) instruments. The same applies for the "cluster" of GM fields in case the non-GM buffer zone is located around the neighbouring fields with the numbers 19 to 26. Afterwards the differences in the gross margins of GM maize and non-GM maize, as well as the additional labour and machinery costs (table 3.1.21) are used to calculate the additional costs of this measure which are referred to the real landscape patterns. It can be observed that there a big variations in the additional costs of non-GM buffer zones depending on the sizes of the GM fields, the width of the buffer zones as well as the underlying assumptions concerning the economic performance of Bt maize in France: In case of a 10 % GM adoption rate in the region, the per-hectare costs of non-GM buffer zones range between around 4 €/ha and 17 €/ha for a 9 m wide buffer zone or around 7 €/ha and 30 €/ha in case of a 18 m wide buffer zone respectively (figure 3.1.12). Thus the proportions of additional costs of non-GM buffer zones vary between 0.6 % and

4.1 % of the current gross margin of crop maize production in France. Not surprisingly the costs of 18 m wide non-GM buffer zones are substantially higher than those of buffer zones with only 9 m width. In addition, the per-hectare costs significantly decrease with an increasing field size of the GM plot (figure 3.1.12).

The effects of non-GM buffer zones on the GM adventitious presence level in neighbouring fields are shown in table 3.1.26 for those non-GM fields in which GM adventitious presence levels exceeding the threshold of 0.9 % have been registered in the basic situation. It can be shown that even with a 18 m wide non-GM buffer zone around the large GM field No. 22, it might be difficult to meet the current threshold of 0.9 % in small neighbouring fields (represented by field No. 24 and 26), while there are no difficulties if the non-GM fields have a larger size (table 3.1.26). In this sense the moderate costs of non-GM buffer zones around large GM fields have to be interpreted carefully taking into account the specific situation in the neighbourhood which might require additional measures to meet the current threshold of 0.9 %. This again indicates the high variations in the effects of specific co-existence measures both in agronomic and economic terms.

Figure 3.1.12: Costs of buffer zones in maize crop production in France (10 % GM adoption rate in region)



Source: University of Applied Sciences of Weihenstephan 2005

The same strong variations in the per-hectare costs of non-GM buffer zones can be observed if we assume a 50 % GM adoption rate in crop maize production in Poitou-Charantes and locating of the non-GM buffer zones around each GM field. Due to the high variety in field sizes of the eight considered GM fields (with the field numbers 19 to 26) the additional per-hectare costs vary between around 1.1 €/ha and around 60 €/ha (tables 3.1.24, 3.1.25), representing around 0.1 % or 8.1 % of the current gross margin of crop maize production in France. In particular in very small GM fields with field sizes below 1 ha, substantial additional costs emerge when non-GM buffer zones have to be established. This especially holds true if planting of Bt maize should be more economic than non-GM varieties (table 3.1.25). As shown in table 3.1.27, the current threshold level of 0.9 % can be met in neighbouring non-GM fields in almost all situations simulated by INRA in case a 18 m wide non-GM buffer is established around each of the eight GM fields. This measure causes additional costs ranging from around 7 €/ha to 60 €/ha depending on the field size of the GM field (table 3.1.27). In case a buffer zone of 9 m is established in the eight GM fields, there still might be difficulties to meet the threshold of 0.9 % (in particular in field No. 4) although the additional costs are substantially lower in most of the concerned GM fields (table 3.1.27).

In a final step the additional costs are calculated for a non-GM buffer zone around the cluster of the eight GM field (consisting of fields No. 19 to 26) which represents a 50 % adoption of GM maize in the region. Compared to the additional costs of establishing buffer zones around each GM fields, significant cost reductions can be realized by locating non-GM buffer zones around a cluster of GM fields. This holds true for all field sizes and assumptions concerning the potential economic performance of planting GM maize in France (tables 3.1.24, 3.1.25). If we take the 18 m wide buffer zone which is necessary to meet the threshold of 0.9 % in the neighbouring non-GM fields (table 3.1.28), the additional per-hectare costs of a "clustered" buffer zone range between 1.4 €/ha and 4.8 €/ha (tables 3.1.24, 3.1.25), which equal to 0.2 % up to 0.6 % of the current gross margin of crop maize production in France. Compared with the lowest per-hectare costs of non-GM buffer zones which are established around each of the GM fields, cost savings of around 29 % can be observed with "clustered" non-GM buffer zones. These cost savings of "clustered" buffer zones are substantially higher in case of smaller GM fields (tables 3.1.24, 3.1.25, 3.1.28).

Taking the effects of the landscape simulations on GM adventitious presence level and additional costs of non-GM buffer zones together, it can be concluded that the adventitious presence due to cross pollination highly depends on the landscape patterns and field sizes both of GM and neighbouring non-GM fields. Thus the additional costs of co-existence measures (in this case non-GM buffer zones) vary substantially according e. g. to the specific characteristics of the measure (e. g. width of the buffer zone), the size of GM and non-GM fields, or estimations concerning the economic performance of GM maize. In this sense the level of additional costs should be cautiously interpreted since they can only be estimated on a case-by-case basis.

Table 3.1.24: Costs of buffer zones in maize crop production in landscape in France (no difference in gross margins of GM and non-GM maize)

Field	Area	Area of non-GM buffer zone (ha)						Costs of buffer zones per field (€/field)						Costs of buffer zones per hectare (€/ha)					
Num-ber	ha	10 % GM maize around each field		50 % GM maize around cluster of fields		50 % GM maize around each field		10 % GM maize around each field		50 % GM maize around cluster of fields		50 % GM maize around each field		10 % GM maize around each field		50 % GM maize around cluster of fields		50 % GM maize around each field	
		9 m	18 m	9 m	18 m	9 m	18 m	9 m	18 m	9 m	18 m	9 m	18 m	9 m	18 m	9 m	18 m	9 m	18 m
1	8.2																		
2	8.1																		
3	3.3																		
4	1.8																		
5	3.6	0.8	1.4					28.06	49.10					7.79	13.64				
6	12.8																		
7	4																		
8	5.5	1.2	2					42.08	70.14					7.65	12.75				
9	2.7																		
10	3.8																		
11	3.7																		
12	5																		
13	2																		
14	2.8																		
15	5.6																		
16	2.4																		
17	4																		
18	12.7																		
19	54.3					3.4	6.1					59.62	106.96					1.10	1.97
20	27					2.6	4.5					45.59	78.91					1.69	2.92
21	23.2					2.5	4.4					43.84	77.15					1.89	3.33
22	17.3	2.1	3.6	5.5	9.9	2.1	3.6	73.65	126.25	96.44	173.60	36.82	63.13	4.26	7.30	0.78	1.40	2.13	3.65
23	0.2					0.2	0.2					3.51	3.51					17.54	17.54
24	0.6					0.5	0.6					8.77	10.52					14.61	17.54
25	0.5					0.3	0.4					5.26	7.01					10.52	14.03
26	1					0.4	0.7					7.01	12.27					7.01	12.27
27	5.2																		
28	5																		
29	5.5																		
30	8.7																		

Sources: University of Applied Sciences of Weihenstephan based on simulations of INRA 2005

Table 3.1.25: Costs of buffer zones in maize crop production in landscape in France (gross margin of GM maize higher than non-GM maize)

Field	Area	Area of non-GM buffer zone (ha)						Costs of buffer zones per field (€/field)						Costs of buffer zones per hectare (€/ha)					
Number	ha	10 % GM maize around each field		50 % GM maize around cluster of fields		50 % GM maize around each field		10 % GM maize around each field		50 % GM maize around cluster of fields		50 % GM maize around each field		10 % GM maize around each field		50 % GM maize around cluster of fields		50 % GM maize around each field	
		9 m	18 m	9 m	18 m	9 m	18 m	9 m	18 m	9 m	18 m	9 m	18 m	9 m	18 m	9 m	18 m	9 m	18 m
1	8.2																		
2	8.1																		
3	3.3																		
4	1.8																		
5	3.6	0.8	1.4					62.16	108.78					17.27	30.22				
6	12.8																		
7	4																		
8	5.5	1.2	2					93.24	155.4					16.95	28.25				
9	2.7																		
10	3.8																		
11	3.7																		
12	5																		
13	2																		
14	2.8																		
15	5.6																		
16	2.4																		
17	4																		
18	12.7																		
19	54.3					3.4	6.1					204.58	367.04					3.77	6.76
20	27					2.6	4.5					156.44	270.77					5.79	10.03
21	23.2					2.5	4.4					150.43	264.75					6.48	11.41
22	17.3	2.1	3.6	5.5	9.9	2.1	3.6	163.17	279.72	330.94	595.68	126.36	216.61	9.43	16.17	2.67	4.80	7.30	12.52
23	0.2					0.2	0.2					12.03	12.03					60.17	60.17
24	0.6					0.5	0.6					30.09	36.10					50.14	60.17
25	0.5					0.3	0.4					18.05	24.07					36.10	48.14
26	1					0.4	0.7					24.07	42.12					24.07	42.12
27	5.2																		
28	5																		
29	5.5																		
30	8.7																		

Sources: University of Applied Sciences of Weihenstephan based on simulations of INRA 2005

Table 3.1.26: Costs of buffer zones in maize crop production in landscape in France (10 % GM maize in region, dispersed fields, “in the wind”-situation)

GM fields		**Neighbouring non-GM fields**		**Threshold (%)**			**No difference in gross margins of GM and non-GM maize**				**Gross margin of GM maize higher than non-GM maize**			
							Costs per field (€/GM field)		**Costs per ha (€/ha)**		**Costs per field (€/GM field)**		**Costs per ha (€/ha)**	
Number	**ha**	**Number**	**ha**	**0 m**	**9 m**	**18 m**	**9 m**	**18 m**	**9 m**	**18 m**	**9 m**	**18 m**	**9 m**	**18 m**
5	3.6	6	12.8	0.43-1.081	0.188-0.575	0.117-0.384	28.06	49.10	7.79	13.64	62.16	108.78	17.27	30.22
8	5.5	No neighbouring fields with thresholds higher than 0.9 %					42.08	70.14	7.65	12.75	93.24	155.4	16.95	28.25
22	17	24	0.6	0.9-3.01	0.247-1.625	0.159-1.223	73.65	126.25	4.26	7.30	163.17	279.72	9.43	16.17
		26	1	1.339-3.763	0.402-1.974	0.248-1.467								
		27	5.2	0.245-1.125	0.087-0.671	0.063-0.524								

Sources: University of Applied Sciences of Weihenstephan based on simulations of INRA 2005

Table 3.1.27: Costs of buffer zones in maize crop production in landscape in France (50 % GM maize in region, clustered fields, “in the wind”-situation, buffer zone around each field)

GM fields		**Neighbouring non-GM fields**		**Threshold (%)**			**No difference in gross margins of GM and non-GM maize**				**Gross margin of GM maize higher than non-GM maize**			
							Costs per field (€/GM field)		**Costs per ha (€/ha)**		**Costs per field (€/GM field)**		**Costs per ha (€/ha)**	
Number	**ha**	**Number**	**ha**	**0 m**	**9 m**	**18 m**	**9 m**	**18 m**	**9 m**	**18 m**	**9 m**	**18 m**	**9 m**	**18 m**
19	54	27	5.2	0.26-1.257	0.109-0.8	0.073-0.63	59.62	106.96	1.10	1.97	204.58	367.04	3.77	6.76
20	27	7	4	0.316-1.608	0.156-1.131	0.123-0.953	45.59	78.91	1.69	2.92	156.44	270.77	5.79	10.03
21	23						43.84	77.15	1.89	3.33	150.43	264.75	6.48	11.41
22	17						36.82	63.13	2.13	3.65	126.36	216.61	7.30	12.52
23	0.2						3.51	3.51	17.54	17.54	12.03	12.03	60.17	60.17
24	0.6						8.77	10.52	14.61	17.54	30.09	36.10	50.14	60.17
25	0.5						5.26	7.01	10.52	14.03	18.05	24.07	36.10	48.14
26	1						7.01	12.27	7.01	12.27	24.07	42.12	24.07	42.12

Sources: University of Applied Sciences of Weihenstephan based on simulations of INRA 2005

Table 3.1.28: Costs of buffer zones in maize crop production in landscape in France (50 % GM maize in region, clustered fields, “in the wind”-situation, buffer zone around the field cluster)

GM fields		Neighbouring non-GM fields		Threshold (%)			No difference in gross margins of GM and non-GM maize				Gross margin of GM maize higher than non-GM maize			
							Costs per field (€/GM field)		Costs per ha (€/ha)		Costs per field (€/GM field)		Costs per ha (€/ha)	
Number	**ha**	**Number**	**ha**	**0 m**	**9 m**	**18 m**	**9 m**	**18 m**	**9 m**	**18 m**	**9 m**	**18 m**	**9 m**	**18 m**
19	54	27	5.2	0.26-1.257	0.109-0.8	0.073-0.63	96.44	173.59	0.78	1.4	330.93	595.68	2.67	4.80
20	27	7	4	0.316-1.608	0.156-1.131	0.123-0.953								
21	23													
22	17													
23	0.2													
24	0.6													
25	0.5													
26	1													

Sources: University of Applied Sciences of Weihenstephan based on simulations of INRA 2005

3.2 Economic impact of co-existence measures in sugar beet

3.2.1 Seed production

In France there are two different methods to produce sugar beet seeds. In the most commonly used method seedlings are sown on a nursery field and later planted on a final production field for producing the seeds (so-called seedling method). This method is used by around 80 % of the sugar beet seed producers in France, mainly in the south western regions of France. In the second method ("In place sowing") the seed-producing plants are directly sown in the final production field, i.e. there is no planting of seedlings .. Due to the wider distribution, the seedling method is used for calculating economic impacts of co-existence measures in sugar beet seed production.

