JRC Scientific and Technical Reports

European Coexistence Bureau (ECoB)

Best Practice Documents for coexistence of genetically modified crops with conventional and organic farming

1. Maize crop production

Authors: Marta Czarnak-Kłos, Emilio Rodríguez-Cerezo

EUR 24509 EN - 2010

EUROPEAN COMMISSION

Institute for Prospective Technological Studies

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The mission of the JRC-IPTS is to provide customer-driven support to the EU policy-making process by developing science-based responses to policy challenges that have both a socio-economic as well as a scientific/technological dimension.

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JRC59319

EUR 24509 EN
ISSN 1018-5593
ISBN 978-92-79-16558-0
doi:10.2791/4619

Luxembourg: Publications Office of the European Union

Printed in Spain

This best practice document is the result of work carried out by the European Coexistence Bureau – Technical Working Group for Maize, consisting of the following European Commission staff and experts nominated by EU Member States:

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Acknowledgements:

The authors would like to express their gratitude to the former heads of the European Coexistence Bureau, Stephen Langrell (JRC IPTS) and Anne-Katrin Bock (JRC) for their involvement at early stages of preparation of this Best Practice Document.

The authors would also like to thank Manuel Gomez-Barbero (DG AGRI), Sigrid Weiland (DG AGRI), Alice Stengel (DG SANCO) and Damien Plan (JRC IHCP) for their valuable comments on the report.

Executive Summary

The European Coexistence Bureau (ECoB) was created in 2008 by the Directorate-General for Agriculture and Rural Development (DG AGRI) and the Joint Research Centre (JRC) to implement the Agriculture Council conclusions of 22 May 2006, inviting the Commission to engage in works related to coexistence between genetically modified (GM) and non-GM farming in close cooperation with Member States and stakeholders. The Council invited the European Commission to identify the best practices for technical segregation measures and to develop crop-specific guidelines for coexistence regulations while leaving the European Union (EU) Member States the necessary flexibility to adapt the recommendations to their specific climatic and agricultural conditions.

The ECoB, located on the premises of the JRC's Institute for Prospective Technological Studies (IPTS), consists of a scientific Secretariat (formed by permanent JRC staff and seconded national experts) and crop-specific technical working groups (TWGs) consisting of technical experts nominated by interested Member States (currently one dealing with maize crop production).

The management practices for maize crop production proposed in this Best Practice Document (BPD) are the result of a consensus building process which started in October 2008. The ECoB Secretariat was responsible for collection of inputs from TWG members and exchange of information between them, analysis of the collected data and preparation of drafts of the Best Practice Document for consultation. The ECoB Secretariat proposed compromise solutions on controversial issues when necessary. This Best Practice Document was finally adopted by consensus within the Technical Working Group in May 2010.

For this BPD, about 30 stakeholder organisations were consulted via Advisory Groups managed by the Commission (on Cereals, Oilseeds and Proteins; on Organic Farming and on Rural Development including external stakeholder groups: EuropaBio, European Seed Association, Greenpeace and Friends of the Earth).

- **Legislative context**

In the 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, coexistence refers to the ability of farmers to make a practical choice between conventional, organic and GM-crop production, in compliance with the legal obligations for labelling and/or purity standards.

The ability of the agricultural sector to provide both products is the key factor to ensure the consumers' freedom in this area. As agriculture is an open system, the possibility of adventitious presence of GM crops in non-GM harvests exists and therefore suitable technical and organisational measures may be necessary to ensure coexistence and, consequently, consumers' choice further down the food chain.

The European legislation[1] establishes a threshold, at a level of 0.9%, below which the marketed products containing adventitious or technically unavoidable traces of genetically modified organisms (GMOs) authorised to be used as and in products in the European Community do not require labelling. The Recommendation 2003/556/EC[2] on guidelines for the development of national strategies and best practices to ensure coexistence of genetically modified crops with conventional and organic farming advises that the coexistence measures should not go beyond what is necessary to ensure that the legally binding threshold of 0.9% is respected. The current Best Practice Document has been developed in relation with that objective.

On 13 July 2010, the College has adopted a new Recommendation on coexistence replacing Commission Recommendation of 23 July 2003. The new Recommendation better reflects the possibility for Member States to establish coexistence measures to avoid the unintended presence of GMOs in conventional and organic crops and their need for sufficient flexibility to take into account their regional and national specificities and the particular local needs of conventional, organic and other types of crops and products.

This new Recommendation takes into account the fact that the potential loss of income for producers of particular agricultural products is not necessarily limited to exceeding the labelling threshold set out in EU legislation at 0.9%. In certain cases, depending on market demand and on the respective provisions of national legislations the presence of traces of GMOs in particular food crops –even at a level below 0.9%- may cause economic damage to operators who would wish to market them as non containing GMOs. In view of the new Recommendation, the best practices proposed in this document remain valid to ensure that legally binding threshold of 0,9% established by European legislation is respected, and given the flexibility of the options presented they represent also a useful tool for Member States which decide to aim at lower levels of admixture.

In addition, the Commission is currently working on the impact assessment of the establishment of thresholds for labelling GMO traces in conventional seeds and will examine the establishment of such thresholds in the light of the new policy on GMO cultivation.

The development of specific legislation or non-binding coexistence guidelines is in the competence of individual Member States. According to the coexistence report[3] of April 2009 published by the Commission, 15 Member States have at present adopted dedicated legislation on coexistence and three further Member States have notified drafts of the legislation to the Commission.

• Scope of the Best Practice Document

This document, containing consensually agreed best practices for coexistence of GM maize with conventional and organic maize, is intended to assist Member States in the development or refinement of their coexistence legislation or voluntary standards for good agricultural practice.

The document covers maize crop production, be it grain production, whole plant use or the

1 Directive 2001/18/EC of the European Parliament and of the Council of 12 March 2001 on the deliberate release into the environment of genetically modified organisms and repealing Council Directive 90/220/EEC. *OJ L 106, 17.4.2001, p. 1–39*
Regulation (EC) No 1830/2003 of the European Parliament and of the Council of 22 September 2003 concerning the traceability and labelling of genetically modified organisms and the traceability of food and feed products produced from genetically modified organisms and amending Directive 2001/18/EC. *OJ L 268, 18.10.2003, p. 24–28*

2 Commission Recommendation of 23 July 2003 on guidelines for the development of national strategies and best practices to ensure the coexistence of genetically modified crops with conventional and organic farming. *OJ L 189, 29.7.2003, p. 36–47*

3 European Commission, 2009. Report from the Commission to the Council and the European Parliament on the coexistence of genetically modified crops with conventional and organic farming. COM (2009) 153 final.

sweet maize production. Maize seed production was not addressed in the document.

The document is applicable to currently grown heterozygous, single event GM maize. The proposed measures should be adapted in the case of different zygosity or copy numbers of GM loci being introduced in new varieties and approved for cultivation.

• Maize crop production in the EU

In 2009, grain maize was cultivated on 5.6 million hectares in the EU, the highest share (29%) being cultivated in Romania. In the case of silage maize, the main European growers are France and Germany with an area of around 1.5 million hectares in each of those countries (Eurostat[4], data retrieved February 2010).

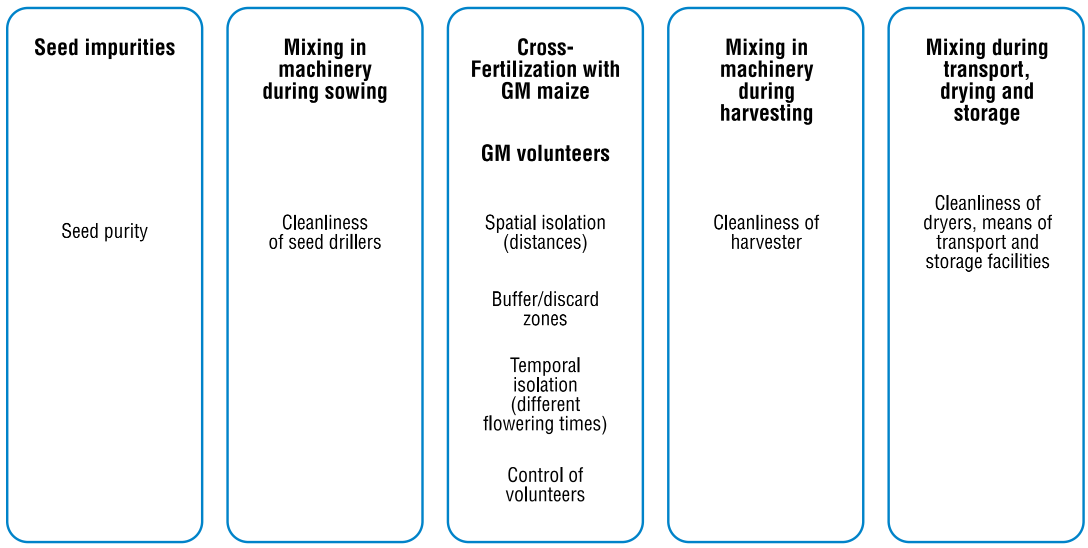
Only limited data is available regarding organic maize production and the dedicated areas may vary considerably from year to year. The main producer of organic maize in Europe is Italy, with a share of organic maize production of about 1.8%.

As stated in the Commission report of 2009 on coexistence, the commercial experience with cultivation of GM maize is limited, as in 2008 the cultivation of the only authorised event, MON 810, was reported by 6 Member States (CZ, DE, ES, PT, RO and SK) on a surface of about 100 000 ha (about 1.2% of the total maize acreage in EU 27 in this year). In 2009 GM maize cultivation was discontinued in Germany. The total area planted in the EU decreased to about 95 000 ha. The decrease was caused by several factors, including the decreased total area of maize production in Europe. Spain continued to be the largest EU grower with 80% of the total Bt maize area in Europe and an adoption of GM crops on the level of 22%.

• Review of the available information on management of adventitious GM presence in maize crop production

The TWG-Maize has carried out a comprehensive evaluation of the available data concerning field experiments and commercial cultivation of GM maize conducted predominantly in European climatic conditions. The information

Potential sources of GM admixture in non-GM maize crops and possible management practices



Based on: Devos et al. 2009

4 http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database

was provided by TWG members who submitted publications (e.g. peer reviewed articles, results of monitoring conducted in Member States), unpublished results and descriptions of practices currently applied in Member States.

Various sources of possible GM admixture in non-GM harvests through the production chain were analysed by the TWG-Maize, as well as the factors influencing the GM admixture level. The possible sources of admixture during different steps of the production chain and relevant management practices are summarised in the figure above.

Seed purity

The presence of GM seeds in non-GM seed lots was considered one of the critical issues. The TWG-Maize decided to discuss scenarios of best practices to limit outcrossing (the main source of GM admixture in maize crop production) to different levels (from 0.1% to 0.9%) to accommodate for different scenarios of impurities coming from seeds. The GM content in non-GM harvests was expressed in haploid genome equivalents in this document.

Outcrossing with GM maize

Cross-pollination between maize fields has been widely studied in Europe in recent years. The outcrossing level can be mitigated by using the appropriate isolation distances, pollen barriers or separation of flowering time. The recommendations to limit the outcrossing level were based on the results of field trials, modelling approach and some data regarding crop production.

The most widely used coexistence measure is based on spatial isolation of GM and non-GM fields. In the case of a measure being applied to limit the outcrossing to level below the legally binding labelling threshold (0.9%) the recommended isolation distance did not exceed 50 m.

In the case of fields located in close proximity the barren ground isolation distance can be replaced by maize plants (so called buffer or discard zones). Such maize barriers are usually more effective in reduction of outcrossing levels than the isolation distances. In the case of non-maize barriers such an effect was not observed.

Several factors, like field size and shape, prevalent wind direction, the presence of physical barriers between the fields and land topography, were analysed as influencing the level of outcrossing between the maize fields. These variables are however not easily represented or accounted for. Therefore, the TWG-Maize giving recommendations decided to consider the situation which favours the GM pollen flow (non-GM fields located downwind from the pollen donor) and not to propose any modifications of the measures according to the abovementioned variables.

The possible contribution of volunteers to the overall GM admixture content was discussed in the document and considered a minor source of GM content in non-GM harvests in present agricultural conditions.

Mixing with GM seeds/harvest during sowing, harvesting, transport and storage.

The available data regarding possible commingling with GM seeds/harvest during sowing, harvesting, transport and storage are very limited. The main source of GMO presence in non-GM harvests at the farm gate is the mixing of GM and non-GM material during harvesting. Harvesters used to collect the non-GM harvest after collecting the GM one should be therefore "flushed" with non-GM maize.

• Costs of coexistence measures

The costs associated with the application of management practices were already assessed in previous studies. The costs of the use of isolation distances (the most widely applied management tool) will basically correspond to *opportunity cost* which relates to not growing GM varieties on certain parts of the farm and may vary depending on the regional conditions. In the case of the isolation distance being replaced by a buffer zone some direct costs connected to the sowing of two types of maize could also be taken into account.

• Cross-border issues

Currently cross-border issues related to GM cultivation were analysed only by two Member States, Denmark and Germany. Both administrative and technical issues were identified as potentially problematic, as well as different liability and compensation schemes existing in those countries.

The development of consensually agreed guidelines for maize crop production may contribute to the reduction of these problems if, on the basis of best practices described in this document, technical segregation measures were to become similar in Member States. The issues regarding administrative and compensation schemes were outside the scope of the best practice document.

• Best practices for coexistence measures in maize crop production

The best practices were based on the abovementioned analysis of existing information concerning possible sources of adventitious presence of GM material in non-GM crops. On this basis, TWG members submitted their proposals for management practices, which were analysed and standardised by the ECoB Secretariat.

The TWG-Maize have consensually agreed the recommendation of the following best practices for each potential source of admixture:

Seed purity

The seeds used by farmers should comply with the EU purity requirements. The seeds should be stored in a way that minimizes the risk of any unintended use of GM varieties and their commingling with non-GM varieties.

