

New case studies on the coexistence of GM and non-GM crops in European agriculture



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■ Executive summary and conclusions

- This report analyses the need and feasibility of changes in agricultural practices to ensure coexistence between GM and non-GM crop production in the EU. The term coexistence refers to the ability of farmers to choose between conventional, organic or GM-based crop production, in compliance with the relevant EU legislation on labelling and/or purity standards. EU regulations have introduced a 0.9% labelling threshold for the adventitious presence of GM material in non-GM products. Since agriculture does not take place in a closed environment, suitable technical and organisational measures during cultivation, harvest, transport and storage may be necessary to ensure coexistence. Coexistence measures should make it possible for farmers growing non-GM crops to keep the adventitious presence of GM material in their harvest below the labelling thresholds established by Community law.
- A previous set of case studies published by an JRC/IPTS-ESTO consortium¹ concluded in 2002 that the need for coexistence measures in the EU was not general, and depended on the agricultural landscape (size, form and relative positions of GM and non-GM plots), farm typologies and the crops considered (maize, oilseed and potato were studied). This report focused on the feasibility of coexistence measures designed to be taken by non-GM crop farmers if they wished to avoid adventitious GM presence above labelling thresholds, and the possible economic consequences of having to label their crops as GM. In 2002, there were still no coexistence guidelines or decrees issued by Member States, so GM crop farmers were under no obligation to take any measure to avoid adventitious presence in non-GM crops.
- On 23 July 2003, the European Commission adopted Recommendation 2003/556/EC on guidelines for coexistence, reaffirming that measures for coexistence should be developed by the Member States. The guidelines specify that those farmers who introduce the new production type in a region should bear responsibility for implementing the farm management measures necessary to limit gene flow. Following these guidelines, measures currently being discussed by Member States are designed to be taken by GM crop farmers. Furthermore, since seeds may be a source of adventitious GM presence in agriculture, the European Commission initiated discussions on setting specific thresholds for the adventitious presence of GM seeds in conventional seeds, lower than those allowed in the final crops (0.9%). Therefore, seed production might have to operate under different coexistence requirements than crop production. These discussions are still ongoing.

Objectives

- Taking into account these developments, a new consortium JRC/IPTS-ESTO was formed in 2003² with the task of analysing new case studies on how GM and non-GM production systems can coexist in the same region with the probability of adventitious admixture

1 Scenarios for coexistence of genetically modified, conventional and organic crops in European agriculture. (2002) DG-JRC-IPTS-ESTO Technical Report EUR 20394 EN. Members of this consortium were IPTS, INRA (France); NIAB (UK); CEST (UK); Fraunhofer ISI (Germany); ADAS Consulting Ltd (UK).

2 Members of this consortium were JRC-IPTS, Empresa Pública Desarrollo Agrario y Pesquero-DAP (Spain), University of Applied Sciences of Weihenstephan and Fraunhofer-ISI (Germany), and INRA (France).

minimised by adapting farming practices, if necessary. The specific objectives are to:

- Identify agronomic measures for coexistence that could be implemented by GM crop farmers and study their techno-economic feasibility.
- Introduce the landscape scale for estimating gene flow and levels of adventitious presence of GM crops in non-GM crops. Also, simulate in real agricultural landscapes the efficacy and feasibility of coexistence measures.
- Identify and evaluate specific measures needed to meet the thresholds being discussed for seed production. Also, describe how different levels of initial seed purity affect the final level of adventitious presence in the crops produced.
- Study the effects of long time periods on the level of adventitious presence of GM crops. This is relevant for crops producing seeds with a long life and dormancy period, which can build banks of GM seeds in the soil.

Case studies: scope and methodological approach

- The case studies selected are seed and crop production of maize, sugar beet and cotton (plus oilseed rape for the analysis of coexistence over time) in defined EU regions. Maize is the only major GM crop authorised for cultivation in the EU and is thus a priority for coexistence research. The other crops are among the list of GM varieties in the development/authorisation pipeline³. The scope of the studies is agricultural production up to the farm gate.
- The report considers two scenarios for the presence of GM crops in the landscape (10% and 50% share of GM varieties in the respective crop) and different target thresholds for the level of adventitious GM presence: 0.1% and 0.9% for crop production and 0.1%, 0.3% and 0.5% for seed production.