Sugar beet seeds are produced in a biannual development circle and on two different fields in France. In August/September of the first year the base seeds are sown on the nursery field in order to produce seedlings which are planted in the final production field in the second year. The seeds of these seedlings are harvested as certified seeds. Generally the production of sugar beet hybrid seeds takes a lot of efforts and includes intensive control activities during production with respect to relatives of *Beta vulgaris* ssp. *vulgaris* L. Therefore it might be possible that potential sources of GM adventitious presence (e. g. fodder beet and Swiss chard) are destroyed in a distance of one kilometre around a sugar beet hybrid seed field. Nevertheless, a variety of critical points has been identified in the agronomic analyses related to sugar beet seed production both on the nursery plot and on the final seed production field (for details see Messéan, A., F. Angevin, et al. (2006)). Several of the suggested measures either do not cause additional costs for GM farmers or they are difficult to estimate due to lack of data. In table 4.4.1 those critical points and additional measures are listed which are relevant for GM farmers and can be quantitatively calculated in the context of the project. This table also shows relevant thresholds of GM adventitious presence which can be achieved by the suggested additional measures.

Table 3.2.1: Critical points and additional measures in sugar beet seed production in France

Step of the production process		Current practice / additional measure	Threshold of GM adventitious presence (%)
1	Nursery plot management	*Field pattern precisely defined on a map* Map of the region with localisation of fields with GM seed production	0.1; 0.3
2	Sowing	*Careful cleaning of the drill between two plots and at the end of the nursery* Careful control of drill cleanness: 0.5 hours/ha	0.1
3	Seedling harvest	*Preparation and conditioning of seedling on the nursery plot* Careful supervision and quality assurance: Costs not possible to estimate in this study	0.1; 0.3
		Plot monitoring the subsequent years Supervision of the potential re-growths for several years and additionally destruction in case of occurrence of weed beets We consider the global costs as identical to 2 hours/ha whatever the occurrence or control techniques	0.1-0.5
4	Destruction of excess seedlings	*Spray of total herbicide after lifting* Change to selective herbicide instead of total herbicide	0.1-0.5
5	Seed production	*Field identification to ensure accurate delay between two seed crops* Map of the region with localisation of fields with GM seed production	0.1;0.3
6	Isolation distance	*Between pollinators of the same ploidy: 300 m* 1,000 m isolation distance if the gene is born by the pollinator 0.5 hours/ha	0.1-0.5
		Between pollinators of the different ploidy: 600 m Map of the region with localisation of fields with GM seed production: 0.5 hours/ha	0.1;0.3
		Between sugar beet seed production and other types of beets:1,000 m Common management of production area by seed companies	0.1;0.3
		Seed production area global management by mechanical or chemical destruction Increase the area where it must be done: 5 hours/year for supervision and hand pulling	0.5
		Seed production area global management by mechanical or chemical destruction Increase the area where it must be done: 10 hours/year for supervision and hand pulling	0.3
		Seed production area global management by mechanical or chemical destruction Increase the area where it must be done: 25 hours/year for supervision and hand pulling	0.1
7	Planting	No additional time required. No costs of additional measures calculated in this study.	0.1-0.5
8	Field Management	No additional time required. No costs of additional measures calculated in this study.	0.3

Step of the production process		*Current practice /* additional measure	Threshold of GM adventitious presence (%)
9	Pollinator Destruction	*Ploughing to speed up emergence of re-growth (e.g. false sowing)* Very careful false sowing (period of intervention: just after harvest)	0.3
		One false sowing One additional false sowing with use of rotary harrowing or Danish cultivator: 1 additional soil tillage	0.1
		Conventional Machine cleaning in the field In-field cleaning with water of mower machine used for pollinator destruction: 0.5 hours/ha	0.1;0.3
10	Harvest	*Combines cleaned in the plot* Combine must be cleaned more carefully with water before leaving each field (transportation loss) and on the farm (admixture between fields): additional labour time	0.1-0.5
11	Transport and storage	No costs of additional measures calculated in this study.	
12	Post Harvest	*Control of re-growth the following year* Control of re-growth the 3 following years (1 hours/ha and year including handpulling)	0.3
		Control of re-growth the following year Control of re-growth the 3 following years (3 hours/ha and year including hand pulling)	0.1
13	Seed cleaning and processing	No costs of additional measures calculated in this study.	
14	Distribution	No costs of additional measures calculated in this study.	
1) These numbers represent the number of the production process (in accordance to the production scheme of INRA)			

Source: Working report of INRA 2004

In case new isolation distances have to be kept by farmers producing GM sugar beet seeds, it is necessary to modify the existing organisational system for spreading of the sugar beet seed producing fields in a region as well as the control of the required isolation distances. It is estimated that the re-organisation of the existing system requires 0.5 hours/ha which equals to 3.81 €/ha (taking into account the minimum wages of 7.61 €/h for 2004 in France). These additional costs for re-organising the existing system occur in each of the analysed threshold levels.

In addition to modifying the existing organisational system of sugar beet seed production, several measures are suggested in order to meet a specific threshold, which are already foreseen in the rules for production of certified sugar beet seeds in France. However, it might be necessary to carry out some of the activities more carefully or slightly modify the procedures in order to avoid any adventitious presence of GM material. One example is cleaning of the drilling machine between two plots and at the end of the nursery as well as a very careful control of the drill cleanness (see measure 2.3 in table 3.2.5) which is estimated to require additional 0.5 hours/ha labour time. It is estimated that 3.5 hours/ha (including transport of the water tank to the field) are required for cleaning of the combine after each plot. Including opportunity costs for renting the combine (which are due to the leasing fees for the time requirements for cleaning instead of using the combine for harvesting) results in costs of around 123 €/ha for this measure.

Another example of activities, which have to be carried out more carefully, is the control of seedling plots in subsequent years: In order to achieve a threshold of 0.5 % or below, it is foreseen to very carefully monitor a potential re-growth of seedlings in subsequent years which is estimated to require 2 hours/ha additional labour time including a potential destruction of the re-grown seedlings. The direct costs of different destruction techniques of the re-grown seedlings are shown in table 3.2.2. Currently the remaining parts of excess seedlings are destroyed using a total herbicide in order to minimise risk of their regrowth. Due to the assumed herbicide tolerance of a GM sugar beet seed variety (i. e. resistance against the herbicide Round up), this total herbicide cannot be used for destruction of the excess seedlings anymore, so that another option for this task has to be taken into account when calculating additional costs of co-existence measures. According to price information for herbicides provided by agricultural co-operatives, the most cost effective way to destroy the excess seedlings is the use of a selective herbicide which is estimated to cost 12.83 €/ha more than the current practice (table 3.2.2). The option to use a different type of total herbicide which would be less costly than applying the selective herbicide is not taken into account due to ecological disadvantages of this herbicide.

Table 3.2.2: Costs of destruction techniques of re-grown seedlings

Costs of destruction techniques of excess seedlings	Current costs	Additional costs
	€/ha	
Current practice: Total herbicide (Round up Turbo)	31.29	
Selective herbicide (Starane XL)	44.12	12.83
Soil tillage	70.31	39.02
Hand pulling	15.22	0.00
Another total herbicide (U46 M-Fluid)	19.69	0.00

Source: University of Applied Sciences of Weihenstephan 2004 (based on price data of agricultural co-operatives)

In the following the costs of combinations of additional measures are calculated for different threshold levels of GM adventitious presence in sugar beet seed production in France. The co-existence costs for a threshold of 0.5 % are shown in table 3.2.3. In order to reach this threshold additional costs occur for modifying the organisational system of sugar beet seed production (3.81 €/ha each on the nursery and production field), supervising a potential re-growth of seedlings (15.22 €/ha), spraying a selective herbicide to destroy excess seedlings (12.83 €/ha), supervising of and hand pulling on an increased production area (38.05 €/ha) and cleaning of the combine with water before leaving each plot (75.64 €/ha) (table 3.2.3). In total the additional costs of the suggested co-existence measures account to around 197 €/ha (table 3.2.6) which have to be carried out and paid by the GM farmer.

Table 3.2.3: Costs of additional measures in sugar beet seed production for threshold of 0.5 % GM adventitious presence

No.	Production step	*Current practices /* additional measure	Time	Costs
			hours/ha	€/ha
1	Isolation distance	*Between pollinators of the same ploidy: 300m/* 1,000 m isolation distance if the gene is born by the pollinator: 0.5 hours/ha	0.5	3.81
3	Seedling harvest	*Plot monitoring the subsequent years/* Supervision of the potential re-growths for several years and additionally destruction in case of occurrence of weed beets	2	15.22
4	Destruction of excess seedlings	*Spray of total herbicide after lifting/* Change to selective herbicide instead of total herbicide	-	12.83

No.	Production step	*Current practices /* additional measure	Time	Costs
			hours/ha	€/ha
6	Isolation distance	*Between pollinators of the same ploidy: 300m/* 1,000 m isolation distance if the gene is born by the pollinator: 0.5 hours/ha	0.5	3.81
		Seed production area global management by mechanical or chemical destruction/ Increase the area where it must be done: 5 hours/year for supervision and hand pulling	5	38.05
10	Harvest	*Combines cleaned in the plot/* Combine must be cleaned more carefully with water before leaving each field (transportation loss) and on the farm (admixture between fields): additional labour time	3.5	123.24
1) These numbers represent the number of the production process (in accordance to the production scheme of INRA)				

Sources: Calculations of University of Applied Sciences of Weihenstephan 2004 based on simulations of INRA 2004

The co-existence costs for a threshold of 0.3 % in sugar beet seed production are shown in table 3.2.4. In order to reach this threshold additional costs occur for modifying the organisational system of sugar beet seed production (3.81 €/ha each on the nursery and production field), supervising a potential re-growth of seedlings (15.22 €/ha), spraying a selective herbicide to destroy excess seedlings (12.83 €/ha), supervising of and hand pulling on an increased production area (76.1 €/ha), very carefully false sowing (7.61 €/ha), in-field cleaning with water of mower machine (3.81 €/ha), cleaning of the combine with water before leaving each plot (75.64 €/ha) and controlling the re-growth of sugar beet plants in the following three years (7.61 €/ha) (table 3.2.4). In total the additional costs of the suggested co-existence measures account to around 246 €/ha (table 3.2.6).