Outcrossing with GM maize

The outcrossing with GM maize can be mitigated by applying appropriate spatial or temporal isolation measures. The spatial measures, like isolation distances and buffer or discard zones replacing isolation distance, can be applied in all Member States. The use of temporal measures, based on shifting the flowering times of GM and non-GM fields in order to prevent outcrossing, depends on climatic conditions and is limited to Mediterranean countries and Romania.

Isolation distances

The isolation distances which allow mitigating outcrossing were proposed separately for maize grain production and whole plant use. In order to take into account different climatic and agronomic conditions, the recommendations given for any admixture level are expressed as a range. The outcrossing with GM maize is the only source of admixture taken into account. The table below shows the isolation distances recommended by the TWG-Maize.

Proposals for isolation distances which can be recommended to reduce outcrossing to different levels in case of grain maize and the whole plant use

The isolation distances for admixture levels from 0.1% to 0.9% were proposed by the TWG-Maize, to allow for the adjustment of necessary practices according to different scenarios concerning GM content in seeds. This also allows adventitious or technically

Proposals for isolation distances which can be recommended to reduce outcrossing to different levels in case of grain maize and the whole plant use

Admixture level	Proposed isolation distances	
	grain maize	whole plant use
0.1%	105 to 250 -500 m	85 to 120 m
0.2%	85 to 150 m	50 to 65 m
0.3%	70 to 100 m	30 to 55 m
0.4%	50 to 65 m	20 to 45 m
0.5%	35 to 60 m	15 to 40 m
0.6%	20 to 55 m	0 to 35 m
0.7%	20 to 50 m	0 to 30 m
0.8%	20 to 50 m	0 to 30 m
0.9%	15 to 50 m	0 to 25 m

unavoidable presence from sources other than cross-pollination (machinery etc.) to be taken into account.

Buffer/discard zones

Buffer zones, created around the donor field, fully replacing the required isolation distance were considered a useful coexistence tool. In this situation the TWG-Maize recommended the replacement of 2 m of isolation distance by 1 m of buffer. The partial replacement of isolation distances by buffer zones needs further investigation. The discard zones created around the recipient field could also be an effective tool, however further investigation is needed to propose concrete measures.

Temporal isolation measures

The use of temporal isolation measures was considered highly dependent on climatic conditions in a given Member State and its effectiveness may vary year to year. In general the measures proposed below may replace spatial isolation measures and reduce outcrossing to levels below 0.1%.

The use of staggered sowing dates as a tool allowing to reduce outcrossing to levels below 0.1%, in the case of varieties having the same maturity class, can be recommended in the countries listed in the table below.

In France, according to the information provided by the French TWG member, the measure based on delayed sowing should be used only in combination with other measures (e.g. reduced isolation distance), according to specific recommendations published previously.

The use of varieties of different maturity classes as a tool to allow the reduction of outcrossing to levels below 0.1% in the case of varieties sown at

Minimal sowing delays recommended to reduce outcrossing between donor and receptor fields

Member State	Minimal sowing delays recommended
Greece	45-50 days
Italy	at least 30 days
Portugal	20 days
Romania	15-20 days

the same date, was recommended in the case of the countries listed in the table below.

Similar to the staggered sowing dates case, in France the varieties of different maturity classes may be used in combination with other measures, according to specific recommendations published previously.

Admixture resulting from the use of the same seed drillers, harvesters, means of transport or storage places for different production systems

All the machines, means of transport and storage places should be cleaned in an appropriate way in case the non-GM seeds or harvest were to be sown, harvested, transported or stored after the GM material. The use of dedicated machinery or storage places eliminates the risk of admixture.

• Areas where coexistence is difficult to achieve

The TWG-Maize acknowledges the fact that in specific cases the application of recommended best practices may be difficult. Several factors may contribute to this, such as: smaller fields than considered in the isolation distance tables; elongated fields; short field depth; and a level of adoption of GM maize.

In those cases, alternative measures may be used, e.g. communication between farmers to minimise problems including the voluntary agreements on harvest labelling and clustering of fields of one production system.

• Review of the document and next TWG-Maize activities

The TWG members expressed the need for periodical revision of the Best Practice Document as new data becomes available in the future. The timeframe of such revisions remains undecided.

The experts stressed as well that the harmonised approach to the monitoring of the efficiency of the coexistence measures is required and, possibly, the development of guidelines for such monitoring. This issue will be addressed by the Technical Working Group during its next activities.

Minimal differences in maturity classes recommended to reduce outcrossing between donor and receptor fields

Member State	Minimal recommended differences in maturity classes (in FAO units)
Greece	400
Italy	200
Portugal	200
Romania	200
Slovenia	250
Spain	300

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1. Introduction

1.1. Legislative context for coexistence

Coexistence refers to the ability of farmers to choose between the cultivation of genetically modified (GM) crops or non-GM crops, in compliance with the relevant legislation on the release of genetically modified organisms into the environment, food and feed legislation and the labelling requirements for GM organisms established by those legal acts.

Placing genetically modified organisms (GMOs) on the market is strictly controlled in the European Union. The main pieces of legislation (Directive 2001/18/EC on the deliberate release into the environment of genetically modified organisms, and Regulation No 1829/2003 on genetically modified food and feed) were developed to ensure the protection of human health and the environment, providing a harmonised approach to the assessment of potential environmental and health risks which might be connected to placing GMOs on the market. Their aim is also to ensure the free movement in the EU of those GMOs which are considered safe and to ensure consumer choice.

Once a GMO event is authorised for cultivation on the European Union market (according to any of the above mentioned legislation) the varieties containing this GMO event may be marketed throughout the EU. EU seed legislation (in particular Directive 2002/53/EC on the Common catalogue of varieties of agricultural plant species) requires that all seed varieties, including GM varieties, must meet defined criteria with respect to distinctness, uniformity and stability (D.U.S.). In the case of agricultural species the variety has to comply also with criteria connected to value for cultivation and use (V.C.U.). National authorities that have authorised the marketing of seeds of a certain new variety in their territory are obliged to notify the European Commission of their acceptance of the variety, so that it is included in the common catalogue.

All GMOs and food-feedstuffs derived from them have to be clearly labelled in the EU to ensure customer choice. European legislation allows for exceptions to the labelling requirements, to accommodate any adventitious or technically unavoidable presence of traces of GM material. Directive 2001/18/EC as amended by Regulation (EC) No 1829/2003 establishes a threshold (at a level of 0.9%) below which traces of market approved GM products intended for direct processing do not generate labelling requirements, if they are adventitious or technically unavoidable. Regulation (EC) No 1829/2003 establishes a labelling threshold for food and feedstuffs at the same level. Those labelling rules are also valid for organic products, including food and feed, according to Regulation (EC) No 834/2007.

No tolerance thresholds exist in the EU for products containing GM events which are not authorised for marketing and use. In this case "zero tolerance" applies, meaning that such products cannot be marketed or used in the EU.

Some producers and stakeholders in the food/feed chain, especially from the organic but also from the conventional sector prefer to keep their products free of any GM admixture. These producers demand labelling of products which contain GM admixture above the agreed practical "limit of quantification" of GM content (roughly around 0.1%). Since these particular requirements for segregation are not based on specific EU legislation, they will not be further considered in the document.

The ability of the agricultural sector to maintain different production systems is a key condition to ensure the customer's choice through the food chain. Agriculture is however an open system and the possibility of adventitious presence of GM crops in non-GM harvests exist. Consequently, adequate technical and organisational measures during cultivation, on-farm storage and transport may be needed to ensure coexistence.

It is recognised that local conditions, such as climate or local farm structures, may have a significant impact on the effectiveness and efficiency of coexistence measures. Therefore the establishment of coexistence measures is in the competence of individual Member States. In the Recommendation 2003/556/EC on "Guidelines for the development of national strategies and best practices to ensure the coexistence of genetically modified crops with conventional and organic farming" the European Commission advises that farmers growing non-GM crops should be able to maintain their production system while farmers who want to grow authorised GM crops have the opportunity to do so. Coexistence measures should not go beyond what is necessary to ensure that legally binding thresholds of 0.9% established by European legislation are respected. This Best Practice Document has been developed with this objective.

On 13 July 2010, the College has adopted a new Recommendation on coexistence replacing Commission Recommendation of 23 July 2003. The new Recommendation better reflects the possibility for Member States to establish coexistence measures to avoid the unintended presence of GMOs in conventional and organic crops and their need for sufficient flexibility to take into account their regional and national specificities and the particular local needs of conventional, organic and other types of crops and products.

This new Recommendation takes into account the fact that the potential loss of income for producers of particular agricultural products is not necessarily limited to exceeding the labelling threshold set out in EU legislation at 0.9%. In certain cases, depending on market demand and on the respective provisions of national legislations the presence of traces of GMOs in particular food crops –even at a level below 0.9%- may cause economic damage to operators who would wish to market them as non containing GMOs. In view of the new Recommendation, the best practices proposed in this document remain valid to ensure that legally binding threshold of 0,9% established by European legislation is respected, and given the flexibility of the options presented they represent also a useful tool for Member States which decide to aim at lower levels of admixture.

1.2. Mandate of ECoB

The majority of Member States have already developed specific legislation for coexistence or have developed technical segregation measures in the form of good agricultural practices (European Commission, 2009). However, practical experience in Europe is still confined to certain regions. In light of the above, research continues to be important in order to provide a sound scientific background to develop appropriate coexistence measures at national or regional level.

On 22 May 2006, the Agriculture Council adopted conclusions on the coexistence of genetically modified crops with conventional and organic agriculture. These conclusions highlight the political attention given by Member States to this issue. The Council also considered the outcome of the stakeholders' conference "Co-existence of genetically modified, conventional and organic crops - Freedom of Choice" (Vienna, 4-6 April 2006), which stimulated broad discussions with all stakeholders.

The Council Conclusions provide a specific mandate for the Commission to engage in further work in relation to coexistence. Amongst other objectives, the Council invites the Commission to:

- *Identify, in close co-operation with the Member States and stakeholders, best practice for technical segregation measures and, on the basis of this work, develop guidelines for crop-specific measures. At the same time, ensure that the crop-specific guidelines leave the necessary flexibility for Member States to take account of their regional and local factors (share of different crops in cultivation, crop rotations, field sizes, etc.).*

- *Explore with Member States possible ways of minimizing potential cross border problems related to coexistence.*

- *Explore sustainable solutions, which are in line with EU law, for areas where agricultural structures and farming conditions are such that farm level coexistence is difficult to achieve for a given crop.*

In order to contribute to the implementation of the Council Conclusions, Directorate-General for Agriculture and Rural Development (DG AGRI) and the Joint Research Centre (JRC) have agreed to set up a European Coexistence Bureau (ECoB).

The European Coexistence Bureau consists of a Secretariat and crop-specific Technical Working Groups (currently there is only one, dealing with maize coexistence).

The ECoB Secretariat is formed by permanent staff of the Joint Research Centre (JRC) of the European Commission and detached national experts seconded to the Commission. The secretariat works in close collaboration with DG AGRI. Its mission is to organise the exchange of technical-scientific information on the best agricultural management practices for coexistence and, on the basis of this process, to develop agreed crop-specific guidelines for technical coexistence measures.

The Technical Working Group consists of experts nominated by the Member States (one expert per country). Their main task is to develop a Best Practice Document.

1.3. Scope of the Best Practice Document

A reference document for the best practices for coexistence of GM maize with conventional and organic maize (Best Practice Document) contains a set of consensually agreed, best agricultural management practices that will ensure coexistence, while maintaining economic and agronomic efficiency on the farm.

The present Best Practice Document is limited to GM maize containing single transgenic events, as no practical experience regarding the cultivation of stacked events in Europe is available to date. The Best Practice Document could be applicable to both insect-resistant GM maize varieties (known as Bt maize, of which some events have already been cultivated in the EU) and to herbicide tolerant GM maize, of which one event (T25) was approved for cultivation in the EU but no varieties were registered and cultivated so far.

The Technical Working Group decided to limit the scope of the document to the compliance with legally binding thresholds. Given the flexibility of the options presented the document will represent also a useful tool for Member States which decide to aim at lower levels of admixture.

The Best Practice Document covers three types of maize production: cultivation for grain production (including feed/food uses and corn cob mix or CCM), cultivation for whole plant use (i.e. silage) and sweet maize production. The Best Practice Document does not cover maize seed production.

The Best Practice Document is intended to assist Member States in the development or refinement of national or regional legislative approaches to coexistence. Where Member States or regions do not intend to develop legislation for coexistence, the document could support the development of voluntary standards for good agricultural practice.

2. Maize Cultivation in European Union

2.1. Maize biology

Maize is an open pollinating crop (Purseglove, 1972) which relies on wind for pollen dispersal. Male and female flowers are separated on the plant by about 1 – 1.3 m (Aylor et al. 2003). Some of the currently grown varieties display protandry, e.g. pollen is shed before the silks of the same plant are receptive (Angevin et al. 2008), while in the case of others flowering is almost simultaneous (Rühl, personal communication). Self pollination of up to 5% may be observed (Purseglove, 1972 as cited in Messeguer et al. 2006).

Maize pollen grains are roughly spherical with a diameter of around 90 µm (Di-Giovanni et al. 1995) and are much larger than other wind pollinated species like timothy or ragweed (Jarosz et al. 2003). According to Kiesselbach, 1949 (as cited in Aylor et al. 2003) the average size maize tassel produces ~25 million pollen grains, however the number reported in more recent publication is much lower: 9.6 to 11.3 million pollen grains (Uribelarrea et al. 2002). Pollen is released mainly during dry (and drying) conditions, typically for a period of 5-8 days (Aylor et al. 2003). Most of the pollen remains within a few metres of the emitting plant (Bateman, 1947a,b; Raynor et al. 1972; Messéan et al. 2006), but some long-distance dispersal is also possible (Jones and Brooks, 1950; Byrne and Fromherz, 2003; Bannert and Stamp, 2007). No clear cut-off distance beyond which cross-fertilisation does not occur was found (Devos et al. 2005).