- For each case study, the report (i) identifies key sources of adventitious GM presence in non-GM crops, (ii) estimates the levels of adventitious presence (expressed as the percentage of seeds, grains or roots harvested that are GM) with current and adapted farming practices, (iii) proposes adapted agronomic practices and technical measures to reduce adventitious presence to desired thresholds and (iv) evaluates the techno-economic feasibility of such proposals.
- To estimate the levels of adventitious GM presence and the effect of changes in farming practices, a combination of expert opinion and gene flow models are used. These models can operate at landscape level, and take into account agricultural practices, climate and crop rotations.
- The report describes in specific appendixes the status of validation of these models with field data, a process that is on-going. In addition to the prediction of adventitious presence levels, the ability to simulate, compare and rank specific coexistence measures according to their efficiency is what makes models a unique tool for the purpose of these case studies.

Coexistence in maize crop production

- Maize is a major crop in the EU. Grain maize is grown for its dry seed, which is processed into a range of animal and human foods. France is the leading EU grower of grain maize (nearly 2 million hectares), and GM maize is the only GM crop grown commercially in the EU (mainly in Spain, where 58 000 hectares were grown in 2004). The region of Poitou-Charentes accounts for 12% of maize production in France and is selected as a case study because of the potential adoption of GM maize varieties (for controlling weeds and/or corn borer infestations) and the availability of a digitised dataset on the maize field landscape.

Key sources of adventitious presence and measures to reduce it

- Three key sources of adventitious presence are identified for maize crops: traces of GM seeds in non-GM seed lots, cross-pollination from neighbouring GM fields, and the sharing of harvesting machinery between GM and non-GM fields. For current GM maize varieties, simulations using the MAPOD® model show that the contribution of initial seed impurities to final adventitious GM presence is roughly additive. Different levels of GM traces in seeds (ranging from 0.01% to 0.5%) are considered in the report for quantifying the final adventitious GM presence in the crop. Based on expert opinion and a literature review, it is estimated that the contribution of harvesting machinery ranges from 0% (dedicated harvesters) to 0.4% (shared harvesters and lack of cleaning practices).
- The contribution of cross-pollination and the strategies to reduce it are first tested by performing simulations with MAPOD® in a simple one-field to one-field design. Simulations show that two variables related to the agricultural landscape (the relative position of GM and non-GM fields with respect to dominant winds and the relative sizes of neighbouring GM and non-GM fields) have a major effect. Since these parameters are difficult to change, the impact of three measures targeting GM crop growers in order to reduce gene flow is simulated. The most robust strategy is the introduction of isolation distances between GM and non-GM fields. Sowing a non-GM maize buffer strip around GM fields is also effective. Lastly, using GM varieties with different flowering dates compared with

non-GM varieties is highly effective but is too dependent on meteorological conditions and hampered by associated yield losses⁴.

- A decision table is provided in the report to determine the isolation distances necessary to keep adventitious GM presence due to gene flow below a desired threshold, for different field sizes and wind orientations. The decision table also shows how isolation distances can be reduced when combined with non-GM buffer strips of different widths and/or with flowering time lags. By adding the contributions from seed impurities and harvester sharing, the table offers a decision tool for selecting coexistence measures in maize.

Feasibility of coexistence at landscape level

- The one-field to one-field simulations show the importance of considering actual agricultural landscapes when estimating gene flow. A digitised version of the 23 000 ha maize landscape⁵ of Poitou-Charentes, including the spatial distribution of maize fields, areas, perimeters and owners, is used as the input to the MAPOD® model. Estimations of adventitious presence levels due to cross-pollination are then carried out in actual maize field landscapes. Simulations with MAPOD® are also used to test the regional impact of selected coexistence measures (found to be efficient in the previous section). Adding the contributions due to seed impurity and shared harvesters allows the feasibility of coexistence to be studied at regional level. This is expressed in the report as the share of maize area in the region able to comply with a target coexistence threshold.