Table 3.2.4: Costs of additional measures in sugar beet seed production for threshold of 0.3 % GM adventitious presence

No.	Production step	*Current practices / additional measure*	Time	Costs
			hours/ha	€/ha
1.	Nursery plot management	*Field pattern precisely defined on a map/* Map of the region with localisation of fields with GM seed production: 0.5 hours/ha	0.5	3.81
3	Seedling harvest	*Preparation and conditioning of seedling on the nursery plot/* Careful supervision and quality assurance: Costs not possible to estimate in this study	Costs not possible to estimate in this study	
		Plot monitoring the subsequent years/ Supervision of the potential re-growths for several years and additionally destruction in case of occurrences of weed beets	2	15.22
4	Destruction of excess seedlings	*Spray of total herbicide after lifting/* Change to selective herbicide instead of total herbicide	-	12.83
6	Isolation distance	*Between pollinators of the same ploidy: 300 m/* 1,000 m isolation distance if the gene is born by the pollinator: 0.5 hours/ha	0.5	3.81
		Between pollinators of the different ploidy: 600 m/ Map of the region with localisation of fields with GM seed production: 0.5 hours/ha		
		Between sugar beet seed production and other types of beets:1000 m/ Common management of production area by seed companies: 0.5 hours/ha		
		Seed production area global management by mechanical or chemical destruction/ Increase the area where it must be done: 10 hours/year for supervision and hand pulling	10	76.1
9	Pollinator destruction	*Ploughing to speed up emergence of re-growth (e.g. false sowing)/* Very careful false sowing (period of intervention: just after harvest)	1	7.61
		Conventional machine cleaning in the field/ In-field cleaning with water of mower machine used for pollinator destruction: 0.5 hours/ha	0.5	3.81
10	Harvest	*Combines cleaned in the plot/* Combine must be cleaned more carefully with water before leaving each field (transportation loss) and on the farm (admixture between fields): additional labour time	3.5	123.24
12	Post harvest	*Control of re-growth the following year/* Control of re-growth the 3 following years: 1 hours/ha and year including handpulling	1	7.61

1) These numbers represent the number of the production process (in accordance to the production scheme of INRA)

Sources: Calculations of University of Applied Sciences of Weihenstephan 2004 based on simulations of INRA 2004

The co-existence costs for a threshold of 0.1 % in sugar beet seed production are shown in Table 4.4.5. In order to reach this very low threshold a variety of additional measures have to be carried out. Additional costs occur for modifying the organisational system of sugar beet seed production (3.81 €/ha each on the nursery and production field), careful cleaning of the drilling machine (3.81 €/ha), supervising a potential re-growth of seedlings (15.22 €/ha), spraying a selective herbicide to destroy excess seedlings (12.83 €/ha), supervising of and hand pulling on an increased production area (190.25 €/ha), additional false sowing (70.31 €/ha), in-field cleaning with water of mower machine (3.81 €/ha), cleaning of the combine with water before leaving each plot (75.64 €/ha) and controlling the re-growth of sugar beet plants in the following three years (22.83 €/ha) (Table 4.4.5). The additional costs of the suggested co-existence measures account to a total of around 450 €/ha (table 3.2.6).

Table 3.2.5: Costs of additional measures in sugar beet seed production for threshold of 0.1 % GM adventitious presence

No.[1]	**Production step**	***Current practices /*** **additional measure**	**Time** hours/ha	**Costs** €/ha
1	Nursery plot management	*Field pattern precisely defined on a map/* Map of the region with localisation of fields with GM seed production: 0.5 hours/ha	0.5	3.81
2	Sowing	*Careful cleaning of the drill between two plots and at the end of the nursery/* Careful control of drill cleanness: 0.5 hours/ha	0.5	3.81
3	Seedling harvest	*Preparation and conditioning of seedling on the nursery plot/* Careful supervision and quality assurance: Costs not possible to estimate in this study	Costs not possible to estimate in this study	
3		*Plot monitoring the subsequent years/* Supervision of the potential re-growths for several years and additionally destruction in case of occurrence of weed beets	2	15.22
4	Destruction of excess seedlings	*Spray of total herbicide after lifting/* Change to selective herbicide instead of total herbicide	-	12.83
6	Isolation distance	*Between pollinators of the same ploidy: 300m/* 1,000 m isolation distance if the gene is born by the pollinator: 0.5 hours/ha	0.5	3.81
		Between pollinators of the different ploidy: 600 m/ Map of the region with localisation of fields with GM seed production: 0.5 hours/ha		
		Between sugar beet seed production and other types of beets:1000 m/ Common management of production area by seed companies: 0.5 hours/ha		
		Seed production area global management by mechanical or chemical destruction/ Increase the area where it must be done: 25 hours/year for supervision and hand pulling	25	190.25

No.[1]	Production step	*Current practices /* additional measure	Time hours/ha	Costs €/ha
9	Pollinator destruction	*One false sowing/* One additional false sowing with use of rotary harrowing or Danish cultivator: 1 additional soil tillage		70.31
		Conventional machine cleaning in the field/ In-field cleaning with water of mower machine used for pollinator destruction: 0.5 hours/ha	0.5	3.81
10	Harvest	*Combines cleaned in the plot/* Combine must be cleaned more carefully with water before leaving each field (transportation loss) and on the farm (admixture between fields): additional labour time	3.5	123.24
12	Post harvest	*Control of re-growth the following year* Control of re-growth the 3 following years: 3 hours/ha and year including hand pulling	3	22.83
1) These numbers represent the number of the production process (in accordance to the production scheme of INRA)				

Sources: Calculations of University of Applied Sciences of Weihenstephan 2004 based on simulations of INRA 2004

An overview of the costs of co-existence measures for the differing thresholds in sugar beet seed production is given in table 3.2.6. For a threshold of 0.5 % the total costs of additional co-existence measures amount to almost 197 €/ha which equals to 6.4 % of the variable production costs or 6.2 % of the gross margin of sugar beet seed production respectively. These costs are strongly influenced by cleaning the harvester with water after each plot (63 % of the overall costs) as well as the general management and supervision of an increased area for sugar beet seed production (19 % of the overall costs) (table 3.2.6). In order to achieve a threshold of 0.3 % in sugar beet seed production in France, additional measures are required which cost around 246 €/ha which equals to 8.1 % of the variable production costs or 7.7 % of the gross margin respectively. High influence on these costs have cleaning of the harvester with water after each plot (50 % of total costs) and the general management and supervision of an increased production area (31 % of total costs) (table 3.2.6). When changing to a threshold of 0.1 %, almost a doubling of the costs of co-existence measures can be expected compared to the 0.3 % threshold, i.e. almost 15 % of the variable production costs are necessary in order to meet the threshold of 0.1 %. Almost half of the additional costs are caused by the supervision and global management of an increased production area, which is estimated to cause substantial labour costs of around 190 €/ha (42 % of the overall costs). Other important costs positions are cleaning of the combine with water after each plot (27 % of overall costs) as well as one additional false sowing in order to destroy pollinators (16 % of overall costs), while the other measures contribute with small percentages to the overall costs at the 0.1 %-threshold level (table 3.2.6).

Table 3.2.6: Overview of additional costs of co-existence measures with different thresholds in sugar beet seed production

Costs of additional measures[1]	0.1 %		0.3 %		0.5 %	
	€/ha	%	€/ha	%	€/ha	%
Nursery field						
1 Precisely defined map with localisation of GM fields	3.81	1%	3.81	2%	3.81	2%
2 Careful control of drill cleanness	3.81	1%	-			
3 Extra supervision of potential re-growths	15.22	3%	15.22	6%	15.22	8%
4 Destruction of seedlings: use of selective herbicide	12.83	3%	12.83	5%	12.83	7%
Seed production field						
6 Field identification	3.81	1%	3.81	2%	3.81	2%
6 Additional mechanical or chemical destruction -respectively 25,10 and 5 hours for supervision and global management	190.25	42%	76.1	31%	38.05	19%
9 Additional false sowing to destroy pollinators	70.31	16%	-		-	
9 In-field cleaning of mower machine	3.81	1%	3.81	2%	-	
10 Clean combine with water after each plot	123.24	27%	123.24	50%	123.24	63%
12 Additional control of re-growth	22.83	5%	7.61	3%	-	
Total costs	**449.90**	**100%**	**246.42**	**100%**	**196.95**	**100%**
Proportion of variable production costs	**14.7%**		**8.1%**		**6.4%**	
Proportion of gross margin [2)]	**14.1%**		**7.7%**		**6.2%**	

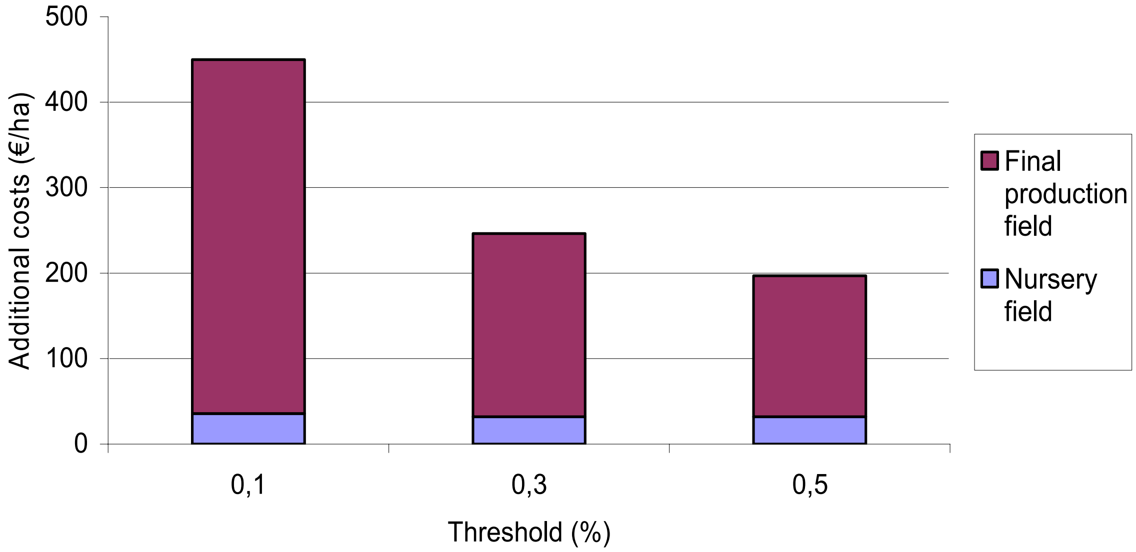
The numbers in the column represent the number of the production process (in accordance to the production scheme of INRA)

1) Gross margin of sugar beet seed production: 3,180 €/ha

Source: University of Applied Sciences of Weihenstephan 2004

When comparing the co-existence costs of the different thresholds in sugar beet seed production, it can be observed that the absolute level of these costs related to the nursery field do not differ a lot between the different thresholds under investigation, but a strong increase can be expected for measures required at the final production field when changing from a 0.5 % to a 0.1 % threshold (figure 3.2.1). This is mainly due to a strong increase in the costs of the global management and supervision of an enlarged production areas as well as the need of additional measures for soil tillage.

Figure 3.2.1: Additional costs of co-existence measures for differing thresholds of sugar beet seed production in France



Source: University of Applied Sciences of Weihenstephan 2004

3.2.2 Crop production

According to the agronomic analyses and simulations there are currently no co-existence problems in sugar beet crop production in France and Lower Bavaria. This is mainly due to the fact that the vegetative tubers of sugar beets do not produce seeds in the first year of the production cycle, thus not allowing any cross pollination problems between neighbouring fields. In this sense no additional measures would be required in order to comply with the threshold of 0.9 %. As outlined in detail in Messéan, A., F. Angevin, et al. (2006), sugar beet crop production might be influenced by co-existence related agronomic problems resulting from an increase of GM seeds in the seed bank in case weed beets produce GM seeds in the years following the cultivation of this crop. Therefore the costs of suggested practices are analysed in the following in order to reduce the distribution of GM seeds of sugar beet in the landscape.

Critical points in sugar beet crop production exist during sowing (i. e. admixture of GM and non-GM varieties of seeds) and during the cultivation period in case GM weed beets are growing in the field which produce high number of seeds (table 3.2.7). Proposed measures in order to overcome these critical points are the cleaning of the drilling machine after sowing GM varieties, hand pulling or the use of a selective herbicide to destroy weed beets and extra ploughing. These measures are regarded as appropriate for thresholds of 0.1 %, 0.3 % and 0.9 %.