At anthesis water comprises about 60% of the fresh weight of maize pollen. Pollen dehydrates as it moves through the atmosphere until it lands on a stigma (Luna et al. 2001). Maize pollen is, in general, desiccation intolerant and loses water rapidly. Luna et al. (2001) found an 80% relative loss of pollen viability during 1 h after the pollen was shed and 100% after 2 h in dry conditions in Mexico.

The water content in maize pollen also plays an important role in its flight dynamic (as reviewed by Devos, 2008). During drying the pollen shape changes and its density increases, which changes its settling speed. The lightest (here also the driest) pollen travels the longest distances, but is the least viable (Aylor, 2002 as cited in Devos, 2008), which makes high levels of outcrossing at long distances less probable.

Maize has lost the ability to survive in the wild during the long domestication process and needs human intervention to disseminate its seeds. Also it cannot persist as a weed, although the kernels from the previous year may survive the winter and germinate the following year (OECD, 2003).

Maize can produce fertile hybrids with some teosinte species. No outcrossing of maize with *Tripsacum* species is known to occur in the wild (OECD, 2003).

None of the above mentioned species can be found in Europe, so the gene flow between maize and its wild relatives cannot occur in the EU. However the commercially grown hybrid maize can outcross with the landraces, which are local plant varieties that differ from cultivars that have been developed by modern plant breeding. Landraces represent a crucial component of plant genetic resources and their preservation against gene introgression from modern varieties, both genetically modified and conventional, is necessary.

2.2. Maize crop production in the EU

The EU is the fourth largest grain maize producer in the world, after the USA, China and Brazil. In the EU-27, grain maize was cultivated on about 5.6 million hectares (2009) with a production of 57 million tonnes (2009). Another major maize product is silage maize (or green maize), produced on about 5.1 million hectares in 2008 (Eurostat[5], data retrieved February 2010).

Aggregated EU data suggest that 75% of grain maize is used for feed production, and 20% for industrial use (General Association of Maize Growers (AGPM) website[6]; data retrieved December 2008).

2.2.1. Cultivation area for conventional, organic and GM maize

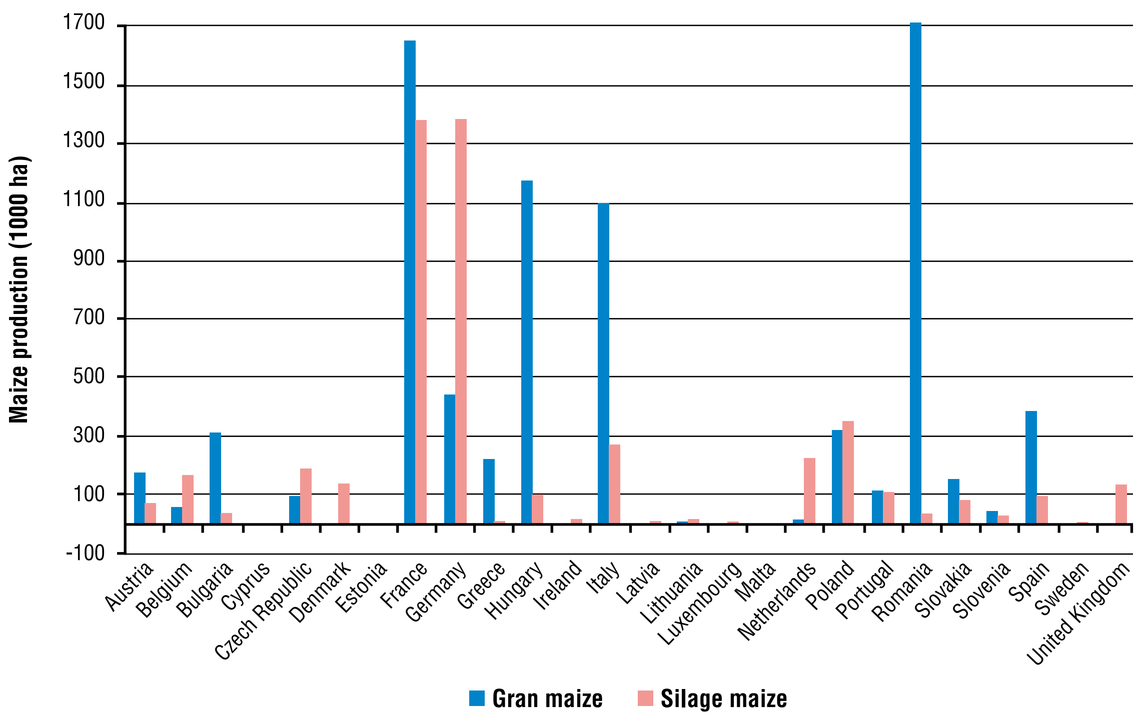
Grain maize – total production area

In the EU-27, the main grain maize growers by area are Romania (29%), France (19%), Hungary (13%) and Italy (12%) (see Fig. 1). Based on production, France (which makes up 24% of the EU27 production, on average between 2004 and 2008) and Italy (17%) rank before Romania (15%) and Hungary (13%).

Grain maize – organic production area

Data for organic grain maize production is scattered and available only for some EU Member

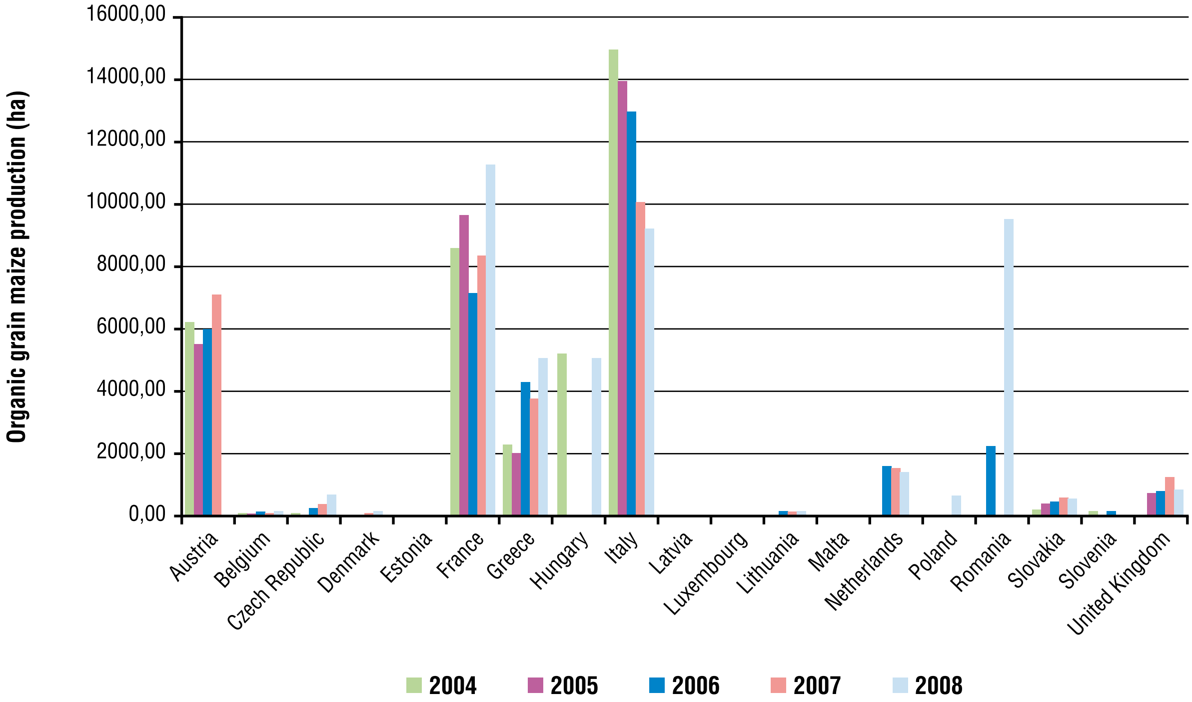
Figure 1: Area for grain and silage maize production (average of 2004-2008)



Data: Eurostat; no data for grain maize production for MT, CY, DK, EE, IE, LV, SE.

5 http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database
6 http://www.agpm.com/

Figure 2: Organic grain maize area in the EU (2004-2008)



Data: Eurostat (all countries included in the graph for which data was mentioned at least for one year, including 0 ha).

States (Fig. 2). Generally, comparatively small areas are dedicated to organic maize production, 14 ha in Slovenia to 11279 ha in France (2008). Other big producers of organic grain maize are Italy and Greece (9247 ha and 5061 ha in 2008, respectively). Shares of organic in grain maize production by area range from 0.14% (Belgium), 0.5% (France), 1.3% (Italy) to 3.7% (Austria) and 7.2% (The Netherlands)[7].

GM maize – total production area

Currently, GM maize (the only insect-resistant type, so called Bt maize) is cultivated in six EU Member States to varying extents (Table 1). Nearly three-quarters of the EU production area is located in Spain, with a total of about 79000 hectares in 2008. In Spain, the cultivation area of GM maize represents about 22% of the national grain maize production area. However the regional adoption of GM maize cultivation is uneven (due to differences in the pressure of corn borer pests) and in some regions (Catalonia) the share of GM maize is already above 70-80%. GM maize in Spain is used for grain production and sold to feed manufacturers.

Silage (or green) maize – total production area

France and Germany (accounting for 28% of the EU average production area in 2004-2008 each) are the two main producers of silage maize in the EU (Fig. 1). Whereas in France the area cultivated for silage maize is similar in size to the area cultivated for grain maize, in Germany silage maize is the predominant maize cultivated.

Silage (or green) maize – organic production area

For organic silage maize production very little data is available (Fig. 3). The areas cultivated with organic silage maize in some different Member States vary considerably from one year to the next (e.g. Greece) and data are

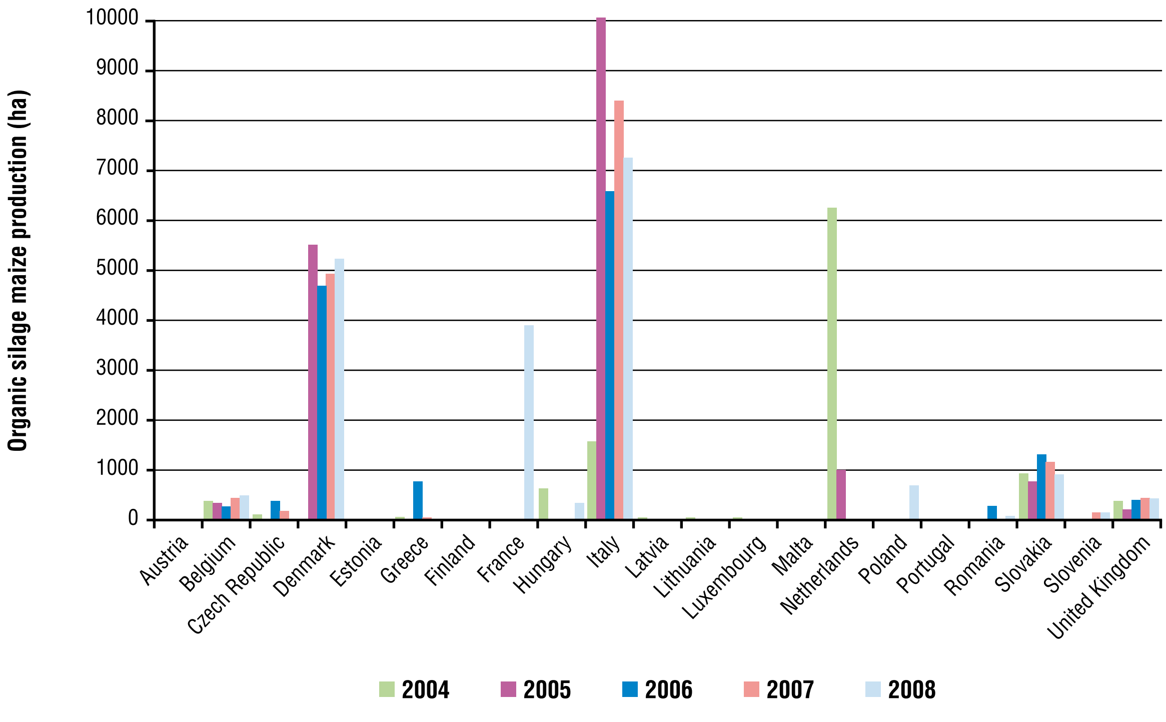
7 In general, the organic area accounted for about 4% of EU25 Utilised Agricultural Area in 2005 (6.1million ha), with the highest share being 11% in Austria in 2005.

Table 1: Bt maize cultivation in the EU (in ha)

	2005	2006	2007	2008	2009
Czech Republic	150	1290	5000	8380	6480
France	492	5028	22135	0	0
Germany	341	950	2685	3173	0
Poland[8]	0	100	327	3000	3000
Portugal	750	1250	4263	4851	5094
Romania			350	7146	3244
Slovakia	0	30	900	1931	875
Spain	53225	53667	75148	79269	76057
EU	54958	62315	110808	107750	94750

Data: for 2006,2007 James 2007 (ISAAA); for 2008 Polish newsletter Kukurydza Nr 52 2008 based on ISAAA data, adapted; data for 2009: DE,FR,SK data provided by TWG members, CZ: "Experience with Bt maize cultivation in the Czech Republic 2005 – 2009" Czech Ministry of Agriculture; PL, RO James 2009 (ISAAA); PT: Coexistence between genetically modified, conventional and organic crops. (Coordinators: de Carvalho P.C. and Algarroba F. Status Report for 2009, Lisboa; ES: Spanish Ministry of Agriculture (http://www.mapa.es/agricultura/pags/semillas/estadisticas/serie_maizgm98_06.pdf)

Figure 3: Organic silage maize production in EU Member States



Source: Eurostat (all countries included in the graph for which data was mentioned at least for one year, including 0 ha).

not available for all years. For countries with more continuous data available, the share or organic silage maize area ranges from 0.23% (Belgium) to 1.8% (Italy).