3 "Review of GMOs under research and development and in the pipeline in Europe" (2003) DG JRC-IPTS-ESTO Technical Report. European Commission (EUR 20680 EN).

4 A potentially effective measure is the use of different sowing dates for GM and non-GM varieties, which will result in different flowering dates. While this is rather difficult in the region studied, due to the narrow window of suitable weather conditions for sowing, it may be a measure worth considering in other maize regions, particularly further south.

5 The geographic information system (GIS)-based dataset was kindly provided by the Joint Research Centre - Institute for Protection and Security of the Citizen (JRC-IPSC).

- A first analysis of the landscape shows that maize fields are clustered (grouped around water supply points). These clusters vary in area and number of farmers owning one or more fields within a cluster. Farmers may decide to cultivate only one type of maize in each cluster, which reduces the analysis to coexistence between different clusters. However, there will be cases where farmers do not agree and will grow GM and non-GM maize fields in the same cluster, making it necessary to analyse intra-cluster coexistence.
- Coexistence between clusters is fairly easy. Levels of adventitious presence below the 0.9% target can be achieved simply by cleaning shared harvesters, whatever the proportion of GM maize in the landscape (10% or 50%). Coexistence between clusters may be feasible for thresholds lower than 0.9%, but then there is a need to introduce additional measures.
- Intra-cluster coexistence is also possible at regional level. In fact, if shared harvesters are cleaned, the majority of the maize area (85%-90%) would comply with a 0.9% threshold. The remaining area corresponds to fields particularly affected by cross-pollination (e.g. a small non-GM field downwind of GM fields). Achieving 100% compliance of the regional maize area for a 0.9% threshold is possible, but requires additional measures. Simulation results offer numerous solutions, from single measures (isolation distance) to combinations of reduced distances and buffer strips. Ensuring coexistence intra-cluster coexistence at 0.1% would not be technically feasible.
- Reducing the maximum adventitious presence of GM seeds in initial seed

lots⁶ would allow less strict coexistence measures to be adopted at crop level (e.g. reduction of mandatory isolation distances). However this entails the introduction of new coexistence measures and costs for maize seed production (see seed section below).

Economic consequences of coexistence measures

- A particular feature of mandatory isolation distances is that they do not affect all farmers equally, because the distribution of maize fields is not random. Farmers whose neighbouring fields lie beyond the isolation distance will not face economic constraints in deciding whether or not to plant GM varieties and will experience no economic impact at farm level. Using an actual maize landscape, the report studies what proportion of fields and farms would be affected in Poitou-Charentes by different isolation distances. It therefore offers a tool for reducing isolation distances to values that are effective but minimally disruptive (for example in combination with other measures).
- Farmers intending to use GM varieties but with neighbouring non-GM maize fields within the isolation distance will be constrained in their choice. Consensus expert opinion is that farmers will manage these fields by sowing non-GM maize. The economic consequences would then be related to the opportunity cost of not growing GM maize. At farm level, this cost amounts to the difference in economic performance between the GM and non-GM maize varieties⁷. At regional level, the economic effects will depend on the landscape area affected. Other aggregated economic consequences of a reduced use of GM crop varieties at regional level would need further study.

⁶ In the simulations, seed impurities ranged from 0% to a maximum of 0.5%.

⁷ No data on economic performance is available for the region studied since GM maize is not yet grown, and no ex-ante studies have been performed. Ongoing JRC studies are assessing the economic performance of GM and non-GM maize in Spain, the only EU country where there is significant cultivation.