Table 3.2.7: Critical points and additional measures in sugar beet crop production

Critical points	Proposed adaptation of current practice	Thresholds (%)
Sowing	Cleaning of the drilling machine	0.9
Cultivation	Hand pulling to destroy weed beets Use of a selective herbicide Extra ploughing	

Sources: University of Applied Sciences of Weihenstephan based on simulations of INRA 2004

Below the costs of these proposed measures are calculated for sugar beet crop production in Picardie and Lower Bavaria. The costs for cleaning the drilling machine are shown in table 3.2.8 taking into account two alternatives namely using own machinery or renting a drilling machine. In case own machinery is used only labour costs for cleaning have to be calculated resulting in costs of almost 8 € in France and around 10 € in Germany (table 3.2.8). If the drilling machine is rented, additional opportunity costs (which are due to the leasing rate for the time requirements for cleaning instead of using the machine for drilling) have to be taken into account resulting in significantly higher costs of 24 € in Picardie and almost 27 € in Germany.

Table 3.2.8: Costs of cleaning the drilling machine

Cleaning the drilling machine		**France**	**Germany**
Time for cleaning	h/cleaning	1	1
Labour costs	€/h	7.61	10.5
Labour costs per cleaning	**€/cleaning**	**7.61**	**10.5**
Costs of renting	€/ha	20	20
Time for drilling	hours/ha	1.22	1.22
Opportunity costs if the drilling machine were rented	€/ha	16.39	16.39
Total costs	**€/cleaning**	**24.00**	**26.89**

Source: Calculations of University of Applied Sciences of Weihenstephan 2004

The costs of destructing growing weed beets in a GM sugar beet field by hand pulling are shown in table 3.2.9. These costs are mainly influenced by the time requirements of hand pulling, the labour costs and the frequency of occurrence of weed beets within the cultivation period. Due to lower labour costs, the costs of this measure are slightly lower in France, e. g. 15.22 €/ha in case of two times hand pulling compared to 21 € in Germany (table 3.2.9).

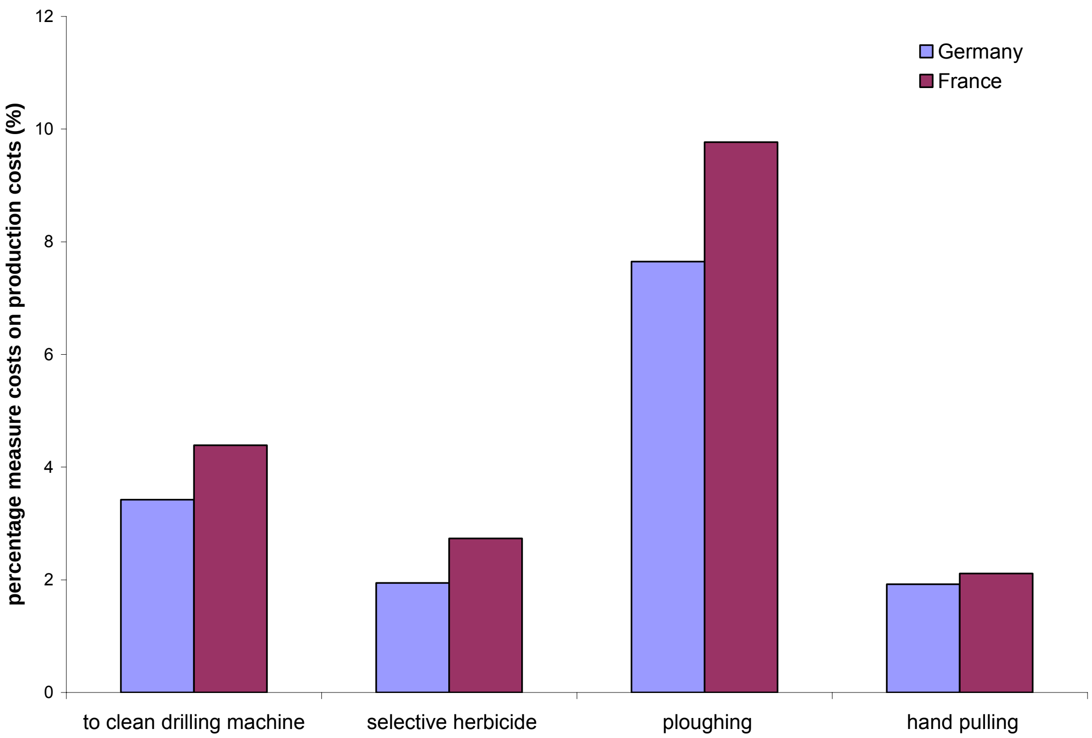
Table 3.2.9: Costs of destruction of weed beets by hand pulling

Destruction of weed beets by hand pulling		**Occurrence of weed beets**		
		1	**2**	**3**
Labour time for hand pulling	h/hectare	1	1	1
Labour costs in France	€/hour	7.61	7.61	7.61
Costs of weed beet hand pulling in France	**€/hectare**	**7.61**	**15.22**	**22.83**
Labour costs Germany	€/hour	10.5	10.5	10.5
Costs of weed beet hand pulling in Germany	**€/hectare**	**10.5**	**21**	**31.5**

Source: Calculations of University of Applied Sciences of Weihenstephan 2004

In addition to cleaning of the drilling machine and hand pulling of weed beets, the use of selective herbicides as well as extra ploughing is suggested in order to overcome critical points in sugar beet crop production. The costs of these single measures are already calculated in sugar beet seed production resulting in 44.12 €/ha for applying a selective herbicide and 70.31 €/ha for additional ploughing (table 3.2.3). In order to show the relative weight of the costs of additional measures, the percentage of these costs in relation to the total variable production costs of sugar beet crop production are illustrated in figure 3.2.2. Cleaning of the drilling machine causes costs of around 3.5 % of variable production costs in Lower Bavaria and of more than 4 % in Picardie. While one time extra ploughing costs between 8 % and 10 % of the current production costs in the two regions (figure 3.2.2), there are only minor differences in the use of a selective herbicide or hand pulling for destruction of weed beets being both in the range of 2 % to 3 % of variable production costs in both regions.

Figure 3.2.2: Costs of additional measures in % of total variable costs in sugar beet crop production



Source: Calculations of University of Applied Sciences of Weihenstephan 2004

In order to identify the most effective measures to control the critical points in sugar beet crop production, the measures with the lowest costs related to the different critical points are combined in table 3.2.9 Assuming renting of the drilling machine both in Lower Bavaria and Picardie and a twice hand pulling of weed beets in both regions, total costs of adapting current practices are calculated to 39.22 €/ha in France and 47.89 € in Germany (table 3.2.9). These costs relate to 5.5 % of the variable production costs in Picardie and 1.5 % of the gross margin (A quota). Due to the higher general economic performance of sugar beet crop production in Lower Bavaria compared to Picardie, the costs of adapting practices in the German region equal to 4.4 % of the variable production costs and 1.4 % of gross margin (A quota).

Table 3.2.10: Costs of adapting current practice in sugar beet crop production

Critical points	**Adaptation of current practice**	**Measure cost (€/ha)**	
		France	**Germany**
Sowing	Cleaning the drilling machine	24.00	26.89
Cultivation	Two times hand pulling to destroy the weed beets	15.22	21.00
Total costs		**39.22**	**47.89**

Source: Calculations of University of Applied Sciences of Weihenstephan 2004

After analysing the efficiency of single co-existence related measures in sugar beet crop production, the impacts of different agronomic activities on the future development of the number of GM seeds in the seed bank of GM and neighbouring fields are analysed in a second step of this chapter. For this purpose four differing farm types have been defined of which three are located in Picardie and one in Lower Bavaria.

The efficiency of different co-existence measures and its impact on the future content of GM seeds in the seed bank of a field, on which originally GM sugar beet have been cultivated, are investigated in a first part of the analysis. For this purpose INRA simulated the development of the number of GM seeds in the seed bank after 15 years with differing GM adoption rates in the region (see Messéan, A., F. Angevin, et al. (2006)). The results of these simulations as well as the costs of reducing the number of GM seeds by hand pulling of weed beets are shown in table 3.2.11 taking into account a 50 % GM adoption rate in the region. Similar results for a GM adoption rate of 10 % in the region are provided in table A1 of the annex of this report.

Table 3.2.11: Efficiency of co-existence measures on GM fields in different farm types in sugar beet crop production (50 % adoption of GM in region)

Measure	**Farm 1 France (large, clustered fields)**	**Farm 2 France (large, dispersed fields)**	**Farm 3 France, (small, dispersed fields)**	**Farm 4 Germany, (small, dispersed fields)**
	Number of GM seeds in seed bank after 15 years			
0 hand pulling	7,130	4,120	2,020	2,220
1 hand pulling	143	50	38	38
2 hand pulling	113	33	28	26
Costs of reducing GM seeds in seed bank (€/1,000 seeds)				
1 hand pulling	1.09	1.87	3.84	4.81
2 hand pulling	253.67	447.65	761.00	875.00

Sources: Calculations of University of Applied Sciences of Weihenstephan based on simulations of INRA 2004

Summarizing the results of the different simulations related to the efficiency of different measures in reducing the future GM seed content on fields with GM sugar beet crop production, the following main findings can be identified (tables 3.2.11, A1):

- With costs of around 75 €/ha to 80 €/ha (per ploughing), ploughing by far has the highest costs of all simulated measures and additionally adverse effects (i.e. a substantial increase in number of GM seeds in seed bank) on the GM seed content in future years. This holds true for a GM adoption rate of 10 % and 50 % in the region.
- A high efficiency of the first hand pulling of weed beets on the GM field can be stated in order to reduce the future increase of GM seeds in the seed bank. Taking into account a 50 % GM adoption, rate this activity costs around 1 to 2 €/1,000 seeds in large farms and between 3 to 5 €/1,000 seeds in small farms (table 3.2.11). In case there is only a GM adoption of 10 % in the region, we still find a high efficiency of the first hand pulling of weed beets on the GM field, but the relative costs of this measure increase due to the lower base of adventitious presence with GM seeds in this scenario (table A1).

- In all scenarios and farm types the efficiency of the second hand pulling of GM weed beets is substantially lower compared to the first hand pulling thus resulting in high relative costs of the second hand pulling often exceeding 100 €/1,000 seeds.
- The costs of the use of paternal transgenes which are also simulated by INRA do not primarily influence the GM crop-producing sugar beet farmer but occur during the breeding process of the GM varieties, thus maybe resulting in additional costs for breeding companies. Therefore they are not considered in the cost analyses of this report.

As a second part of the analyses of co-existence measures in sugar beet crop production, the efficiency of different agronomic measures and its impact on the future content of GM seeds in the seed bank of neighbouring non-GM fields (besides a field on which GM sugar beet have been cultivated), are investigated below. For this purpose INRA simulated the development of the number of GM seeds in the seed bank of these neighbouring non-GM fields after 15 years with differing GM adoption rates in the region and differing agronomic practices on these fields (e. g. organic agriculture, no hand pulling of weed beets on non-GM fields). One major finding of these simulations is the aspect that there might be a substantial increase in the number of GM seeds in the seed bank in particular on non-GM fields without hand pulling of weed beets, while it is rather unlikely that the number of GM seeds in the seed bank exceed a critical level on the neighbouring non-GM fields with other agronomic practices. Therefore the efficiency of different co-existence measures which are carried out on a GM field and their impact on the number of GM seeds in the neighbouring non-GM field without hand pulling are shown in table 3.2.12 taking into account a 50 % GM adoption rate in the region. Similar results for a GM adoption rate of 10 % in the region are provided in table A1 of the annex of this report.