Sweet maize

Sweet maize, compared to grain maize and silage maize, is a niche market, with a worldwide

8 Data for Poland not confirmed

cultivation area of about 350,000 ha [General Association of Maize Growers AGPM; website]. About 20% of production takes place in the EU-27 (ca. 70,000 ha). France was reported to have 20,500 ha (2006), whereas Germany reported 1525 ha (2007). Greece and The Netherlands each have about 700 ha dedicated to sweet maize production [data from TWG members].

2.2.2. Maturity classes used

The overview of maize maturity classes used in Member States for grain and silage production is summarised in the Table 2 below. In order to allow comparisons the maturity classes are expressed in FAO units, even if this unit is not normally used in a given Member State.

Table 2: Maturity classes of maize used in Member States

Member State	Use	Maturity classes
Austria	Grain maize	200 - 490
	Silage maize	230 - 440
Belgium	Grain/Silage	170 – 250; biogas production 260 - 330
Bulgaria	data not provided	
Cyprus	Silage maize	600 - 700
Czech Republic	Grain/Silage	180 - 440, usually 200-350
Denmark	Silage maize	170 - 250
Estonia	Silage maize	180 - 200
Finland	Silage maize	150 - 200
France	Grain maize	180 -600
	Silage maize	180 - 400
Germany	Grain/Silage	170 - 350
	Biomass	~500 - ~600
Greece	Grain maize	<550 - >700
	Silage maize	650 - >700
Hungary	Grain/Silage	200 – 500 (600)
Ireland	Silage maize	plastic cover: 220 - 270 uncovered: 180 - 230
Italy	Grain/Silage	300 (200 in the case of non-irrigated fields) - 700
Latvia	Silage maize	225 - 230
Lithuania	Silage maize	220 - 230
Luxembourg	Grain maize	200 - 260; energy maize up to 350
	Silage maize	180 - 280
Malta	data not available	
Netherlands	Grain/Silage	180 - 250
Poland	Grain/Silage	180 - 290(300)
Portugal	Grain maize	200 - 600
	Silage maize	200 - 700
Romania	Grain maize	220 - 600
	Silage maize	250 - 700
Slovakia	Grain/Silage	200 - 500
Slovenia	Grain/Silage	100 – 700 (80% 280 – 400)
Spain	Grain/Silage	200 - 800
Sweden	Silage maize	180 - 230
United Kingdom	Grain/Silage	190 - 240

2.2.3. Sowing dates

The overview of dates at which maize is sown in Member States for different kinds of production is summarised in the Table 3 below.

Table 3: Maize sowing dates

Member State	Use	Sowing dates
Austria	Grain/Silage	10.04 – 05.05 (10.05 in the case of wet land)
	Forage maize	25.04 – 31.05
Belgium	Grain/Silage	15/20.04 – 15.05
Bulgaria	data not provided	
Cyprus	Silage maize	15.03 – 30.06
Czech Republic	Grain/Silage	Warmer regions (Moravia) 10.4.-25.4. Other regions 15.4.-10.5.
Denmark	Silage maize	10.04 – 30.04
Estonia	Silage maize	01-20.05
Finland	Silage maize	15.05 – 06.06
France	Grain maize	Very early varieties: 15.04 – 15.05 Early to mid early varieties: 10.04 – 15.05 Mid early to late varieties: 05.04 – 15.05
	Silage maize	Very early: 15.04 – 15.05 Early to mid early: 10.04 – 15.05 Mid early to late: 05.04 – 15.05
Germany	Grain/Silage	Southern part beginning of April Northern part mid April
Greece	Grain maize	01.04 – 20.04 (only 5% sown 15.03-31.03)
	Silage maize	15.03 – 20.04 (only 5% sown after 20.04)
Hungary	Grain maize	10.04 – 30.04
	Silage maize	10.04 – 20.05
Ireland	Silage maize	Plastic cover: 01.04(early region)/14.04(late region) – 08.05 Open cultivation: 14.04(early region)/21.04(late region)– 08.05
Italy	Grain/Silage	Beginning of March – end of May As second crop: 15.05 - June
Latvia	Silage maize	Southern region 05-10.05 Northern region 10-15.05
Lithuania	Silage maize	01-20.05
Luxembourg	Grain/Silage	20.04 – beginning of May
Malta	data not available	
Netherlands	Grain/Silage	20.04 – 10.05
Poland	Grain/Silage	20.04 – 10.05
Portugal	Grain maize	15.03 – 30.04
	Silage maize	15.04 – 20/25.05
Romania	Grain maize	Northern and Central regon:10.04 – 10.05 Eastern region: 01.04 – 10.05 Southern and Western region: 25.03 – 30.04
	Silage maize	Northern and Central regon:15.04 – 15.05 Eastern region: 10.04 – 10.05 Southern and Western region: 01.04 – 30.04
	Forage maize (as second crop)	Northern and Central regon:15.06 – 15.07 Eastern region: 10.06 – 15.07 Southern and Western region: 10.06 – 01.07
Slovakia	Grain/Silage	20.04 – beginning of May
Slovenia	Grain/Silage	10.04 – 25.04
Spain	Grain/Silage	Beginning of March – end of May
Sweden	Silage maize	20.04 – 10.05
United Kingdom	Grain/Silage	Late March (plastic cover) – end of May

2.3. Existing segregation systems in maize production

The segregation of specific types of maize is a well known issue. There are several segregation systems in place, although none of them deal with GM varieties' segregation. The only system with a "regulatory" status is the production of certified maize seeds grown for sale. Other production systems (waxy maize, sweet maize) follow "private" segregation schemes and standards prepared by industry and farmers. In a brief overview below, the applicability of such systems to segregate GM from non-GM maize is discussed.

Certified maize seed production

Legislation aimed at ensuring a sufficient purity of maize seeds grown for sale exists throughout the world (Bock et al. 2002).

Maize seed varieties currently grown in Europe are F1 hybrids, and the production plots are set up with separate fertile male lines and de-tasselled female lines. Due to the lower amounts of pollen produced in a seed production field (only the male plants produce pollen, and the amount of pollen produced is lower than in conventional varieties) such a system is more sensitive to cross-pollination by surrounding maize crop fields (Messéan et al. 2006, Sanvido et al 2008). Therefore, measures to prevent cross-pollination in maize seed production fields are necessarily stricter than those needed to protect normal crop production fields. Thus, segregation measures used in seed production cannot be directly applied to achieve GM and non-GM maize coexistence in crop production.

Waxy maize

Waxy maize contains a high proportion of amylopectin in its starch (>99%), which makes it more suitable for use in processed food (stabilisers and emulsifiers production) and in the paper industry (Bock et al. 2002).

The price premium paid by the processors depends on the meeting of quality standards set by the companies involved. Usually the minimum purity threshold for waxy maize production is 96%. As the tolerance for impurities in waxy maize production (4%) is significantly higher than the labelling threshold for non-GM production (0.9%), the measures used for segregation in this production system are not directly applicable to ensure GM/non-GM maize coexistence.

Sweet maize

Sweet maize production differs from other maize types. It is harvested at the stage when kernels have high sugar content (before maturity, at the early dough stage). Currently the super-sweet varieties, which contain more sugar than sweet varieties and convert it to starch less rapidly therefore maintaining their sweetness for a longer time after harvest, are reported to comprise over 90% of fresh market sales of sweet maize (Beckingham, 2007).

Cross-pollination with other maize types can cause starchy kernels to be produced and may result in reduced eating quality. Therefore, all sweet corn must be isolated from other maize fields.

No concrete threshold exists in sweet maize production. However, the isolation distances proposed by various stakeholders of between 200 and 400 m exceed even the requirements for seed production.

3. Review of the available information on management of adventitious GM presence in maize crop production

The final GM content in a non-GM harvest at the first point of sale may come from various sources. The whole maize production system has been analysed many times, recently by Devos et al. (2009), in order to identify the sources of admixture and possible management practices. The chart below presents the sources of GM admixture in non-GM maize production at the various stages of the process, starting from seed material up to the first point of sale.

Below follows a review of the available literature and information presented by the TWG-Maize concerning sources and management of adventitious presence in maize production.

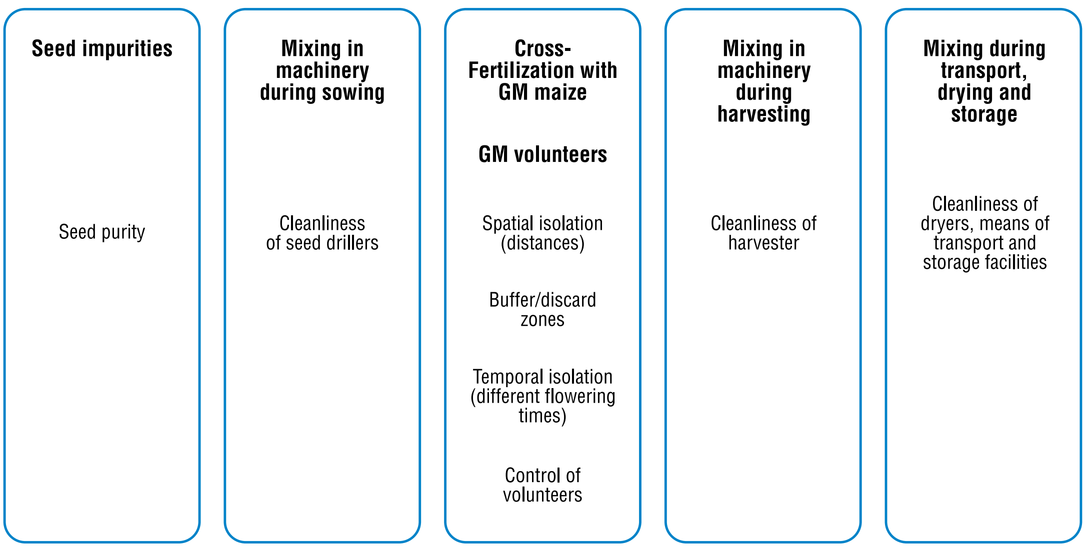
3.1. Seed impurities

Among the potential sources of adventitious GM presence in maize harvests, the presence of GM seeds in conventional seed lots is a critical one and must be managed to achieve coexistence. It is clear that the best approach to manage this is the use of certified maize seeds that comply with legal EU obligations. Below we review such current legal obligations and also the results of recent surveys in Member States on the purity of commercial maize seed (where they refer to the adventitious presence of GM material).

3.1.1. Current legal obligations

European and international seed legislation recognises that an absolute purity of seed lots is not possible. Cross-pollination is a usual phenomenon, particularly in allogamous crops such as maize. Maize seed production takes place in open fields and cross-pollination cannot be fully controlled. Therefore several purity standards have been established, regulating i.e. the presence of traces of seeds of other varieties or other species in the seed lots.

Figure 4: Potential sources of GM admixture in non-GM maize crops and possible management practices



Based on: Devos et al. 2009.

Directive 2001/18/EC on GMO release allows for the establishment of thresholds for the adventitious presence of GM seeds in non-GM seed lots. These thresholds (currently under assessment by the Commission) should be lower than 0.9% to ensure that the labelling threshold of final harvests is possible to comply with.

Currently, without a threshold above which adventitious or technically unavoidable presence of authorised GM seeds in non-GM seed lots should be labelled, any detectable traces of GM seeds authorised for cultivation should trigger the labelling of the seed lot as "containing GM".

Maize seed lots proved to contain traces of *not authorised* GM events must not be marketed within the EU.

Over the last few years, discussions have taken place in the European Commission and in experts committees on the possible values of labelling GM thresholds for seeds of different species. Several values have been mentioned. For the purpose of the work of the TWG-Maize in establishing the best practice for segregation of maize crop production, different scenarios were considered in the Best Practice Document, corresponding to different scenarios for possible impurity level in conventional maize seed lots of 0.1%, 0.3% or 0.5%.

The fact that the GM content in this document is expressed in haploid genome equivalents was not considered contradictory to the possible establishment of seed thresholds in % of seeds (as in other seed standard legislation).

3.1.2. Information on the results of inspection carried out in Member States

The monitoring and control of adventitious presence of GMOs in seed lots is the responsibility of Member States. A study of practices in this area was conducted in 2006 (http://ec.europa.eu/environment/biotechnology/pdf/seeds_study_2007.pdf). A total of 23 out of 27 Member States provided the requested information.

The majority of EU Member States (19) have enforced a formal programme for inspection and control of adventitious traces of GMOs in conventional seed lots. Two further Member States, Belgium and the United Kingdom, had no formal programme, but GM presence was monitored within either a nationally coordinated programme (Belgium) or a voluntary programme (United Kingdom). In Latvia, the controls had been conducted on an ad hoc basis. Finally three Member States – Estonia, Lithuania[9] and Malta – did not have any inspection or control programme in place.

In the absence of an EU agreed threshold for adventitious presence of GM material in conventional seed lots, the questionnaire revealed that the level of GM presence at which lots are either rejected or GM labelling is requested was not consistent across the Member States. The majority of Member States operates a zero tolerance policy (defined by the agreed practical "level of quantification", around 0.1%). Others, like the Czech Republic, Greece, Sweden[10] and The Netherlands, operate a "tolerance level" – in the case of maize 0.5%.

Also, different units of measurement are used in the Member States. The majority (10 Member States) used the haploid genome equivalents (% GM DNA), while others used % seeds (2 Member States) and % mass (2 Member States). It should be noted that the same measurement units are not always used within the same country, i.e. in the case of Federal Länder of Germany[11].

9 According to the information provided by the Lithuanian TWG member, the GMO targeted control and monitoring rules are in force. In the samples analyzed during 2006-2009 no GMO traces were found.

10 According to information provided by the Swedish TWG member, the policy has been changed. Currently the legal steps would be triggered by the identification of GM admixture in a non-GM seed lot irrespective of the admixture level.

11 According to information provided by the German TWG member, currently all Federal Länder use the haploid genome equivalents.