- The economic consequences for GM farmers of introducing mandatory non-GM buffer strips again are related to the opportunity cost of not growing GM maize. At farm level, the impact on gross margins will depend on several factors, including the width of the strip and the size of the field (impacts will be higher for farmers with smaller fields, who will be more likely to opt out GM varieties if buffers strips are mandatory).
 - The effectiveness of cleaning harvesters between GM and non-GM fields for coexistence is clear. A cost of €50-60 per cleaning operation is estimated. This can be reduced by organising the harvest of GM and non-GM varieties in different periods to reduce cleaning operations.
- have fallen to an average ~0.3%, although a significant proportion of lots (30-40%) still exceeds this level.
- For maize seed production, cross-pollination is considered the only source of adventitious GM presence. The contribution of basic seeds and machinery use is considered nil in current production regimes. Since maize seed fields and crop fields are quite different in their pollen production and sensitivity to cross-pollination, two situations must be considered: coexistence between GM and non-GM seed fields (seed-seed coexistence) and coexistence between non-GM seed production and neighbouring GM crop production (seed-crop coexistence).

Coexistence in maize seed production

- France is the leading maize seed producer in Europe and 50% of seed production is concentrated in the South-West (used as a case study). Maize varieties are hybrids and therefore seed production plots are set up with separate rows of male lines and female lines. Such a production scheme is much more sensitive to cross-pollination from neighbouring fields than maize crop production. Seed production is carried out through contracts between seed companies and farmers under strict statutory measures (including isolation distances) to ensure purity and quality. This often includes organising groups of fields dedicated to seed production in clusters.
 - Different thresholds for the presence of GM seeds in maize seeds are being discussed. The current production regime requires the complete absence of seeds other than maize, but has no specific thresholds for varietal purity (the presence of other maize varieties). However, seed operators have for years visually recorded impurities due to cross-pollination. In seeds produced in recent years, visually recorded outcrosses
- Seed-seed coexistence**
- Seed production is organised in clusters of plots. Ensuring coexistence between GM and non-GM maize seed production plots would not require significant changes in current production techniques for a threshold of 0.5%, other than having GM and non-GM plots of similar sizes. For a 0.3% threshold, additional measures need to be taken. A decision table based on MAPOD® simulations is included to present the efficiency of different strategies. For example, arranging GM and non-GM seed plots to ensure optimum orientation with respect to the dominant wind direction or, if not feasible, increasing the current isolation distance are efficient measures. This is technically feasible since such arrangements could be specified in the contracts between the farmers involved in the same seed production cluster and the seed companies. A 0.1% threshold is not obtainable in practice under these conditions.
 - The economic consequences of additional measures for GM seed farmers are variable (depending on relative field sizes and the precise combination of measures), but may exceed 20% of the gross margin, assuming

companies pay to farmers the same prices for GM and non-GM seeds. It would then be unattractive to produce GM maize seed, unless isolated clusters of suitable fields are found.

Seed-crop coexistence

- Ensuring coexistence between GM maize crop fields and non-GM seed production is difficult to achieve even for a 0.5% threshold. Among the potential measures targeting GM crop growers, increasing isolation distances is technically the most efficient. Implementing these distances (in the range of 400-600 m) would lead in practice to the exclusion of GM crop maize production from the vicinity of areas with significant seed production. The most likely alternative for farmers would be to grow non-GM crop maize, where the analysis of economic consequences is then similar to that developed above for crop coexistence and isolation distances.

Coexistence in sugar beet production

- Sugar beet is cultivated for its root and harvested before flowering. Bolting (premature flowering) and cross-pollination in sugar beet production could result in the presence of GM weed beets in non-GM fields, but not in the admixture of GM and non-GM sugar beet roots in the harvest. The only significant source of adventitious presence of GM sugar beet roots in the harvest of non-GM fields is the initial presence of GM seeds in seed lots. Where the adventitious GM presence in non-GM seeds remains below the set threshold, there is no need for specific coexistence measures for sugar beet crop production.
- Sugar beet seed production is strictly regulated and carried out under contracts with seed companies. Farmers must comply with measures to minimise gene flow between

beet forms. Under the current “inter-professional agreement” in France, an overall varietal impurity of 0.2% is acceptable, with a maximum of 0.1% annual beet and 0.1% red and fodder beet. For lots with a higher varietal impurity, acceptance depends on case-by-case negotiation. Compliance with these existing rules should be sufficient to limit adventitious GM presence in non-GM seed production to a 0.5% threshold.