Table 3.2.12: Efficiency of co-existence measures on neighbouring non-GM fields (without hand pulling) in different farm types in sugar beet crop production (50 % adoption of GM in region)

Measure on the GM field	**Farm 1 France (large, clustered fields)**	**Farm 2 France (large, dispersed fields)**	**Farm 3 France, (small, dispersed fields)**	**Farm 4 Germany, small, dispersed fields)**
	Number of GM seeds in seed bank after 15 years			
0 hand pulling	3,960	9,090	33,200	1,640
1 hand pulling	399	393	3,640	196
2 hand pulling	210	202	1,360	96
Costs of reducing GM seeds in seed bank of neighbouring fields (€/1,000 seeds)				
1 hand pulling	2.14	0.88	0.26	7.27
2 hand pulling	40.26	39.84	3.34	105.00

Sources: Calculations of University of Applied Sciences of Weihenstephan based on simulations of INRA 2004

Summarizing the results of the different simulations done by INRA as well as the cost calculations related to the efficiency of different measures on fields with GM sugar beet varieties and their effects in reducing the future GM seed content on neighbouring non-GM fields, the following main findings can be identified (tables 3.2.12, A1):

- In analogy to the situation on the GM fields, ploughing by far has the highest costs (75 €/ha to 80 €/ha per ploughing) of all analysed measures and additionally adverse effects on the number of GM seeds in the seed bank of neighbouring non-GM fields (table A1). This holds true for all farm types and all simulated adoption rates of GM varieties in the region.
- There is again a high efficiency of the first hand pulling of weed beets on GM fields in order to reduce future increase of GM seeds in seed banks of neighbouring non-GM fields.

- This win-win situation in particular holds true for neighbouring non-GM fields without hand pulling. In this situation the first hand pulling of weed beets on GM fields substantially decreases the number of GM seeds in the seed bank of these fields causing relative costs which are often below 2 €/1,000 seeds. This high efficiency of hand pulling of weed beets on the GM fields relates in particular to farm 3 (with small and dispersed fields) on which we find a high base adventitious presence with GM seeds on the non-GM fields (tables 3.2.12, A2).
- In case the base of adventitious presence with GM seeds is relatively low (as it is the case in farm types 1 and 4) the relative costs of the first hand pulling of weed beets on the GM field might exceed 5 €/1,000 seeds (tables 3.2.12, A2). However, this measure still can be recommended as "precautionary activity" in order to keep future adventitious presence with GM sugar beet seeds as low as possible in a region since the absolute costs of two times hand pulling are around 2 % of the total variable production costs of sugar beet crop production in France and Germany (figure 3.2.2).

3.3 Economic impact of co-existence measures in cotton

With respect to the current agronomic practice in cotton production in Andalusia, the following critical points have been identified for admixture of GM and non-GM material:

- Sowing: admixture can take place due to seeds remaining in the seeding machine after sowing a GM cotton plot.
- Cross pollination: although cotton is mainly autogamous, a small rate of out-crossing can occur in cotton as well as a consequence of pollination by insects.
- Harvest: some cotton residue from the previous plot will remain in the harvester so that adventitious admixture can occur if this plot is cultivated with GM cotton.
- Transport: after harvesting cotton is transported to an intermediate warehouse or to a giner with some cotton residues remaining in the back of the truck or in the trailer after unloading so that adventitious admixture can occur in case of transportation of GM and non-GM cotton.

In order to achieve the targeted thresholds of 0.9 % in fibre production and 0.5 % respectively 0.1 % in seed production the measures outlined in table 3.3.1 is suggested as outcome of analysis of agronomic practices and simulation of pollen flow in cotton. In order to prevent admixture of GM and non-GM material the obligatory cleaning of the sowing machine, harvester and trailer are required after using it for GM varieties. An alternative could be the use of differing equipment for GM and non-GM varieties for this purpose. In order to reduce cross pollination between GM and non-GM cotton fields buffer zones of non-GM cotton are suggested around the GM cotton fields (table 3.3.1).

Table 3.3.1: Measures for co-existence in cotton production in Andalusia (thresholds: 0.9 % in fibre production, 0.5 % respectively 0.1 % in seed production)

Critical points	**Proposed adaptation of current practice**	**Cost components of proposed measures**
Sowing	Obligatory cleaning of the hoppers of the drilling machine after sowing GM plots	Time for cleaning the hopper: labour costs, Opportunity costs for non-sowing
	Alternative: Obligatory use of separate sowing machine on GM and non-GM plots	Costs for buying an additional drilling machine or costs for renting a drilling machine
Cross pollination	Obligatory strip (buffer zone) of non-GM cotton around the GM field (minimum 3.8 m)	Costs of additional sowing: includes cleaning the hopper, difference in seed costs (GM and non-GM seeds) Extra treatment of the non-GM area: includes extra plant protection, weed control, etc.
Harvesting	Obligatory cleaning of the harvester after harvesting GM plots	Time for cleaning the harvester: labour costs Opportunity costs for reducing harvesting time
	Alternative: Obligatory use of different harvesters for GM and non-GM crops	Costs for buying an additional harvester or costs for renting a harvester
Transport	Obligatory cleaning of the trailer after transport of GM cotton	Time for cleaning the trailer: labour costs Opportunity costs
	Alternative: Obligatory use of different trailers for GM and non-GM crops	Costs for buying an additional truck or costs for renting a truck
	Alternative: Prohibition of shared transport of GM and non-GM crops on the same farm	Due to high practical problems (handling, control of measure) this proposed measure is not considered in the calculation of additional costs.

Source: University of Applied Science of Weihenstephan based on working report of DAP 2004

3.3.1 Seed production

Concerning cotton seed production in Andalusia, two different situations, are analysed in the study:

- Situation A: Certified seed producing farms which do not cultivate GM cotton within the farm (farm types 1 and 1')
- Situation B: Certified seed producing farms which cultivate GM and non-GM cotton on the same farm (farm types 2 and 2'). Two differing adoption rates are analysed for those farms, namely an adoption rate of 10 % GM cotton on the farm or 50 % adoption rate respectively.

A detailed description of the farm characteristics of the different cotton seed-producing farms is given in table 3.3.2.

Table 3.3.2: Characteristics of cotton seed-producing farms in Andalusia

GM in region	**10 %**	**50 %**	**Characteristics of the farms**			
			Production system	**% GM cotton on farm**	**Average farm size**	**Average size of cotton plot**
Farm types[18]	1	1'	Conventional	0	n. a.	2.77 ha
	2	2'	Co-existence	10/50	n. a.	2.77 ha

Source: Working report of DAP 2004

As an outcome of the agronomic analyses it can be concluded that the level of admixture caused at each critical point will not change as a result of adapted practices in farm type 1 or 1', since these farm types already clean the drilling machine, harvester and the truck or trailer used for transport. Furthermore, the currently required isolation distances for certified seed production of cotton already will prevent cross pollination of neighbouring fields. Concerning farm types 2 and 2', it is assumed that these farm types will not see any change in the level of admixture produced at each critical point with adapted practices, for he same reasons as given for farm types 1 and 1'. In total, no additional measures are required (as that already in place at the identified critical points in order to respect a threshold of 0.5 % GM adventitious presence in cotton seeds. Thus, no additional costs have to be carried by these farmers.

[18] Farm types are described in detail in chapter 3.

3.3.2 Fibre production

Concerning cotton fibre production two different situations are analysed within the frame of this project. On the one hand the situation of farms is taken into account which do not cultivates GM cotton on their own area but partly share machinery with other farmers (farm types 3 and 4). On the other hand the situation of farmers is investigated which cultivate GM cotton in differing proportions on their cotton cropping area (farm types 5 and 6)[19]. In table 3.3.3 an overview is given concerning the modification of current practices in these different types of cotton producing farms in Andalusia.

Table 3.3.3: Modification of current agronomic practices in cotton fibre producing farms

GM proportion / farm types [20]		**Characteristics of the farms**					**Additional measures**
10%	**50%**	**Production system**	**GM cotton (%)**	**Farm size (ha)**	**Cotton area total (ha)**	**Size of cotton field (ha)**	
3	3'	Small conventional	0	16	5	2.77	Clean the drilling machine Clean the harvester Clean the trailer
4	4'	Large conventional	0	160	30	9.7	No measures
5[1)]	5'	Small co-existence	50	16	5	2.77	Clean the drilling machine Clean the harvester Clean the trailer Buffer strip of non-GM-cotton
6	6'	Large co-existence	10/50	160	30	9.7	Clean the drilling machine Clean the harvester Clean the trailer Buffer strip of non-GM-cotton
Farm 5 is not considered in the analysis since it represents a small farm with a total cotton cropping area of 5 ha. It seems very unlikely that such a farm will cultivate 10 % of this area (i. e. 0.5 ha) with GM cotton.							

Source: University of Applied Science of Weihenstephan based on working report of DAP 2004

Farm types 3 and 3’ represent small farms and share machinery for sowing, harvesting and transporting cotton with other farmers. Although those farmers do not cultivate GM cotton on their farms they will clean the drilling machine,

[19] Farm types are described in detail in chapter 3.

[20] Farm types are detailed described in chapter 3.

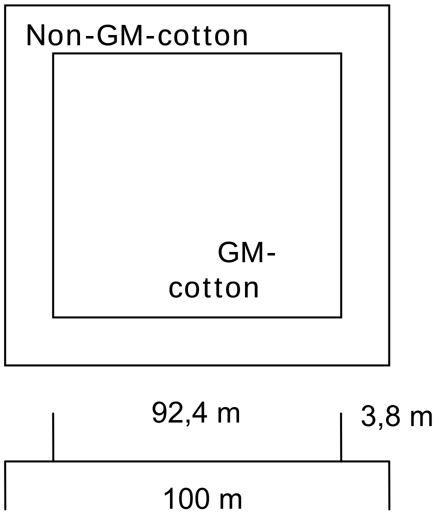
harvester and trailer before starting their work in order to avoid a potential adventitious admixture with GM material being left over from other farmers in the different machinery (table3.3.3)[21]. In contrast, farm types 4 and 4' represent large farms with a total cropping area of 160 ha and 30 ha cotton fibre production. These farms use their own machinery and do not cultivate any GM cotton on their farms. Therefore, it can be assumed that no additional measures have to be taken into account in order to ensure co-existence between GM and non-GM cotton (table 3.3.3), and thus no additional costs will occur on these farms.

The situation on farm type 5' is characterised by a small cotton cropping area of 5 ha of which 50 % are cultivated with GM varieties, thus resulting in a GM and non-GM cotton field on the farm. Since this farmer shares machinery with other farms, he will clean the drilling machine before starting the work on the non-GM cotton field on his farm and continue with the GM plot. In addition, one cleaning of the harvester and trailer for transporting the cotton is required in order to avoid admixture between GM and non-GM material within the farm (table 3.3.3). In addition to cleaning the machinery, a buffer strip of non-GM cotton of a minimum of 3.8 m around the GM cotton field is required in order to avoid cross pollination of GM cotton (figure3.3.1). On farm 5', the proportion between the GM cotton field and the non-GM buffer zone might vary depending on the total size of the cultivated fields, but if we assume that a field with 2.5 ha is cultivated with GM cotton an area of 2,300 m^2 has to be sown with non-GM cotton around the GM cotton field. The buffer zones can be treated with insecticides like non-GM cotton fields (thus resulting in additional insect control costs), or such an insecticide treatment can be abstained from thus being confronted with lower cotton yields due to increased insect infestation. According to a study of Novillo et al. 1999 it can be assumed that non-GM cotton, which is treated with insecticides, has 360 kg/ha lower yields compared to GM cotton. In contrast, if non-GM cotton is not treated with insecticides the farmer will lose 860 kg/ha cotton fibre yield compared with the GM alternative (Novillo et al. 1999). If a farmer does not treat his non-GM cotton fields with insecticides, he will lose around 168 € income in cotton production (assuming an average price of

[21] For these farms cleaning of the drilling machine, harvester and trailer can be regarded as a precautionary measure in order to avoid adventitious admixture with GM material on their farms.

0.85 €/kg cotton) due to yield decreases on the non-GM cotton buffer zone of 3.8 m around a 2.5 ha cotton field.

Figure 3.3.1: Buffer zone of non-GM cotton around GM cotton field



Source: University of Applied Sciences of Weihenstephan 2004

In contrast to farm type 5', farms 6 and 6' represent large farms with own machinery which cultivate both GM and non-GM cotton varieties. This implies that the drilling machine, harvester and trailer for transporting the cotton have to be cleaned once in order to avoid in-farm admixture. In addition, buffer strips of non-GM cotton have to cultivated around the 3 ha GM-cotton field (in the 10 % scenario) or around the two 7.5 ha GM-cotton fields (in the 50 % scenario) respectively (table 3.3.3).