The total number of maize lots analysed between 2001 and 2006 is not known. The number of incidents of adventitious presence of authorised GMOs in maize seed lots reported by Member States was estimated at 274 (390 if figures from Italy were included[12]), while a presence of unauthorised GM maize events was detected in 26 cases.

The levels of adventitious presence of authorised events in maize seed lots identified in 2006 were generally low, with 16 cases not exceeding 0.1% and 18 between 0.1% and 0.3%. Only in 3 cases the adventitious presence exceeded 0.9%.

In summary, for 2006, 1.9% of conventional seed lots tested positive for GMO adventitious presence of authorised events, and traces of non-authorised events were found in 0.28% of samples tested.

3.2. Sowing

Scientific data regarding possible GM admixture resulting from seeds remaining inside seed drillers after sowing operations is very limited.

According to Hanna et al. (2002) small numbers of seeds may be stuck somewhere inside the seed driller and later drop out over a short distance in a row at a random time. It is also not known if the remaining seeds will exit the seed driller individually over a long distance or as a concentrated group at an unknown time and location.

12 The figure reported by Italy (116 cases) seemed high and the authors of the report considered it might refer to tests conducted on grain maize imported for food/feed use; it was not possible for the authors to confirm or refute that. According to information provided by the Italian TWG member after consultation with Ufficio Repressione Frodi (which is in charge of the analysis) data reported for Italy are referring to grain maize for seed use and not for food/feed.

Operators who remove only visible seeds from the seed driller when changing maize varieties would probably get seed contamination below 1% after operating the seed driller over a 1000 ft (304,8 m) distance, when 20 seeds/1000ft of row at 35000 seeds/acre (assuming 30 inch row) are sown. As mentioned previously this admixture may occur at an unpredictable location in the field, unless the seed driller is thoroughly cleaned.

According to Messéan et al. (2006), seed drillers are relatively easy to clean and many farmers do it routinely before starting to sow different varieties. Therefore the sowing step was not considered a significant source of possible GM admixture in the case of maize.

Cleaning recommendations based on empirical work conducted at the Iowa State University, reported by Hanna et al. (2002), depend on the type of seed driller and seed-metering mechanism.

3.3. Cultivation

The outcrossing due to incoming GM maize pollen was considered the main source of adventitious GM presence in non-GM maize harvests. The level of outcrossing can be reduced either by the use of appropriate isolation distances and/or pollen barriers or by the separation of flowering times of GM and non-GM fields. Volunteers of GM maize from previous crops can also be potential sources of GM adventitious presence.

3.3.1. Outcrossing with GM maize

3.3.1.1. Isolation distances

Cross-pollination between fields of maize has been the subject of a large number of recent research projects in Europe and elsewhere (prompted by the need to develop coexistence regulations). These projects (and prior research) coincide in that cross-pollination levels decrease rapidly with the distance from the pollen source in adjacent fields, and therefore spatial isolation of non-GM maize fields from GM maize fields is a recognised strategy for reducing outcrossing levels.

The task of assembling, analysing and comparing data on cross-pollination derived from all these projects has also been recently attempted in comprehensive reviews of the evidence available (reviewed by Devos et al. 2009 and by Messeán et al. 2009).

The range and typology of studies considered by the TWG-Maize

The TWG-Maize identified and considered relevant results from a large set of experiments investigating cross-pollination in maize. These include experiments conducted in the USA (Goggi et al. 2006, 2007; Halsey et al. 2005), Italy (Della Porta et al. 2008), the UK (Henry et al. 2003; Weekes et al. 2007), Germany (Langhof et al. 2008a; Weber and Bringezu 2005; Weber et al. 2007; Langhof et al. in press), Canada (Ma et al. 2004), Spain (Pla et al. 2006; Messeguer et al. 2006), The Netherlands (Van de Wiel et al. 2009) and Switzerland (Bannert and Stamp, 2007).

Altogether, the above set of studies represent various countries and locations, years, different field conditions, scales of analyses, and ways of estimating gene flow. We can therefore be confident that a realistic proportion of gene flow variation has been measured and that the experiments, when considered together, provide a useful and relevant data set.

Regarding experimental design and scale of analysis, the above set of experiments considered by the TWG-Maize include:

- Small donor fields (GM or marker variety) inserted (and therefore with adjacent sides) into a conventional maize field, e.g. Della Porta et al. (2008);
- Donor and receptor fields side by side (donor GM fields of varying size; includes split halves of commercial fields in which one half acts as donor and another as receptor), e.g. Weber et al. (2007);
- Donor and receptor fields positioned in a commercial or simulated commercial landscape, e.g. Bannert and Stamp (2007).

To estimate cross-pollination, the large majority of these studies use the % of individual F1 progeny with the donor trait (be it a GM trait or a colour marker). A few (usually recent) studies instead use the % of GM DNA in the F1 progeny. However, those that have attempted to statistically compare datasets of different experiments (see below) have been able to use conversion factors between different GM measurement units.

Some studies provide exhaustive information on levels of cross-fertilisation in relation to different distances within a field, while others report the mean GM content in the whole material harvested from non-GM fields.

Comparing data sets from different experiments

A comprehensive study of available data was published by Sanvido et al. in 2008. Studies compared include many of those contributed by the TWG-Maize. The majority corresponded to the side by side design or small donor inserted in receptor field type. The statistical analysis of cross-fertilisation rates showed that distances from the pollen source of 10-25 m resulted in average cross-fertilisation rates of 0.35%. Those values are considerably lower than the cross-fertilisation rates found at 0-10 m from the pollen source, averaging in this review 5.72%. Further increase of the distance from the pollen source reduced cross-fertilization rates, but the rate of reduction was smaller. For example, increasing the distance from 10-25 m to 25-50 m only reduced cross-pollination averages from 0.35% to 0.23%, and at distances from the pollen source of over 50 m cross-fertilisation was still detected at 0.19%.

Most studies compared contained non-GM maize in the space separating a donor field and sample points and not bare ground or other crops (adjacent fields). Also the majority of studies considered for validation of suggested isolation distances used the above mentioned experimental design (Meier-Bethke and Schiemann, 2003; Weber et al. 2007; Henry et al. 2003; Messéan, 1999 and POECB, 2004).

Sanvido et al. (2008), considering the rapid decrease of cross-fertilisation rates within 25 m in experiments with adjacent or concentric fields, proposed bare ground isolation distance of 50 m for grain maize. Riesgo et al. (in press) concluded, on the basis of statistical analysis, that separating fields with genetically modified maize from those with non-GM maize by 40 metres is sufficient to keep GM adventitious presence below the legal labelling threshold.

Another recent paper (Allnutt et al. 2008) compared over 55 field trials of the commercial split-field design performed in the UK, and was able to fit a mathematical function relating % of GM DNA found in receptor fields with the orthogonal distance to the pollen source. The function allows one to not only estimate the average % of outcrossing at a given distance but also to predict the probability of remaining below the desired threshold at different confidence levels. The function was validated afterwards with a number of studies performed in other EU countries (Spain - Pla et al. 2006, Italy - Della Porta et al. 2008, Germany - Weber et al. 2007), with varying designs including fields separated by bare ground and a landscape of commercial GM/non-GM maize fields. The function can also include variables such as receptor field size. In the worst case scenario (small recipient field, 0.25 ha) the statistical analysis shows that, with a confidence level of 98%, the distances of 19 m, 41 m and 251 m are sufficient to comply with 0.9%, 0.5% and 0.1% GM DNA content being the result of cross-pollination. Since different types of experiments are included in the dataset, the results are, according to the authors, applicable to buffer zones[13] (of non-GM maize) or bare ground isolation distances.

Finally, others have developed predictive gene flow models at the landscape level which can be used to assess the feasibility of coexistence in various contexts and to identify the coexistence measures that farmers could put into place. One of these models is MAPOD, elaborated by Angevin et al. 2008. According to data reported by Messéan et al. 2006, based on MAPOD simulations, in the case of the smallest fields (< 5 ha) the isolation distance necessary to comply with the labelling threshold was 50 m, and 300 m was sufficient to meet the 0.1% target level.

Models reproduce the functioning of agro-systems and take into account the relevant factors and processes as well as their interactions. They thus allow the simulation of the behaviour of agro-systems in non-observed situations at different scales (from field to field to landscape) (Messéan et al. 2006).

Maize pollen dispersal: different types of modelling for different uses

Several types of approaches to model gene flow exist, in particular pollen dispersal, from empirical to physical models (Lavigne et al. 2004; Beckie and Hall, 2008).

One of the approaches is to fit simple mathematical functions to experimental data. Such models are difficult to extrapolate to other climate or cropping systems (Bateman, 1947; Gliddon, 1999; Funk et al. 2006). Their predictive

13 Buffer zone – a number of rows of non-GM maize sown along one or more borders of the GM field (usually facing the non-GM field) in order to reduce pollen-mediated gene flow. It may replace the isolation distance fully or partially. The non-GM maize sown as a buffer zone must be of the same maturity class as the GM variety and must be sown at the same time. It may be harvested together with the GM crop and must be labelled as containing GM when placed on the market.

value remains restricted to a specific context (Beckie and Hall, 2008).

On the contrary, mechanistic or physical models represent physical phenomena and describe the flow in which pollen grains are dispersed, as well as the conditions of their emission, transport and deposition (McCartney and Fitt, 1985; Loos et al. 2003; Jarosz et al. 2004; Dupont et al. 2006). These models are very informative but include many parameters, some of them being difficult to assess. They require numerous input data and are often costly in terms of computation time. For most of them, only the pollen transportation is modelled, which allows a better understanding of the phenomenon, while neither the pollen viability nor the silk fecundation are modelled, thereby limiting their use for the efficiency evaluation of coexistence rules.

An intermediate approach exists, which could be qualified as quasi mechanistic: only the major phenomena are modelled in a simple form while the parameters with a biological/physical meaning are estimated using field experiments (Klein et al. 2003; Angevin et al. 2008). This approach combines simplicity of use and adaptability to different agro-climatic contexts.

Whatever the type of model, the accuracy of its predictive value and its range of validity has to be evaluated while comparing its output data with experimental results (different from those used to design the model).

The specific case of open pollinated varieties

The vast majority of maize cultivation nowadays takes place using hybrid seeds, instead of "open pollinated" varieties. Data from older experiments suggests that the cross-fertilisation rate among open pollinated varieties was distinctly higher than those reported for hybrid varieties, probably due to the biology of maize flowering (reviewed by Sanvido et al. 2008). Ingram (2000) analysed data mostly from older experiments in which open pollinating varieties were used. To limit outcrossing levels to 1% or less required, according to the author, 200 m of isolation distance and compliance with the 0.5% and 0.1% target levels 300 m and 500 m respectively.

Cultivation of open pollinated varieties is however important for some Member States, i.e. Italy where several traditional local varieties are registered in regional repertoires or local lists on the basis of regional laws.

Seeds of local varieties in Italy are exchanged within local communities – "conservation networks", which are formed by interested farmers. Local varieties are diffused in small areas and the quantities of seeds being exchanged are limited. No data concerning the production, area or amounts of seeds being planted are currently available.

Bitocchi et al. (2009) compared an "old" collection of landraces, obtained before the introduction of modern hybrids, with the recent collection. The detected level of introgression was very variable among populations and in most of them was low. On that basis, the authors concluded that the coexistence between different types of agriculture is possible with the adoption of correct practices aimed at limiting introgression from undesired sources. Those practices could be the same in the case of conventional and GM varieties. Therefore there is no need to elaborate the dedicated coexistence measures.

Buffer and discard zones[14]

Several researchers have concluded that, at close distance, a barren zone between donor and receptor maize fields is less effective at reducing cross-pollination than the same space planted with maize plants (so called "buffer zones"). Those non-GM plants act both as an isolation distance/

14 Discard zone - a number of rows of non-GM maize facing the GM field(s) that will be harvested separately from the non-GM crop and must be labelled as containing GM when placed on the market.

physical barrier and as an additional pollen source, which increases the pollen competition (reviewed by Beckie and Hall, 2008).

Buffer zones

The majority of data relating cross-pollination with the distance from source was obtained in experiments using *adjacent* fields. This suggests that buffer zones are an efficient measure for reducing cross-pollination, which could be applied, in theory, without the need for a minimum separation distance between fields.

For very small fields however there is always the practical limitation that the necessary size of a buffer zone may represent too high a share of the field (even if a wide enough buffer zone would limit cross-pollination sufficiently). In practice, a minimum isolation distance may be required in certain worst cases. Messéan et al. (2006) suggest that buffers alone in the case of very small non-GM fields located downwind of large donor fields do not always lower the adventitious presence to below the labelling thresholds. Devos et al. (2008) have made a similar suggestion.

A statistical analysis of several experiments using adjacent fields (Sanvido et al. 2008) showed that average cross-fertilisation rates were 0.35% at sample points located 10-25 m from the pollen source; a 25 m wide buffer was considered sufficient to limit the cross-fertilisation rate at the field border to an arbitrary level (0.5%).

Gustafson et al. 2006 also suggested the use of 10-20 m buffer zone as a measure for limiting cross-fertilisation to levels not exceeding the "labelling threshold". Similar recommendations were also based on a field study conducted in 2005 in Northern Greece (unpublished data, kindly provided by G.N. Skaracis).

Those data are in accordance with the recently released recommendations of the European SIGMEA project. On the basis of a very comprehensive analysis of data performed in experiments conducted in Europe, buffer zones of 20 to 30 m were recommended as a measure for allowing the reduction of the GM content in non-GM harvests below the labelling threshold (Messéan et al. 2009).

When GM and non-GM fields are not adjacent but separated in the landscape by a certain distance, the efficacy of buffer zones is lower and may even be unnoticed. Messéan et al. (2006) showed that non-GM maize buffers sown around GM maize fields are effective only if the GM and non-GM fields are located close to each other. Results of field trials conducted in Northern Germany (Langhof et al. in press) show a lack of efficiency of 9-18 m buffer zones when the fields were separated by at least 51 m of bare ground.