- Additional measures have been recommended to ensure that such levels are maintained in the long term and even reduced. Depending on the target threshold (0.1%, 0.3% or 0.5%), additional costs would range from 6-14% of the gross margin.
- For the case of herbicide-tolerant sugar beets, the report evaluates the efficacy of measures designed to successfully manage the appearance of herbicide tolerant GM weed beet. The appearance of GM weed beet in neighbouring fields does not translate in adventitious presence of GM in the final crop (roots), and therefore is not a coexistence issue *sensu stricto*, but an agronomic problem that can cause conflict between farmers.

Coexistence in cotton production

- Cotton is the most important non-food crop world-wide and cultivation of GM varieties is widespread. No GM variety is yet authorised for cultivation in the EU but several are in the regulatory pipeline. The agricultural area devoted to cotton in the EU is small but the crop is economically very important for some regions. The case study looks at Andalusia (southern Spain), with over 80 000 ha of cotton fields. Cotton is mostly autogamous and cross-pollination is negligible.
- Provided the adventitious GM seed presence in non-GM seeds remains below 0.5%, practices based on cleaning machinery are

enough to keep the adventitious GM presence below 0.9% for cotton crop production.

- To comply with a threshold of 0.5% adventitious GM presence in cotton seed production, no additional measures are required beyond those already in place for certified cotton seed production, so no extra costs have to be calculated. The report presents a set of stricter practices for achieving lower thresholds in seed and crop production and estimates the additional costs involved.

Effect of seed purity and long time periods on adventitious GM presence in oilseed rape

- Coexistence measures for oilseed rape crops were addressed in a previous study. Two issues are covered in this report: 1) the impact of different initial seed purity levels on final adventitious presence and 2) the effect of long time periods (over 50 years) on adventitious GM presence. This is relevant because oilseed rape has seeds that persist in the soil for long periods.
- The GeneSys-rape model is used for simulating adventitious presence in a number of farm types. The contribution of initial seed impurities to final adventitious GM presence is roughly additive for all types of farm. Cross-pollination and seed persistence in the soil remain the main source of adventitious GM presence. Only for very large fields (where the effect of cross-pollination is diluted) is seed impurity the main source of adventitious presence. Assuring seed purity is therefore not enough to achieve coexistence in oilseed rape and specific measures need to be evaluated.
- GeneSys-rape simulations show that, after the introduction of GM varieties in a region, the rates of adventitious presence will not increase significantly after the second rotation of oilseed rape (simulations up to

50 years). A significant exception is that of farms not buying certified seed but using farm-saved seeds, which led to a continuous increase in adventitious presence over time.

General conclusions

- On the basis of the model simulations and expert opinions gathered in this report, for the case studies covered (maize, sugar beet, cotton), coexistence in seed production is technically feasible for a threshold of 0.5%, with few or no changes in current practices. For maize, this holds true for coexistence between non-GM and GM seed production. However, coexistence of non-GM maize seed production with GM maize crops would need changes in current practices, namely introduction of larger isolation distances (from the current 200-300 m distances to 400-600 m).
- If GM presence in seeds does not exceed 0.5%, coexistence in crop production is technically feasible for the target threshold of 0.9%. For maize, additional measures are needed for some specific situations defined by climatic, landscape and agronomic parameters. The report evaluates measures found to be technically simple and effective. These measures, targeting GM maize growers, have variable farm-level economic consequences that will affect the farmer's decision whether or not to grow GM maize varieties.
- The report illustrates the power of novel gene flow models that actually take into account the spatial patterns of landscapes and agricultural practices. It is now possible to estimate levels of adventitious GM presence in non-GM production resulting from multiple fields and sources, over extended time periods, propose numerous coexistence measures and quickly test their feasibility and consequences at regional level. The information obtained from model

simulations, such as the decision tables presented in this report, is valuable for helping decision-makers set up coexistence strategies. Models simulations are not a

substitute for field experiments, but a way of overcoming the limitations (time scale, spatial coverage, costs) inherent to field work.