Costs of additional measures

Since the costs of additional measures suggested to ensure co-existence in cotton production in Andalusia vary between farm types and the different scenarios, the costs of the single measures in €/ha are calculated for small and large farms in a first step (table 3.3.4). Not very surprisingly, it can be shown that the cleaning of the drilling machine, the harvester and the trailer for transporting the cotton cause much lower costs compared to the renting of additional machinery in order to avoid admixture between GM and non-GM material. This holds true both for small and large farms. In relation to the cultivation of a non-GM cotton buffer strip the costs per hectare between the two alternatives vary between 49.61 €/ha with insecticide treatment and 54.5 €/ha without insecticide treatment (table 3.3.4). However, due to practical difficulties in separately treating a 3.8 m wide strip with insecticides, it is assumed that the farmers do not treat the buffer zone with insecticides although this causes slightly higher costs than the option with insecticide treatment.

Table 3.3.4: Costs of single additional measures in cotton production (€/ha)

Additional measures	**Small farms**	**Large farms**
Cleaning the drilling machine	12.48	10.35
Alternative solution: renting a separate drilling machine	90.10	
Clean the harvester	20.86	17.15
Alternative solution: renting a separate harvester	251.44	
Cleaning the trailer	6.60	6.60
Alternative solution: renting a separate trailer	59.42	
Cultivating a non-GM-buffer strip of 3.8 m		
Without insecticide treatment: yield loss 860 kg/ha* 1)	54.50	
With insecticide treatment: yield loss 360 kg/ha* 1)	50.52	
*) Price for cotton 0.85 €/kg and variable costs for insecticide treatment 371.60 €/ha. 1) 1000 kg are equivalent to 1 tonne		

Source: Calculations of University of Applied Sciences of Weihenstephan based on working report of DAP 2004

The combined costs of additional measures in cotton fibre production in the different farm types are shown in table 3.3.5. The costs of the singular measures of the suggested measures (which have been calculated in a first step) were aggregated for this purpose. Although the additional costs both for treatment of the buffer strips with insecticides and without insecticides are calculated and included in table 3.3.5, the alternative "without insecticide treatment" will be used for subsequent interpretation of the results[22] The additional costs for farm type 3', which is not producing GM cotton but shares machinery with neighbouring farms, amount to around 40 € per year for cleaning of the equipment. For the other small farm which produces GM cotton on 50 % of the total cotton area of the farm (farm type 5'), additional costs amount to around

[22] Although the alternative „without insecticide treatment" causes slightly higher costs than the treatment with insecticides (table 3.3.4), it is assumed that farmers use the first option due to practical difficulties to treat a 3.8 m strip with insecticides.

126 €/farm which equals to around 50 €/ha GM cotton. Due to the small area of GM cotton on this farm, the additional costs reach around 2.5 % of the variable production costs of cotton or almost 5.4 % of the gross margin respectively (table 3.3.5).

In contrast to the situation on farm type 5', the situation on farm 6 is characterized by a large area of cotton, for which two different adoption scenarios of GM cotton are simulated. In case only 10 % of the total cotton area of this farm are cultivated with GM varieties, the total additional co-existence costs (due to cleaning of the machinery and a buffer strip of non-GM cotton around the GM cotton field) are in the same range as for farm type 5', resulting in around 2.1 % of the variable production costs and 4.3 % of the gross margin due to the slightly higher GM cotton area on farm type 6 (table 3.3.5). However, the situation changes if the farmer of farm 6 decides to cultivate GM cotton on 50 % (= 15 hectares) of his total cotton area on the farm: Although total co-existence costs amount to around 336 € for farm type 6', the percentages devoted to these activities are substantially lower compared to the other farm types since only around 1.1 % of the variable production costs or 2.2 % of the gross margin have to be calculated for the suggested measures (table 3.3.5).

Table 3.3.5: Costs of additional measures in cotton fibre production

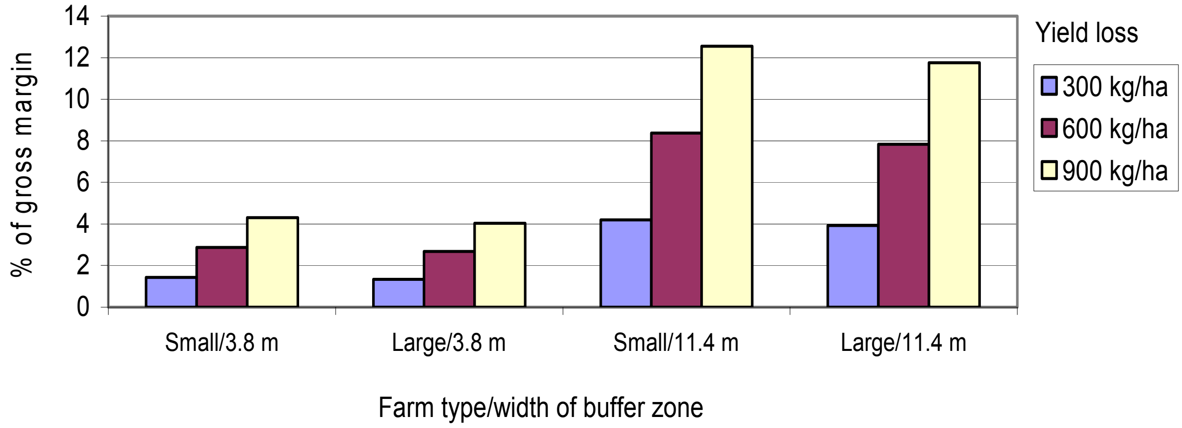
Parameter of production system		Farm type 3'		Farm type 5'		Farm types 6 and 6'			
		Small/conventional		Small/co-existence		Large/co-existence			
GM-cotton on farm	**%**	0		50		10		50	
Average farm size	**ha**	16		16		160		160	
Average cotton on farm	**ha**	5		5		30		30	
GM-cotton on farm	**ha**	0		2.5		3		15	
Number of GM-cotton fields		0		1		1		2	
GM cotton field size	**ha**			2.5		3		7.5	
Additional measures	**€/m**	**Costs of measure**		**Costs of measure**		**Costs of measure**		**Costs of measure**	
		Clean the drilling machine	12.48	Clean the drilling machine	12.48	Clean the drilling machine	10.35	Clean the drilling machine	10.35
		Clean the harvester	20.86	Clean the harvester	20.86	Clean the harvester	17.15	Clean the harvester	17.15
		Clean the trailer	6.60	Clean the trailer	6.60	Clean the trailer	6.60	Clean the trailer	6.60
				Buffer strip of non-GM-cotton a) without IT	86.79	Buffer strip of non-GM-cotton a) without IT	95.17	Buffer strip of non-GM-cotton a) without IT	302.18
				b) with IT	79.00	b) with IT	86.63	b) with IT	275.06
a) without IT **b) with IT**		**Total costs**		**Total costs**		**Total costs**		**Total costs**	
			39.94	a) without IT	126.73	a) without IT	129.27	a) without IT	336.28
				b) with IT	118.94	b) with IT	120.73	b) with IT	314.21
Total costs (without IT) per ha GM-cotton	**€/ha**				50.69		43.09		22.42
Total costs in % of variable production costs	**%**				2.46		2.16		1.12
Total costs in % of gross margin	**%**				5.38		4.28		2.23
Estimated maximum level of admixture	**%**		0.67		0.67		0.57		0.57
IT: Insecticide treatment									

Source: Calculations of University of Applied Sciences of Weihenstephan 2004

Due to the high influence of a non-GM buffer strip around a GM cotton field on the level of the total co-existence costs of a GM farm, a sensitivity analysis has been carried out in order to simulate the effects of differing widths of the buffer zone, varying yield losses as well as the size of the GM field. Detailed results of these analyses for a buffer zone without insecticide treatment are provided in table A3 in the annex of this report. The same relates to the costs of non-GM buffer zones with insecticide treatment which can be found in table A2 in the annex.

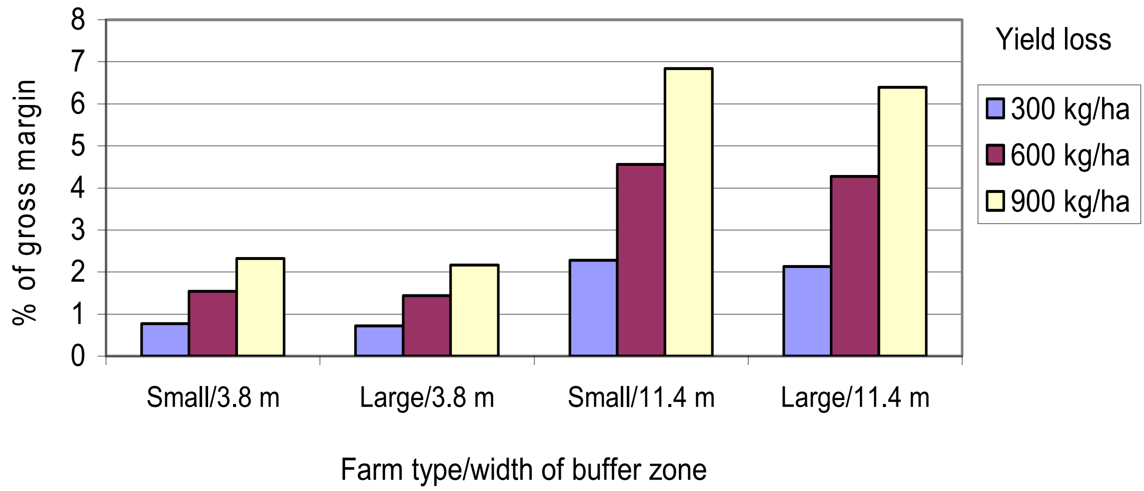
In a first step of the sensitivity analysis the influence of different cost factors of non-GM buffer zones is analysed for 2 ha and 7 ha GM cotton fields since they represent common field sizes in small or large cotton-producing farms in Andalusia. As illustrated in figure 3.3.2 for a 2 ha GM cotton field, the costs of a non-GM buffer zone without insecticide treatment are highly influenced by the required width of the buffer zone as well as the yield losses while there are rather marginal cost differences between small and large farms. In case non-GM buffer zones with a width of 11.4 m are required in order to reduce cross pollination of GM cotton below the threshold of 0.9 % of adventitious presence of GM material, their costs might sum up to around 12 % of the gross margin of cotton fiber production in Andalusia (figure 3.3.2) assuming a yield loss of 900 kg cotton/ha – which represents the level of yield losses found in the study of Novillo et al. 1999. The general results of the sensitivity analysis for the 2 ha GM cotton field are underlined by the findings for the 7 ha GM cotton field without insecticide treatment (figure 3.3.3). However, the total costs of a 11.4 m non-GM buffer zone sum up to a maximum of around 7 % of the gross margin of cotton fiber production (thus being significantly below the corresponding relative costs on a 2 ha GM cotton field) due to the more favourable ratio between the part of the field required for the non-GM buffer zone and the remaining GM cotton producing area.

Figure 3.3.2: Costs of non-GM buffer zones in 2 ha GM cotton field (without insecticide treatment)



Source: Calculations of University of Applied Sciences of Weihenstephan 2004

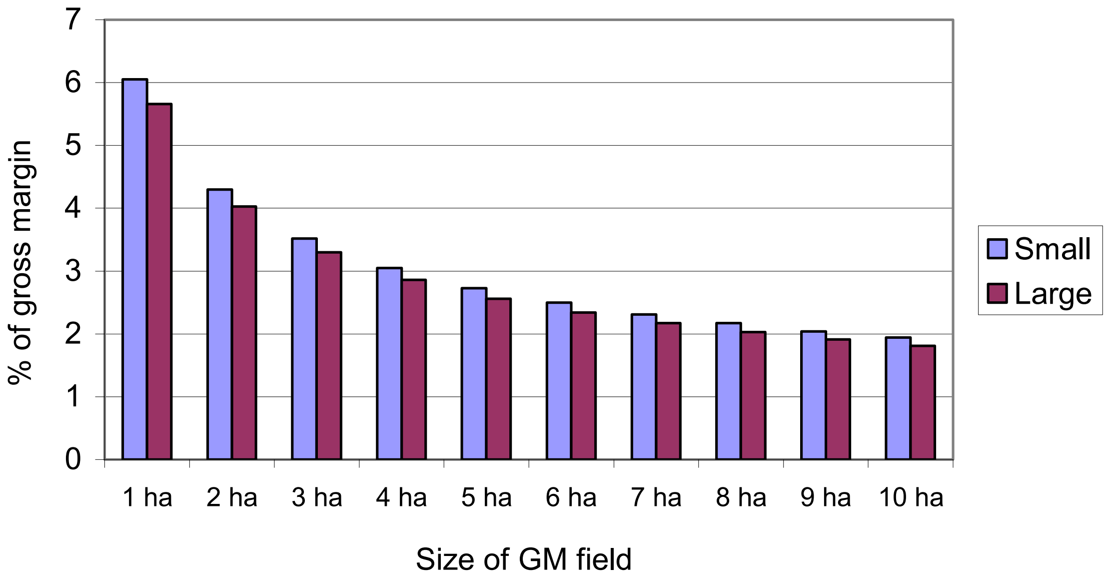
Figure 3.3.3: Costs of non-GM buffer zones in 7 ha GM cotton field (without insecticide treatment)



Source: Calculations of University of Applied Sciences of Weihenstephan 2004

Figure 3.3.4 shows the cost declining effects of increasing GM field sizes for non-GM buffer zones without insecticide treatment. While for such a buffer zone with a width of 3.8 m and 900 kg cotton yield loss without insecticide treatment, additional costs of more than 3 % of the gross margin of cotton production have to be calculated for a field of less than 3 ha, this figure reduces to below 2 % of the gross margin for GM cotton fields of 9 ha or more (figure 3.3.4).