Buffer zones as a measure for coexistence can be particularly attractive to farmers using insect-resistant GM maize (Bt maize). In the case of Bt maize, non-GM pollen barriers can also be used as refugia and are actually recommended in order to delay the appearance of populations of pests resistant to the Bt protein (Vacher et al. 2006). In the case of herbicide tolerant maize the buffer zones may be more difficult to implement and manage since two different herbicide regimes would have to be applied in the same field.

Discard zones

The buffer zone can also be "delimited" around the receptor field (non-GM field) receiving the common name of "discard zone" since the harvest would have to be done separately and labelled and sold as GM. According to Della Porta et al. (2006), as cited in Devos et al. (2008), discard zones are more effective at reducing cross-fertilisation levels than buffer zones created around the donor (GM) field. They suggest that 2 rows of non-GM maize discard were as effective as 12 rows of buffer zone created around the donor field. Gustafson et al. (2006) also proposed different widths for buffer or discard zones.

According to results obtained in Germany (Langhof et al. in press) a separate harvest of the first 3-6 m of non-GM fields located 51 m from a GM-pollen donor may reduce considerably the GM content in the remaining harvest. In the case of a 50 m deep recipient field the discarding of 3 m of non-GM maize reduced the total GM content by over 55% (0.9 to 0.4%), while the reduction obtained by discarding 6 m reached over 71% (0.7 to 0.2%). Further increase of the discard zones' width, to 9 or 12 m, did not show an additional considerable effect. The effect was also less pronounced in the case of increased depth of receptor fields.

Efficacy of buffer zones composed of crops other than maize

The performance of non-maize buffers was tested by Klein et al. (2002) and Langhof et al. (2008b). Experiments show that the outcrossing rates in maize receptor fields were similar for both sunflower (tall crop) and clover grass (small crop). The obtained results suggested that non-maize buffers are not as effective in reducing cross-pollination as maize buffers (Langhof et al. 2008b).

Possibility to replace isolation distances by buffer/discard zones

The findings discussed in previous sections show that isolation distance and/or buffer zones can be used effectively as coexistence measures. However, in some situations, as reviewed by Devos et al. (2008), the isolation distances may be difficult to implement (i.e. in regions where maize is grown on a large area). Therefore the possibility for farmers to choose either isolation distances or buffer/discard zones was recommended by these and other authors.

The combination of both measures and the possibility to replace isolation distances by buffer zones is discussed by several authors proposing different "conversion factors".

According to Brookes et al. (2004) one maize buffer row is as efficient in reduction of cross-pollination between maize fields as 10 m of bare ground separation distance. A slightly higher exchange ratio was proposed by Ingram (2000) who considered 12 m of open field separation comparable to one row of non-GM maize barrier. In contrast, data obtained by Langhof et al. (in press) showed that 12 or 24 rows of non-GM maize buffer created at the donor field edge had no effect on the reduction of GM content in a non-GM field, when combined with 51 m of isolation distance. Klein et al. (2002) assessed that planting 2.4 m of male sterile maize plants can replace 10 m of isolation distance (approximately one row replaces 3 m of isolation distance). The results of this study are however not comparable to previously mentioned ratios, as male sterile plants do not produce pollen and therefore act only as physical barrier between fields.

Maize barriers (discard zones) are used in statutory programs for certified seed production, allowing the decreasing of isolation distances between seed and crop maize fields. In this case, each row of male lines replaces 5 m of isolation distance (GNIS, 2003; Romanian seed law).

3.3.2. Temporal isolation

The availability of pollen during the period when silks are receptive has been recognised as a crucial factor affecting cross-pollination levels (Bateman, 1947b; DuPlessis and Dijkhuis, 1967; Hall et al. 1981; Bassetti and Westgate, 1994; Devos et al. 2005). The highest levels of cross-pollination are observed when the difference in flowering times between donor and receptor fields does not exceed 3 days (Bannert et al. 2008; Della Porta et al. 2008).

Even relatively small differences in flowering times (4-5 days) may lead to a 25% reduction in outcrossing between maize fields (Della Porta et al. 2008). According to Angevin et al. (2008), a four-day flowering lag between donor and receptor fields is sufficient to reduce the GM content in the recipient field to levels below 0.9%. A six-day flowering lag was observed to cause a 50% reduction in outcrossing (Della Porta et al. 2008; Angevin et al. 2008). Outcrossing levels close to zero were observed when differences in flowering exceed 7 days (Della Porta et al. 2008) or 10 days (Messeguer et al. 2006; Palaudelmas et al. 2007).

A difference in flowering dates between donor and receptor fields could be achieved either by sowing maize hybrids of the same maturity class on different dates, or by sowing hybrids of different maturity classes at the same time, or a combination of both. These technical options are analysed below.

Staggered sowing dates

The shift in sowing dates may not be an easily applicable tool for reducing outcrossing levels in large areas of the EU (Messéan et al. 2006; Devos et al. 2008; Weber and Bringezu, 2005).

Experiments conducted in Germany showed that flowering overlap could only be avoided if sowing was delayed by over 25 days (Weber et al. 2007). These large delays in sowing dates may lead to significant yield losses, as reported by Lotz and Groeneveld (2001) and Mayer (2002). Such yield losses associated with sowing delay were not observed in Italy (Otto et al. 2009).

Differentiation of sowing dates seems to be more applicable in Southern Europe where climate and irrigation allows more flexible management of sowing. Experiments to estimate the potential effect of sowing dates delay have been performed in Spain and Portugal. Experiments conducted in Spain showed that in the case of early sowings (31.03 and 20.04), a 20-day delay between the sowing of donor and receptor fields produced only a 3-5 day delay in flowering, while a similar 20-day delay in the case of later sowings (20.04 and 11.05) was more effective and resulted in a 12-13 day delay in flowering (Palaudelmas et al. 2008). Two weeks of sowing delay considerably lowered the distance at which the outcrossing level dropped below 0.01% (from 500 m to 24 m in 2001 and 65 m in 2002) as reported in Halsey et al. (2005). These experiences show that coexistence measures based on establishing fixed differences for sowing dates may not be effective in all situations and could only be recommended in the case of late sowing (Palaudelmas et al. 2008).

In Portugal, a 20-day delay in sowing was reported to reduce the GM content in the non-GM harvest to 0.36% in the case of fields, where relatively large differences in flowering times between plants were observed, while in the case of more homogenous parcels the outcrossing levels did not exceed 0.06% (Carvalho, 2008).

A general conclusion is that it is difficult to predict how differences in sowing dates will translate into differences in flowering dates (largely dependent on weather conditions), therefore it is hard to estimate the efficiency of staggered sowing dates as a coexistence measure.

Use of varieties with different maturity class

According to Messéan et al. (2006), separating flowering times is easier to achieve by the use of maize hybrids with different maturity classes than by sowing on different dates.

However, this practice is of limited use in Europe. Under Central European climatic conditions, expected differences in flowering dates between early and late varieties are not observed every year (Weber, 2008) or may not be achieved at all, as shown by the Austrian DUS Results 2004-2008 (kindly provided by Ch. Leonhardt).

No scientific data could be found by the TWG-Maize to support a proposal for minimal difference in maturity classes which is needed to obtain the sufficient flowering delay. In addition, this practice is complicated by the fact that the yield of earlier varieties is lower than the one which could be obtained when a variety of the optimal maturity class for the given climatic conditions is chosen.

The impact of this strategy to separate flowering times on the grower's gross margin was assessed by Messéan et al. (2006). The cost of change from a very late variety to a late variety (30 degree-days difference - equivalent to 2 days of flowering time lag in French climatic conditions) was assessed at 201 €/ha, while change from a late to a mid-early variety (60 degree-days difference) was calculated at 46 €/ha.

3.3.3. Other factors influencing cross-pollination

In addition to the distance between the donor and receptor fields and their synchronisation of flowering (the two major factors influencing the level of cross-pollination) several other factors were identified as influencing the level of outcrossing. These include field size and shape, prevalent wind direction, presence of pollen barriers, field distribution in the landscape, land topography and GM crop adoption rate.

However, evidence supporting the possibility of farmers managing these factors to achieve reductions in cross-pollination is limited, as discussed below.

Field size and shape

The influence of the size and shape of the recipient field, as well as that of the donor-receptor surface ratio, have been examined by several authors.

The opinions on the influence of the recipient field size on the cross-pollination level differ between scientists. Bateman (1947a) reported that in the case of the recipient field being grown at a moderate distance from a donor variety, provided that the outer rows were discarded, the amount of outcrossing would be independent of the size of the field. Also, Allnutt et al. (2006) showed that an increase of recipient field size from 100 m x 100 m to 600 m x 600 m reduced the isolation distance necessary to comply with the 0.2% target level only by 10m.

Other authors, like Devos et al. (2005) proposed different coexistence measures according to the recipient field size. For receptor fields larger than 5 ha no coexistence measures were considered necessary to comply with the labelling threshold. A similar approach was suggested by Beckie and Hall (2008). This statement cannot be supported on the basis of analysis based on the GM calculator[15] (Allnutt, unpublished data), nor by the analysis performed by Messéan et al. (2006), which shows that the isolation distance can be lowered in cases when the receptor field is bigger than 5 ha, but not eliminated. The isolation distance necessary to comply with a given admixture level falls with increasing receptor size, but in the case of the 0.3% level it remains above zero until the receptor field is above 5000 ha (Allnutt, personal communication).

Allnutt et al. (2008) observed however that the GM content in harvests from the largest fields under investigation was lower than predicted by the model. Klein et al. (2006) explained this phenomenon. Increasing the depth of the receptor plot (at the same time the size of the field increases) dilutes the effect of the pollen flow from the source field. The influence of the recipient field depth was also confirmed by data presented by Arvalis (Bénétrix, 2005). According to data presented by Langhof et al. (in press) in the case of small receptor fields below 100 m in depth (in the case of square fields - 1 ha) the isolation distances, which are effective in limiting outcrossing in the case of bigger receptor field, may not assure compliance with the targeted level.

Those findings are in accordance with the findings of Messeguer et al. (2006), who observed that the GM content is higher in elongated recipient fields with the long side facing the

15 A decision-aid tool, developed by T. Allnutt, based on GM geneflow research from UK farm scale evaluations, the SIGMEA EU funded research project and other maize geneflow data. Available at: http://www.gm-inspectorate.gov.uk/documents/FIELDGMCALCULATOR1.21.xls

source, than in more compact shape fields of the same surface area and orientation. Also Ingram (2000) reported that the isolation distance required to comply with the labelling threshold is shorter in the case of those fields whose short side faces the donor.

No impact of the pollen donor on the pollen receptor surface ratio was found by Bannert et al. (2008) where several ratios from 1:8 to 3.6:1 were investigated. Similar findings were reported by Rühl et al. (2009).

Prevalent wind direction

Maize is a wind-pollinated species so unsurprisingly many researchers observed higher outcrossing levels in receptor fields located downwind from the pollen donor than in ones lying in an upwind direction (Ma et al. 2004; Devos et al. 2005; Bannert and Stamp, 2007; Goggi et al. 2006). Also the median cross-pollination rate increased relative to the mean wind speed (Lécroart et al. 2007).

Simulation models have also taken into account the impact of prevalent wind direction, varying the location of the receptor field (upwind or downwind) to demonstrate that the distances needed to comply with different thresholds are much lower when the recipient field is located upwind from the donor (Messéan et al. 2006).

In some cases, however, the prevalent wind direction could not be determined for a given experimental site (Weber et al. 2007; Van de Wiel et al. 2009) or was not strongly correlated with the observed levels of outcrossing (Della Porta et al. 2008; Halsey et al. 2005; Messeguer et al. 2006). Also, differences in outcrossing levels were observed between experiments conducted on the same site but in different years (Langhof et al. 2008c; Ma et al. 2004), suggesting the variability in prevalent winds in different growing seasons.

As wind direction and strength during maize flowering cannot be predicted in advance with sufficient certainty (Weber and Bringezu 2005; Weber 2008), the members of the TWG-Maize decided that this parameter could not be used for developing proposals for coexistence measures. Therefore for the development of best practices based on isolation distances, conditions favouring pollen mediated gene flow were taken into account (non-GM fields located "downwind" from the pollen donor).

Other barriers (like trees, dykes etc.)

The presence of physical barriers between fields (like trees), particularly those located immediately before a receptor field, reduces cross-pollination levels. Messeguer et al. (2006) observed the lowering of outcrossing level caused by a 2 m high dyke with trees growing on the top. A similar effect was observed by Jones and Brooks (1952) in the case of trees growing close to the donor, which reduced the outcrossing level by about 50% (as cited in Ingram, 2000).

The existing evidence is however too limited to establish concrete proposals for modifications to coexistence measures according to the presence of physical barriers between fields, therefore this factor will not be taken into account during the elaboration of best practices for maize coexistence.

Land topography

Only one recently published paper investigates the influence of land topography on the cross-pollination rate (Vogler et al. 2009). The level of outcrossing increased significantly with decreasing altitude of the receptor field; however the effect seems to be less pronounced than that of other influencing factors.

Due to the limited data available the land topography will not be taken into account as a factor which may allow the modification of recommended coexistence measures.

Field distribution in the landscape and regional GM crop adoption rate

According to model simulations conducted by Lavigne et al. (2008), cross-pollination levels for a given field were lower when simulated only from the closest GM field than when simulated from the whole landscape (multiple sources of pollen). This underestimation increased with the increase of the GM maize share in the landscape. Lécroart et al. (2007), Le Bail et al. (in press) and Viaud et al. (2008) reported simulations for specific regions showing that the proportion of maize fields that did not comply with a given threshold in a region increased relative to the share of GM fields in the area.

The spatial distribution of GM and non-GM fields in a landscape may have a stronger impact on the non-compliant area than the absolute value of adoption rate of GM maize itself (Lécroart et al. 2007; Le Bail et al. in press). Those findings are in accordance with the results obtained by Messéan et al. (2006) who showed that coexistence may be more difficult to achieve in the case of 10% GM fields dispersed in the landscape than in the case of 50% of GM fields organised in a cluster.

In any case, the findings of Viaud et al. (2008) show that on the landscape level, the distance to the nearest GM field is still the major variable for predicting the cross-pollination rate. The TWG-Maize would therefore use the distance to the nearest non-GM field during the elaboration of best practices on a field level, regardless of the GM share and distribution in the landscape since the influence of these variables is not easily represented or accounted for.

3.3.4. Silage (green) maize

Cross-pollination affects only the grain composition. Since the grain content in maize grown for silage would commonly be about 40% (Ingram, 2000; Sanvido et al. 2008), or 50% for green maize harvested at relatively late maturity (Ingram, 2000) shorter isolation distances are recommended to comply with target levels of GM content. The isolation distance of 20 m limits the GM content at the field border to 0.5% according to the review of Sanvido et al. (2008). According to the NIAB report published in 2006 the distances needed to reduce the GM content in a 100 m depth field would be 26 m for 0.9% target content, 40 m for 0.5% target content and 86 m for 0.1% content (in all cases 98% of confidence level was used).

Weber et al (2007) did not find a higher percentage of GM content in grain maize compared to silage maize, however the samples came from different fields, which makes direct comparison impossible. Other German researchers, Langhof and Rühl, could show that maize grain samples in a mean have twice the GM content of whole plant samples comparing kernel and whole plant samples at 200 sampling points within different coexistence field trials (pers. communication).

3.3.5. Sweet maize

Sweet corn should be treated differently from grain maize regarding cross-pollination and coexistence measures. In the case of grain maize, the harvest is homogenised (grains from the field border facing the GM pollen donor and grains from the opposite side and field centre are mixed) causing a "dilution" effect. In contrast, sweet corn may be harvested, sold and consumed as individual cobs. The labelling threshold will then refer to individual cobs.

According to the SCIMAC code of practice and on farm guidelines (1999), for sweet maize an isolation distance of 200 m from the donor field is necessary to comply with the labelling threshold. It has to be stressed that this isolation distance is equal to (or smaller than) the one routinely applied to sweet corn production (see chapter 2.3).

Also, according to Foueillassar et al. (2007), pollen production in sweet maize is higher than in commodity maize, which makes the fields of sweet corn less susceptible to fertilisation by foreign pollen due to increased pollen competition. The rates of cross-pollination observed by the authors in sweet maize fields were generally small, well below 0.1%. Cross-pollination occurred randomly at those levels at field depths from 200 to 300 m. The authors stressed that the outcrossing which may occur in the outer rows of sweet maize production fields should not be taken into account as those rows are generally discarded at harvest.

The TWG-Maize will not propose any specific recommendations for sweet maize as the currently applied management measures seem to be sufficient to limit an undesirable cross-pollination.

3.3.6. Volunteers

Relevance of volunteers according to geographical area

Scientific data on the role of maize volunteers on cross-pollination is limited. The most detailed study was conducted in Spain. Palaudelmas et al. (2009) observed fields in which Bt maize was grown the previous year. Volunteer densities ranged from below 30 to above 7000 plants/ha, the latter representing almost 10% of the total number of plants in the field. Volunteer growth was poor and plants rarely reached the flowering stage. No cob formation on volunteer plants was observed, however some local cross-pollination from volunteers occurred. The estimated potential rate of cross-pollination varied from 0.0% to 0.164%. Also the Italian TWG member (F. Veronesi, personal communication) confirmed that F2 maize volunteers are usually smaller (1-1.2 m high) than F1 hybrid plants and normally do not reach maturity in normal field conditions.

According to Angevin et al. (2008) maize volunteers are rare under European conditions due to the cold winters and the use of ploughing. No European-wide study was conducted so far however, therefore members of the TWG-Maize were asked to provide background data regarding maize volunteers in their countries.

According to the answers received there is no evidence of maize volunteer appearance in the production fields in Denmark, Ireland, Lithuania, Luxembourg, The Netherlands, Romania, the Slovak Republic and the United Kingdom. However the experts did not exclude the possibility of volunteer appearance in Lithuania and Romania.

In the above mentioned countries volunteers are not observed due to the cold winters (Denmark, Romania) or the production system used – the silage maize which is predominantly grown for example in Denmark is harvested before it reaches maturity. Also the climatic conditions, like the high air humidity in The Netherlands may cause the germination of any remaining seeds in the same year. Resulting plants will not survive the low temperatures during the winter.

In Belgium maize volunteers appear extremely rarely. They are also observed in the South-Western part of Poland, but they do not appear every year. In France volunteers were spotted around Paris and in the South-Western part of the territory. In none of the above countries have systematic observations of maize volunteers been carried out.

In Slovenia (except from the central part), in Southern parts of Germany and Northern Italy, maize volunteers' growth can be observed every year, as well as in Austria. Volunteers grow predominantly from parts of the cobs dropped during harvesting, but single plant growth was also occasionally observed in Austria and Slovenia.

In Greece, maize volunteers are occasionally observed on all the territory where maize is grown. In Portugal and Spain maize volunteers are observed every year in all the territory. In Spain, Portugal and Greece the volunteers are normally destroyed during the soil preparation for the sowing and planting of the next crop. Any remaining maize plants would not survive the winter.

Only in Spain, as mentioned previously, a study showing how much maize volunteers contribute to overall GM adventitious presence in a non-GM harvest has been carried out.

Management practices for volunteers

Generally no specific management practices are applied in any of the European countries to control maize volunteers. They may usually be easily controlled by currently applied agricultural techniques and may therefore be considered a negligible source of potential adventitious presence.

In three Member States, however, control measures for GM maize volunteers are foreseen by law. In the Slovak Republic no conventional crops from the same botanical species can be grown in a field where a GM crop was grown previously, for a period of at least two years. Similar requirements were introduced in Lithuania, but with the shorter, one year, period. Any volunteers appearing in the field should be destroyed. Similar measures have been also introduced in Germany by the Good Farming Practice of Bt maize cultivation in the frame of the Act of Genetic Engineering. Non-GM maize cultivation following GM maize is only allowed after two years. Additionally, volunteers have to be monitored and the field has to be free of these in the year prior to non-GM maize cultivation.

The TWG-Maize will not propose any specific management measures aimed at maize volunteer control, as the volunteers (if they appear) are already sufficiently controlled by currently applied agricultural techniques. With zero tillage or minimum tillage the presence of volunteers should be regarded with greater attention by the farmers involved, as the volunteers may increase the GM content in both grain maize (as a source of GM pollen) and in green maize.

3.4. Harvesting

The combine harvester could be a source of grain commingling on the farm due to its complexity and the difficulty in cleaning out the mechanism (Hanna et al. 2004; Messéan et al. 2006).

According to Hanna et al. (2004) the traditional operator practice of emptying the combine by operating it until "empty" leaves 30 to 120 pounds (13.6 to 54.4 kg) of grain inside the machine. Two bushels of unwanted grain (in the case of maize 50.8 kg) mixed into the subsequent harvest represent an impurity level of 0.1% in 2000 bushels (50.8 t).

Also Messéan et al. (2006) assessed the adventitious presence levels due to combine harvesters. When a non-GM field was harvested after the GM field the admixture is significant only in the first trailer collected.

The use of dedicated harvesters eliminates the risk of admixture, while in the case of harvesters which have been cleaned the admixture was estimated to be 0.1% in the first trailer. When no cleaning was performed the first trailer may contain even 0.4% GM admixture.

3.5. Drying, transport and storage

No detailed scientific data concerning possible admixture levels due to drying procedure (applicable only to grain maize) were found by the TWG-Maize.

According to the French report (Meynard and Le Bail, 2001) the risk related to grain transfer cannot be assessed because there are no data allowing the precise evaluation of admixture at each stage of handling: quantities of grain remaining in elevators and silo bottom, grains caught in the different handling chains. Besides, concerning maize, at the level of purity required for segregated food chains (such as waxy), according to the consulted experts, the effects of grain transfer were considered negligible when compared to the risks associated with drying. In fact, after the passage of a batch in a dryer, 2% to 3% of grains could remain in the machine and be mixed in the following batch (Source: French technical Institute for cereals - Arvalis), therefore dryers are a bottleneck in the separation process of food/feed chains.

According to POECB studies conducted for 3 years (2002-2004) the necessary conventional maize volume to achieve GM levels below 0.9% in a subsequent non-GM lot being dried after the GM lot depends on the final GM maize moisture and quantity.

In the case of maize intended to be used by the feed industry only one conventional maize batch is needed to flush-clean the dryer after the GM maize batch.

No data concerning the possible admixture levels due to the transport and storage as well as the necessary cleaning procedures were found by the TWG-Maize.

4. Cost analysis of management practices

The cost of isolation distances will basically correspond to *the opportunity cost* incurred by not growing the GM maize on those parts of the farm (Messéan et al. 2006). This cost is roughly the difference in the farmer's gross margin between the GM maize and the alternative crop planted.

For calculating the costs in the case of conventional maize being planted as an alternative crop (as is very likely) a study of Gómez Barbero et al. (2008) can be taken into consideration. This study is based on a survey of commercial farms in three provinces of Spain. It found that in the 2002-2004 period the impact of Bt maize adoption on gross margins ranged, depending on the particular province, from being neutral to an increase of €122 per hectare per year due to increased yields and reduced pesticide use in Bt maize.

In a hypothetical scenario of several GM farmers agreeing to implement a buffer zone around a cluster of GM fields (instead of each field individually) the costs will be substantially reduced.

Some *direct costs* can also be attributed to the need for planting two types of maize (the need to organise sowing operations with two types of seeds).

Costs related to the changing of flowering time by using varieties of shorter vegetation period plants were estimated at 201 €/ha, if the late variety instead of the very late one (30 degree-days difference) was sown. In the case of change from late to mid-early variety the cost was lower, around 46 €/ha (Messéan et al. 2006).

The costs of cleaning shared machinery were estimated at about 38 € in the case of cleaning a single seed driller, over 56 € per cleaning of the combine harvester and around 1.5 € in the case of cleaning a trailer or truck used for transport of GM harvest. Different types of additional costs connected with coexistence were assessed by Bénétrix (2005). In the case of machinery cleaning the costs of labour were assessed at 7 €. In this study the additional costs of collecting of harvest were also assessed; in the case of GM maize the average additional cost was 18,28 €/t, while in the case of non-GM maize the cost increased by 1.82 €/t, if the share of collected GM maize did not exceed 10%.

The costs of non-technical coexistence measures (registration, communication to neighbours, obligatory insurances etc.) are not considered in this best practice document.

5. Cross-border issues

Currently only two Member States (Denmark and Germany) have decided to discuss the potential problems which may be faced on their border due to different legal requirements for coexistence foreseen in national legislations.

Identified differences included administrative issues (different deadlines for notification of field location which should be sent to authorities, different requirements regarding information passed to neighbours, different range of information about the GM fields available to the public). Some differences regarding liability and compensation issues were also identified. These included collective responsibility, liability of the farmers and the definition of damage. Those issues were also analysed within the COEXTRA project, where legal aspects of possible compensation claims were discussed in detail (deliverable 7.1). The above mentioned issues are out of the scope of the TWG-Maize's activity.

Some technical issues, i.e. different requirements regarding isolation distances, were also identified as potentially problematic during the Danish-German bilateral meeting.

The development by the TWG-Maize of consensus-based best practices for maize coexistence will not as such solve the potential problems but may contribute to their reduction. If best practices are followed by Member States the legal requirements regarding technical segregation measures could become similar in neighbouring Member States.

6. Best practices for coexistence measures in maize crop production

The TWG-Maize has analysed the potential sources of GM admixture in maize crop production and discussed what measures constitute the best practice to limit adventitious GM content in non-GM maize to below the legal labelling threshold.

Since no labelling threshold for GM content in non-GM seed lots has been established yet, the TWG-Maize decided to take into consideration the following scenarios: 0.1%, 0.3%, and 0.5%. For the best practice document, the TWG-Maize decided to use a worst case scenario (and not the probable one) regarding the average purity of commercial seed lots (i.e. that all maize seed lots put on the market would contain GM seeds up to the labelling threshold).

Therefore, in developing best practices for limiting cross-pollination during cultivation (section 6.3 in this chapter) this initial level of adventitious presence caused by seed impurity had to be taken into account. Since the initial level is not yet fixed, the working conclusion of the TWG-Maize was to discuss scenarios of best practice to limit cross-pollination at various levels (from 0.1% to 0.9%, ideally at 0.1% intervals).

In this document the GM content in non-GM harvests is expressed in haploid genome equivalents.

It should be noted that most of the data used to derive the present best practices, even if they originate from studies that used homozygous traits (e.g. colour markers), were adapted to heterozygous F1 GM maize, i.e. that which contains one GM and one non-GM locus in its diploid genome, and hence produces 50% GM pollen and 50% non-GM pollen. This data would not be directly applicable to any future homozygous GM maize, which would produce only GM pollen. Some previous reports have employed methods to adjust separation distances to the zygosity of GM crop (e.g. NIAB used a 'GM index', which effectively increased separation distances proportionally to the zygosity or copy number of GM loci; those factors were also taken into account in the MAPOD model (Paul et al. 2009). However, in the current recommendations this would require further analysis and separate tables for the different types of GM events. Homozygous and 'multi-copy' GM maize are therefore outside the scope of this document.

6.1. Best practices for seed purity

Impurities in seeds

The seeds used by farmers should comply with EU legislation, which may establish a threshold below which the presence of authorised GMOs in non-GM seed lots shall not have to be labelled.

According to the seed legislation in force, seeds are sold in sealed packages which are appropriately marked. In the case of seeds of a genetically modified variety the label shall clearly indicate that the variety is GM.

Seed storage

Farmers shall ensure that the seeds of GM varieties are transported to the farm and stored upon arrival in their original packaging, and separately from non-GM varieties. If possible separate storage rooms may be used to avoid any non-intended use. Label information should be retained with the seeds.

Surplus seeds should be stored in a similar way, or transferred to sealable, marked containers for appropriate disposal by the grower.