Figure 3.3.4: Costs of non-GM buffer zones in different sizes of a GM cotton field (3.8 m width of buffer zone, without insecticide treatment, 900 kg/ha yield loss in buffer zone)



Source: Calculations of University of Applied Sciences of Weihenstephan 2004

The general results of the sensitivity analyses for non-GM buffer zones without insecticide treatment are found in a similar analysis for non-GM buffer zones, which are treated with selective insecticides resulting in a substantially lower yield decrease in the range of 200 kg/ha to 400 kg/ha cotton. A sensitivity analysis for buffer zones with insecticide treatment underlines the substantial influence of the width of the buffer zones on the overall costs of such a measure (table A4 in the annex). The impact of yield losses on the total costs of buffer zones decreases with insecticide treatment compared to the situation without insecticide treatment, while substantial cost declining effects depending on the size of the GM field can be found in both cases (tables A3 and A4 in the annex).

References

Association of Bavarian sugar beet planter Regensburg (2004): Company report for 2003/2004, Regensburg

Bavarian State Research Centre for Agriculture (2004): Personal communication on economics of sugar beet crop production, August 2004

Benbrook, C.M. (2001): When does it pay to plant Bt-Corn – Farm level economic impacts of Bt-Corn, 1996-2001, Benbrook Consulting Services, Idaho, 2001

Benbrook, C.M., (2003): Impacts of genetically engineered crops on pesticide use in United States: the first years, Benbrook Consulting Services, Idaho, 2003

Bock, A.-K.; Lheureux, K.; Libeau-Dulos, M. et al. (2002): Scenarios for co-existence of genetically modified, conventional and organic crops in European agriculture. Report EUR 20394EN, Seville

Brookes, G. (2002): The farm level impact of using Bt maize in Spain, Canterbury, 2002

Bundesministerium für Verbraucherschutz, Ernährung und Landwirtschaft (2002): Statistisches Jahrbuch über Ernährung, Landwirtschaft und Forsten 2003. Landwirtschaftsverlag GmbH, Münster-Hiltrup

Carpenter, J. and L. Gianessi (2001) : Agricultural Biotechnology : updated benefits estimates, National Center for Food and Agricultural Policy Study, 2001

Centre D'Etudes et de documentation du sucre (2002) : Le Sucre – Mémo statistique, 2002

CGB (2004): Confédération Générale des planteurs de Betteraves 2004

European Commission (2003): Commission recommendation of 23 July 2003 on guidelines for the development of national strategies and best practices to ensure the co-existence of genetically modified crops with conventional and organic farming. Brussels

Fernandez-Cornejo, J. and W.D. McBride (2002): Adoption of bioengineered crops, USDA, 2002

FNAMS (2004): Fédération Nationale des Agriculteurs Multiplicateurs de Semences, Personal communication on economics of sugar beet seed production in France. December 2004

Hugger, H. (2004): Personal communication on economics of maize seed production in south west Germany. Regional Commission/Council of Fribourg, August 2004

Hyde, J., Martin, M.A., Preckel, P.V., Edwards, C.R. (1999): The economic of Bt-corn: valuing protection from the European corn borer, Review of agricultural economics, 21(2), 44-454, 1999

KTBL (2002): Kuratorium für Technik und Bauwesen in der Landwirtschaft e.V., Betriebsplanung Landwirtschaft 2002/2003, 18. Auflage, Darmstadt

Landesanstalt für Landwirtschaft, Institut für ländliche Strukturentwicklung, Betriebswirtschaft und Agrarinformatik (2002): Marktfruchtbericht Bayern – Daten, Fakten, Analysen und Schlagkarteiergebisse 2001/2002, München, 2002

Marra, M.C, Carlson, G., Hubell, B. (1998): Economic impacts of the first crop biotechnologies, Working paper, 1998

Marra, M.C., Pardey, P.G., Alston J.M. (2002): The payoffs to agricultural biotechnology: An assessment of the evidence, Washington, 2002

Maschinen- und Betriebshilfsring Straubing-Bogen e.V. (2003): Verrechnungssätze 2003, Straubing, 2003

Messéan, A., F. Angevin, K. Menrad et al. (2006): New case studies on the co-existence of GM and non-GM crops in European agriculture. Technical Report EUR 22102 EN. I. Institute for Prospective Technological Studies. Brüssel.

Novillo, C., Soto, J., Costa, J. (1999): Resultados en Espana de variedades de algodon protegidas geneticamente contra las orugas de las capsulas. Boletin de Sanidad Vegetal. Ministeria de Agricultura, Pesca y Alimentacion Vol 25 – no.3- 1999. Study of Monsanto Enspana

Phipps R.H. and J.R. Park (2002): Environmental benefits of genetically modified crops: Global and European perspectives on their ability to reduce pesticide use, University of Reading, 2002

Rice, M.E. and C.D. Pilcher (1998): Potential benefits and limitations of transgenic Bt corn for management of the European corn borer, Journal of production agriculture, 12(3), 449-454, 1998

SCEES (2004): Service central des Enquêtes et Études statistiques du ministère de l'Agriculture, de l'Alimentation, de la Pêche et des Affaires rurales

Teyssier, D. (2003): Index des prix et des normes agricoles 2003-2004, 19e édition, Paris, 2003

Teyssier, D. (2004): Index des prix et des normes agricoles 2004-2005, 20e édition, Paris, 2004

Annex

Table A1: Efficiency of co-existence measure on GM and neighbouring fields in different farm types in sugar beet crop production

Farm types	Measures		Additional Costs	Seeds/ha on GM farm				Seeds/ha on non-GM farm fields (no hand pulling)			
	Hand pulling	Ploughing	€/ha GM-sugar beet	Seeds/ha		Reduction of seeds/ha (%)		Seeds/ha		Reduction of seeds/ha (%)	
				10%	50%	10%	50%	10%	50%	10%	50%
BASIC	0	Before sugar beet and potatoes		7880	7130	0	0	511	3960	0	0
Farm 1 France (large & clustered)	1	Before sugar beet and potatoes	7.61	139	143	**98**	**98**	43	399	**92**	**90**
	2	Before sugar beet and potatoes	15.22	108	113	**99**	**98**	44	210	**91**	**95**
BASIC	0	Before sugar beet		2650	4120	0	0	2770	9090	0	0
Farm 2 France (large & dispersed)	1	Before sugar beet	7.61	37	50	**99**	**99**	108	393	**96**	**96**
	2	Before sugar beet	15.22	26	33	**99**	**99**	48	202	**98**	**98**
BASIC	0	Before sugar beet		2240	2020	0	0	9120	33200	0	0
Farm 3 France (small & dispersed)	1	Before sugar beet	7.61	47	38	**98**	**98**	1090	3640	**88**	**89**
	2	Before sugar beet	15.22	35,6	28,3	**98**	**99**	362	1360	**96**	**96**
	0	each year (3 times more)	227.16	233000	263000	**no**	**no**	26800	93800	**no**	**no**
	0	Before wheat (1 time more)	75.72	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
BASIC	0	Before sugar beet		1180	2220	0	0	400	1640	0	0
Farm 4 Germany (small & dispersed)	1	Before sugar beet	10.5	17	38	**99**	**98**	44	196	**89**	**88**
	2	Before sugar beet	21	10	26	**99**	**99**	19	96	**95**	**94**
	0	Each year (4 times more)	312.94	16600	23100	**no**	**no**	795	3100	**no**	**no**
	0	Before wheat (1 time more)	78.24	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Sources: Calculations of University of Applied Sciences of Weihenstephan based on simulations of INRA 2004

Table A2: Efficiency of co-existence measures on neighbouring non-GM fields (without hand pulling) in different farm types in sugar beet crop production (10 % adoption of GM sugar beets in region)

Measure on the GM field	**Farm 1 France (large, clustered fields)**	**Farm 2 France (large, dispersed fields)**	**Farm 3 (France, small, dispersed fields)**	**Farm 4 Germany, small, dispersed fields)**
	Number of GM seeds in seed bank after 15 years			
0 hand pulling	511	2,770	9,120	400
1 hand pulling	43	108	1,090	44
2 hand pulling	44	48	362	19
Costs of reducing GM seeds in seed bank of neighbouring fields (€/1,000 seeds)				
1 hand pulling	16.26	2.86	0.95	29.49
2 hand pulling		126.83	10.45	420.00

Sources: Calculations of University of Applied Sciences of Weihenstephan based on simulations of INRA 2004

Table A3: Sensitivity analysis of costs of a non-GM buffer zone (without insecticide treatment) around a GM cotton field

Width buffer zone (m)	Income loss due to non-GM buffer zone (€/field)			Income loss due to non-GM buffer zone (€/ha)			GM field size (ha)	Proportion of variable production costs (%)						Proportion of gross margin (%)					
								Small farms			Large farms			Small farms			Large farms		
	300	**600**	**900**	**300**	**600**	**900**		**300**	**600**	**900**	**300**	**600**	**900**	**300**	**600**	**900**	**300**	**600**	**900**
3.8	19.01	38.02	57.04	19.01	38.02	57.04		0.92	1.85	2.77	0.95	1.91	2.86	2.02	4.03	6.05	1.89	3.78	0.92
11.4	54.83	109.65	164.48	54.83	109.65	164.48	1	2.66	5.33	7.99	2.75	5.50	8.25	5.82	11.63	17.45	5.44	10.89	2.66
22.8	103.02	206.05	309.07	103.02	206.05	309.07		5.00	10.01	15.01	5.17	10.33	15.50	10.93	21.86	32.79	10.23	20.46	5.00
3.8	27.04	54.08	81.12	13.52	27.04	40.56		0.66	1.31	1.97	0.68	1.36	2.03	1.43	2.87	4.30	1.34	2.68	0.66
11.4	78.91	157.82	236.73	39.45	78.91	118.36	2	1.92	3.83	5.75	1.98	3.96	5.94	4.19	8.37	12.56	3.92	7.83	1.92
22.8	151.19	302.38	453.57	75.59	151.19	226.78		3.67	7.34	11.02	3.79	7.58	11.37	8.02	16.04	24.06	7.51	15.01	3.67
3.8	33.20	66.40	99.60	11.07	22.13	33.20		0.54	1.08	1.61	0.55	1.11	1.66	1.17	2.35	3.52	1.10	2.20	0.54
11.4	97.39	194.77	292.16	32.46	64.92	97.39	3	1.58	3.15	4.73	1.63	3.26	4.88	3.44	6.89	10.33	3.22	6.45	1.58
22.8	188.15	376.29	564.44	62.72	125.43	188.15		3.05	6.09	9.14	3.14	6.29	9.43	6.65	13.31	19.96	6.23	12.45	3.05
3.8	38.39	76.78	115.18	9.60	19.20	28.79		0.47	0.93	1.40	0.48	0.96	1.44	1.02	2.04	3.05	0.95	1.91	0.47
11.4	112.97	225.93	338.90	28.24	56.48	84.72	4	1.37	2.74	4.12	1.42	2.83	4.25	3.00	5.99	8.99	2.80	5.61	1.37
22.8	219.30	438.61	657.91	54.83	109.65	164.48		2.66	5.33	7.99	2.75	5.50	8.25	5.82	11.63	17.45	5.44	10.89	2.66
3.8	42.97	85.93	128.90	8.59	17.19	25.78		0.42	0.83	1.25	0.43	0.86	1.29	0.91	1.82	2.73	0.85	1.71	0.42
11.4	126.69	253.38	380.07	25.34	50.68	76.01	5	1.23	2.46	3.69	1.27	2.54	3.81	2.69	5.38	8.06	2.52	5.03	1.23
22.8	246.75	493.51	740.26	49.35	98.70	148.05		2.40	4.79	7.19	2.47	4.95	7.42	5.24	10.47	15.71	4.90	9.80	2.40
3.8	47.10	94.21	141.31	7.85	15.70	23.55		0.38	0.76	1.14	0.39	0.79	1.18	0.83	1.67	2.50	0.78	1.56	0.38
11.4	139.10	278.20	417.30	23.18	46.37	69.55	6	1.13	2.25	3.38	1.16	2.33	3.49	2.46	4.92	7.38	2.30	4.60	1.13
22.8	271.57	543.14	814.71	45.26	90.52	135.79		2.20	4.40	6.60	2.27	4.54	6.81	4.80	9.60	14.41	4.49	8.99	2.20
3.8	50.91	101.81	152.72	7.27	14.54	21.82		0.35	0.71	1.06	0.36	0.73	1.09	0.77	1.54	2.31	0.72	1.44	0.35
11.4	150.51	301.02	451.53	21.50	43.00	64.50	7	1.04	2.09	3.13	1.08	2.16	3.23	2.28	4.56	6.84	2.13	4.27	1.04
22.8	294.39	588.78	883.18	42.06	84.11	126.17		2.04	4.09	6.13	2.11	4.22	6.33	4.46	8.92	13.38	4.18	8.35	2.04
3.8	54.45	108.89	163.34	6.81	13.61	20.42		0.33	0.66	0.99	0.34	0.68	1.02	0.72	1.44	2.17	0.68	1.35	0.33
11.4	161.13	322.26	483.39	20.14	40.28	60.42	8	0.98	1.96	2.94	1.01	2.02	3.03	2.14	4.27	6.41	2.00	4.00	0.98
22.8	315.63	631.27	946.90	39.45	78.91	118.36		1.92	3.83	5.75	1.98	3.96	5.94	4.19	8.37	12.56	3.92	7.83	1.92
3.8	57.77	115.54	173.32	6.42	12.84	19.26		0.31	0.62	0.94	0.32	0.64	0.97	0.68	1.36	2.04	0.64	1.27	0.31
11.4	171.11	342.21	513.32	19.01	38.02	57.04	9	0.92	1.85	2.77	0.95	1.91	2.86	2.02	4.03	6.05	1.89	3.78	0.92
22.8	335.58	671.17	1006.75	37.29	74.57	111.86		1.81	3.62	5.43	1.87	3.74	5.61	3.96	7.91	11.87	3.70	7.40	11.11
3.8	60.92	121.83	182.75	6.09	12.18	18.28		0.30	0.59	0.89	0.31	0.61	0.92	0.65	1.29	1.94	0.60	1.21	1.81
11.4	180.54	361.08	541.62	18.05	36.11	54.16	10	0.88	1.75	2.63	0.91	1.81	2.72	1.92	3.83	5.75	1.79	3.59	5.38
22.8	354.45	708.91	1063.36	35.45	70.89	106.34		1.72	3.44	5.17	1.78	3.55	5.33	3.76	7.52	11.28	3.52	7.04	10.56

Source: Calculations of University of Applied Sciences of Weihenstephan 2004

Table A4: Sensitivity analysis of costs of a non-GM buffer zone (with insecticide treatment) around a GM cotton field

Width buffer zone (m)	Income loss due to non-GM buffer zone (€/field)			Income loss due to non-GM buffer zone (€/ha)			GM field size (ha)	Proportion of variable production costs (%)						Proportion of gross margin (%)					
								Small farms			Large farms			Small farms			Large farms		
	300	600	900	300	600	900		300	600	900	300	600	900	300	600	900	300	600	900
3.8	40.38	46.72	53.05	40.38	46.72	53.05		1.96	2.27	2.58	2.02	2.34	2.66	4.28	4.96	5.63	4.01	4.64	5.27
11.4	116.45	134.72	153.00	116.45	134.72	153.00	1	5.66	6.54	7.43	5.84	6.76	7.67	12.35	14.29	16.23	11.56	13.38	15.19
22.8	218.82	253.16	287.50	218.82	253.16	287.50		10.63	12.30	13.96	10.97	12.69	14.42	23.21	26.86	30.50	21.73	25.14	28.55
3.8	57.43	66.44	75.46	28.71	33.22	37.73		1.39	1.61	1.83	1.44	1.67	1.89	3.05	3.52	4.00	2.85	3.30	3.75
11.4	167.60	193.90	220.20	83.80	96.95	110.10	2	4.07	4.71	5.35	4.20	4.86	5.52	8.89	10.29	11.68	8.32	9.63	10.93
22.8	321.11	371.51	421.91	160.56	185.75	210.95		7.80	9.02	10.25	8.05	9.31	10.58	17.03	19.71	22.38	15.94	18.44	20.95
3.8	70.51	81.58	92.64	23.50	27.19	30.88		1.14	1.32	1.50	1.18	1.36	1.55	2.49	2.88	3.28	2.33	2.70	3.07
11.4	206.84	239.31	271.77	68.95	79.77	90.59	3	3.35	3.87	4.40	3.46	4.00	4.54	7.31	8.46	9.61	6.85	7.92	8.99
22.8	399.61	462.33	525.04	133.20	154.11	175.01		6.47	7.49	8.50	6.68	7.73	8.78	14.13	16.35	18.57	13.23	15.30	17.38
3.8	81.54	94.34	107.14	20.39	23.58	26.78		0.99	1.15	1.30	1.02	1.18	1.34	2.16	2.50	2.84	2.02	2.34	2.66
11.4	239.93	277.59	315.24	59.98	69.40	78.81	4	2.91	3.37	3.83	3.01	3.48	3.95	6.36	7.36	8.36	5.96	6.89	7.82
22.8	465.78	538.89	611.99	116.45	134.72	153.00		5.66	6.54	7.43	5.84	6.76	7.67	12.35	14.29	16.23	11.56	13.38	15.19
3.8	91.26	105.58	119.90	18.25	21.12	23.98		0.89	1.03	1.16	0.92	1.06	1.20	1.94	2.24	2.54	1.81	2.10	2.38
11.4	269.08	311.31	353.54	53.82	62.26	70.71	5	2.61	3.02	3.43	2.70	3.12	3.55	5.71	6.61	7.50	5.34	6.18	7.02
22.8	524.09	606.34	688.59	104.82	121.27	137.72		5.09	5.89	6.69	5.26	6.08	6.91	11.12	12.86	14.61	10.41	12.04	13.67
3.8	100.04	115.74	131.44	16.67	19.29	21.91		0.81	0.94	1.06	0.84	0.97	1.10	1.77	2.05	2.32	1.66	1.92	2.18
11.4	295.44	341.80	388.17	49.24	56.97	64.69	6	2.39	2.77	3.14	2.47	2.86	3.24	5.22	6.04	6.86	4.89	5.66	6.42
22.8	576.79	667.32	757.84	96.13	111.22	126.31		4.67	5.40	6.14	4.82	5.58	6.33	10.20	11.80	13.40	9.54	11.04	12.54
3.8	108.12	125.09	142.06	15.45	17.87	20.29		0.75	0.87	0.99	0.77	0.90	1.02	1.64	1.90	2.15	1.53	1.77	2.01
11.4	319.67	369.84	420.01	45.67	52.83	60.00	7	2.22	2.57	2.91	2.29	2.65	3.01	4.84	5.61	6.37	4.53	5.25	5.96
22.8	625.27	723.40	821.53	89.32	103.34	117.36		4.34	5.02	5.70	4.48	5.18	5.89	9.48	10.96	12.45	8.87	10.26	11.65
3.8	115.64	133.79	151.94	14.46	16.72	18.99		0.70	0.81	0.92	0.72	0.84	0.95	1.53	1.77	2.01	1.44	1.66	1.89
11.4	342.23	395.94	449.65	42.78	49.49	56.21	8	2.08	2.40	2.73	2.15	2.48	2.82	4.54	5.25	5.96	4.25	4.91	5.58
22.8	670.38	775.59	880.80	83.80	96.95	110.10		4.07	4.71	5.35	4.20	4.86	5.52	8.89	10.29	11.68	8.32	9.63	10.93
3.8	122.70	141.96	161.22	13.63	15.77	17.91		0.66	0.77	0.87	0.68	0.79	0.90	1.45	1.67	1.90	1.35	1.57	1.78
11.4	363.42	420.45	477.49	40.38	46.72	53.05	9	1.96	2.27	2.58	2.02	2.34	2.66	4.28	4.96	5.63	4.01	4.64	5.27
22.8	712.75	824.62	936.48	79.19	91.62	104.05		3.85	4.45	5.05	3.97	4.59	5.22	8.40	9.72	11.04	7.86	9.10	10.33
3.8	129.38	149.69	169.99	12.94	14.97	17.00		0.63	0.73	0.83	0.65	0.75	0.85	1.37	1.59	1.80	1.28	1.49	1.69
11.4	383.45	443.63	503.82	38.35	44.36	50.38	10	1.86	2.15	2.45	1.92	2.22	2.53	4.07	4.71	5.34	3.81	4.40	5.00
22.8	752.83	870.98	989.13	75.28	87.10	98.91		3.66	4.23	4.80	3.78	4.37	4.96	7.99	9.24	10.49	7.47	8.65	9.82

Source: Calculations of University of Applied Sciences of Weihenstephan 2004

Table A5: Costs of increasing isolation distances and planting additional male rows in maize seed production (crop-seed situation): wheat as alternative crop

Field size		Additional measures		Contami-nation rate with additional measure	Costs of additional measures 1)			
GM-crop field	Non-GM seed field	Isolation distance	Extra male rows		Extra male rows	Wheat as alterna-tive crop	Total costs	% of gross margin
ha		m	number	%	€ / 10 ha GM field			%
10	1	**200**	**20**	**1.42**				
		300	**0**	**1.05**				
		100	0	0.73	0	53.8	53.8	0.7
		200	0	0.53	0	107.5	107.5	1.4
		300	0	0.40	0	161.3	161.3	2.1
		400	0	0.31	0	Not possible on a 10 ha GM field	Not possible on a 10 ha GM field	Not possible on a 10 ha GM field
		500	0	0.24	0			
		600	0	0.19	0			
		700	0	0.15	0			
	5	**300**	**0**	**0.77**				
		200	**20**	**1.07**				
		100	20	0.54	1347.4	53.8	1401.2	17.8
		200	20	0.40	1347.4	107.5	1454.9	18.5
		300	20	0.30	1347.4	161.3	1508.7	19.2
		400	20	0.23	1347.4	Not possible on a 10 ha GM field	Not possible on a 10 ha GM field	Not possible on a 10 ha GM field
		500	20	0.18	1347.4			
		600	20	0.15	1347.4			
		700	20	0.12	1347.4			
	10	**100**	**20**	**2.98**				
		200	**0**	**0.94**				
		100	0	0.61	0	53.8	53.8	0.7
		200	0	0.43	0	107.5	107.5	1.4
		300	0	0.32	0	161.3	161.3	2.1
		400	0	0.24	0	Not possible on a 10 ha GM field	Not possible on a 10 ha GM field	Not possible on a 10 ha GM field
		500	0	0.19	0			
		600	0	0.15	0			
		700	0	0.12	0			
		800	0	0.10	0			

1) Gross margin of Bt maize: 786 €/ha; Gross margin of wheat: 769 €/ha

The blue figures in the table represent the current situation.

Sources: Simulations of INRA and calculations of University of Applied Sciences of Weihenstephan 2005