6.2. Best practices for seed driller management

The use of dedicated seed drillers for different production systems eliminates the risk of admixture.

To use the seed driller for non-GM seeds prior to GM seeds would have a similar effect.

The seed drillers used for sowing a genetically modified variety should be cleaned thoroughly before they can be used for sowing non-GM seeds.

The storage tanks should be emptied before moving the seed driller from the GM field.

Cleaning with compressed air may be used.

Seed drillers can be also routinely emptied and afterwards operated for a small distance on a GM field in sowing position in order to remove any remaining seeds.

6.3. Best practices for reduction of cross-pollination from GM fields

6.3.1. Isolation distances

Grain maize

The TWG-Maize concluded that isolation distances are indeed a practice that can be recommended to reduce cross-pollination.

Table 4 below shows the ranges of isolation distances recommended for complying with different admixture levels. Outcrossing with GM maize is the only source taken into account. The recipient field is located downwind from the pollen donor and fields flower simultaneously (conditions favouring pollen mediated gene flow).

Table 4: Proposals for isolation distances which can be recommended to reduce cross-pollination to different levels in case of grain maize

Admixture level	Proposed isolation distances
0.1%	105 to 250-500 m[16]
0.2%	85 to 150 m
0.3%	70 to 100 m
0.4%	50 to 65 m
0.5%	35 to 60 m
0.6%	20 to 55 m
0.7%	20 to 50 m
0.8%	20 to 50 m
0.9%	15 to 50 m

The range is based on the proposals of the TWG members, which have been analysed and adjusted by the ECoB (see Appendix). They represent the ranges of values obtained by different field trials and methods of analysis which were chosen as suitable for the different MS requirements e.g. climate, agricultural, landscape.

16 The upper range of the limit is based on results of field trials conducted in conditions favouring pollen-mediated gene flow; the samples were taken at max. 250 m from the pollen source; 500m is the estimated distance at which GM presence should not be detected in any of the samples.

The table can be used as well to allow for adventitious or technically unavoidable presence from other sources, e.g. seeds, machinery and storage facilities, and to comply with the labelling threshold at the farm gate (the target threshold should be lowered).

Example: if the seed lot contains 0.5% of GM seeds (speculative assumption) and additional admixture from other sources is expected to be 0.1%, then the admixture level for outcrossing, which would allow complying with the labelling threshold at the farm gate should be: 0.9% (labelling threshold) – 0.5% (GM seed in lot) – 0.1% (other sources) = 0.3%

Whole plant use

Cross-pollination affects the grain composition only. Therefore the distances recommended to manage cross-pollination in the case of whole plant use (e.g. silage maize) differ from those for grain maize.

However, in the case of fields where the final use of the harvest (grain or the whole plant) is not determined at the time of sowing, the isolation distances recommended for grain production should be applied.

In this section we present a proposal for isolation distances based on proposals submitted by the TWG members and the analysis performed by the ECoB (see appendix 1).

Table 5 below shows the proposals for the ranges of isolation distances recommended for complying with different admixture levels. Outcrossing with GM maize is the only source taken into account in this table. The recipient field is located downwind from the pollen donor and fields flower simultaneously (conditions favouring pollen mediated gene flow).

The ranges were obtained in a similar way to that of grain maize (see previous section for explanation). They represent the ranges of values obtained by different field trials and methods of analysis which were chosen as suitable for different MS requirements e.g. climate, agricultural, landscape. Silage maize contains a maximum of 50% of GM content compared to grain maize, distances shown are therefore lower than in Table 4.

To allow for adventitious or technically unavoidable presence from other sources, e.g. seeds, machinery and storage facilities, and to comply with the labelling threshold at the farm gate the target threshold should be lowered (see grain maize section).

Table 5: Proposals for isolation distances which can be recommended to reduce cross-pollination to different levels in the case of whole plant use

Admixture level	Proposed isolation distances
0.1%	85 to 120 m
0.2%	50 to 65 m
0.3%	30 to 55 m
0.4%	20 to 45 m
0.5%	15 to 40 m
0.6%	0 to 35 m
0.7%	0 to 30 m
0.8%	0 to 30 m
0.9%	0 to 25 m

6.3.2. Use of buffer/discard zones

Buffer zones

The data reviewed in section 3.3.1.2. demonstrate that the isolation distance can be fully replaced with the non-GM maize buffer zone created around the donor field when the donor and receptor fields are adjacent. The complete isolation distance can be replaced by a non-GM maize buffer zone half as deep as the isolation distance. The measure would be equally effective in the case of both insect resistance and herbicide tolerance traits.

The partial replacement of isolation distances by buffer zones could allow the necessary isolation distances to be lowered on a pro rata basis (as foreseen in coexistence legislation in some Member States), however more precise measures cannot be proposed due to the limited data available. The TWG-Maize concluded that further investigation is needed to prove its efficacy and to propose concrete measures.

Discard zones

Discard zones created around the conventional maize field to partially replace the isolation distance could in certain conditions be used as a coexistence measure because discarding edges of recipient fields can reduce the GM-content in the total non-GM harvest.

This measure was not however investigated intensively. Further investigation is needed to prove its efficacy and to propose concrete measures.

6.3.3. Practices based on temporal isolation

There is scientific evidence to support that cross-pollination during cultivation of maize can be reduced if the donor and receptor fields do not flower simultaneously. To achieve this in practice, two measures could be implemented, namely the use of staggered sowing dates and/or the use of maize varieties of different maturity classes. Chapter 3 has reviewed some information available on the feasibility and effectiveness of these measures.

The TWG members representing seven Member States considered possible measures based on the temporal isolation of flowering which could be applicable in the climatic conditions of their countries.

The possibility of the use of such measures is dependent on local climatic conditions. The performance of the same maize varieties may be different from country to country; therefore the recommendations for temporal isolation should be based on practical experience gained in those countries.

Staggered sowing dates

The temporal isolation of flowering between donor and receptor field is obtained by delayed sowing of either donor, or recipient field with varieties of the same maturity class. Despite the fact that this measure is not always reliable due to specific weather conditions (Messéan et al. 2006; Palaudelmas et al. 2008) four TWG members submitted recommendations for minimal delay in sowing dates (see Table 6 below). Proposed

Table 6: Minimal sowing delays recommended to reduce outcrossing between donor and receptor fields

Member State	Minimal sowing delays recommended
Greece	45-50 days
Italy	at least 30 days
Portugal	20 days
Romania	15-20 days

Table 7: *Minimal differences in maturity classes recommended to reduce outcrossing between donor and receptor fields*

Member State	Minimal recommended differences in maturity classes (in FAO units)
Greece	400
Italy	200
Portugal	200
Romania	200
Slovenia	250
Spain	300

delays in sowing should prevent a flowering overlap between donor and recipient fields.

The combination of temporal isolation based on staggered sowing and other coexistence measures, especially isolation distances, is also possible from a theoretical point of view (Messéan et al. 2006). However, in practical terms desired flowering shifts could often not be obtained due to weather conditions. Therefore the measures to achieve partial temporal isolation, to be combined with other measures, were recommended only by the TWG member nominated by France[17].

Different maturity classes

The temporal isolation of flowering can also be obtained by the use of varieties with different maturity classes sown at the same date. Six TWG members submitted recommendations for the minimal differences in maturity classes necessary to avoid flowering overlap (see Table 7 above). Similarly, as in the case of staggered sowing dates, the measures to achieve partial temporal isolation, to be combined with other measures, were recommended only by the TWG member nominated by France[17].

6.4. Best practices for harvester management

A clear difference should be made between harvesters used for silage and grain maize.

In the case of silage maize harvesting any plant remaining on the front of the chuff cutter should be removed before leaving the GM field. No additional cleaning measures are necessary, as the amount of plant material remaining inside the cutter is limited.

In the case of grain maize the use of dedicated harvesters for different production systems eliminates the risk of admixture. Using the harvester for non-GM maize prior to GM maize would have a similar effect.

Should this be impossible, any cobs and/or whole plants remaining on the front of the harvester should be removed before moving from the GM field to a conventional one. Harvesters should be flush-cleaned by harvesting non-GM maize from at least 2000 m^2 (Guide 2009 for a good management of Bt crops). Harvested non-GM maize used for such cleaning should be labelled as containing GMO.

17 In France this measure could be implemented in the south of the country but as a single practice would lead to extreme recommendations in terms of sowing delays or choice of varieties, with either the risk of not avoiding flowering overlap and/or negative consequences on yield.
This measure remains efficient to diminish cross-pollination but should be considered in combination with other practices to be feasible (as presented in Messéan et al. 2006).

6.5. Best practices for dryer management

The use of dedicated dryers for different production systems eliminates the risk of admixture. The planning of drying schedules so that non-GM farmers use the dryer first would have a similar effect.

Should this be impossible the dryer should be cleaned in a suitable way.

6.6. Best practices for transport

The use of dedicated trucks for different production systems eliminates the risk of admixture.

Should this be impossible the trucks used should be routinely emptied at the end of transportation of the GM harvest and thoroughly cleaned. The effectiveness of cleaning should be checked by visual inspection of the truck, as due to their size maize kernels are easily detectable.

6.7. Best practices for storage

The use of dedicated storage places or silos eliminates the risk of admixture.

Should this be impossible the harvest material of genetically modified and unmodified crops can be stored in the same plant in physically separated compartments. The GM harvest should be clearly identifiable.

The facilities/compartments where the GM harvest was stored should be thoroughly cleaned after the commodity is removed. The effectiveness of cleaning should be checked by visual inspection.

7. Areas where coexistence is difficult to achieve

Situations may exist in which the application of recommended practices may be difficult.

The factors which may affect the applicability of the measures recommended in this document include small and elongated fields, small field depths and the level of adoption of GM maize.

In these situations alternative measures may be used e.g. communication between the farmers to minimise possible problems, clustering of GM/non-GM fields based on the voluntary decision of the involved operators, and voluntary agreements between involved farmers on labelling harvest as containing GMO.

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9. Appendix I

Analysis of the proposals for isolation distances Submitted by the TWG-Maize

The figures in this section refer to "*isolation distances recommended by TWG members to meet different admixture levels when isolation distance is the only measure applied to reduce cross-pollination, recipient fields are located downwind from pollen donor and fields flower simultaneously (conditions favouring pollen mediated gene flow)*".

1. Grain maize

Fourteen members of the TWG-Maize submitted proposals for best practices for grain maize cultivation, based on isolation distances. Proposals, which were not accompanied by scientific justifications, obtained from the TWG members representing Italy, Lithuania, Poland, Portugal, Romania, Slovakia and Spain, were excluded from further analysis.

There is considerable variability between the scientifically justified TWG members' proposals with respect to the supporting evidence and the suggested isolation distances. A first classification has been made by the ECoB based on the type of supporting studies/evidence provided by the TWG members. Four types of supporting evidence can be identified.

1.1. Proposals of TWG members based on large data sets of field experiments analysed with statistical tools

Proposals based on large sets of results of field experiments statistically analysed were obtained from the member nominated by the United Kingdom.

	UK	Evidence used to justify proposal
0.1%	251 m	Results based on GM calculator – a decision-aid tool, developed by T. Allnutt, based on GM gene flow research from UK farm scale evaluations, the SIGMEA EU funded research project and other maize geneflow data; distances for a 0.25 ha receptor field and a 98% confidence level are shown.
0.2%	121 m	
0.3%	76 m	
0.4%	53 m	
0.5%	41 m	
0.6%	32 m	
0.7%	26 m	
0.8%	22 m	
0.9%	19 m	

Two additional proposals were submitted by the TWG members justified as well by the studies described above in the UK proposal, with certain modifications (due to these modifications no confidence levels are known).

	EL	IE	Evidence used to justify proposal
0.1%	400 m	210 m	**EL**: Based on GM calculator (see UK's contribution) for a 200x200 m receptor field. A worst case scenario was considered (100% GM maize in the landscape) **IE**: The distances are based on the NIAB 2006 Report to DEFRA ('UK Farm Scale Evaluations'). The distances are based on non-GM fields of a depth of 100 m. Additional safety margins of 50% for thresholds in the range 0.3% to 0.9%, and safety margins of 100% for thresholds in the range 0.1% to 0.2% were added.
0.2%	200 m	168 m	
0.3%	100 m	108 m	
0.4%	70 m	98 m	
0.5%	50 m	90 m	
0.6%	40 m	83 m	
0.7%	30 m	75 m	
0.8%	25 m	69 m	
0.9%	20 m	66 m	

1.2. Proposals of the TWG member based on a modelling approach

The proposals based on a modelling approach, obtained from the TWG member nominated by France, are shown in the table below.

	< 5 ha	5 to 10 ha	>10 ha	Evidence used to justify proposal
0.1%	300 m	200 m	150-200 m	Results based on MAPOD model.
0.2%	150 m	100 m	100 m	
0.3%	100 m	50 m	50 m	
0.4%	50 m	20 m	20 m	
0.5%	50 m	20 m		
0.6%	20 m			
0.7%	20 m			
0.8%	20 m			
0.9%	20 m			

1.3. Proposals based on data sets of national field experiments

The proposals based on data sets of field experiments, obtained from the TWG member nominated by Germany, are shown in the table below.

	D	Evidence used to justify proposal
0.1%	300 – 500 m	Langhof, M., B. Hommel, A. Husken, J. Schiemann, P. Wehling, R. Wilhelm, and G. Ruhl. 2008a.Two year field study on maize gene flow over large distances. In: Breckling, B., Reuter, H. & Verhoeven, R. (2008) Implications of GM-Crop Cultivation at Large Spatial Scales. Theorie in der Oekologie 14. Frankfurt, Peter Lang.
0.2%		
0.3%		
0.4%		
0.5%		
0.6%		
0.7%		
0.8%		
0.9%	80 – 100 m	

1.4. Proposals based on analysis of available literature

The proposals based on published data sets, obtained from the TWG members nominated by Denmark and Austria, are shown in the table below.

	DK	AT	Evidence used to justify proposal
0.1%		500m[1]/300m[2]	**DK**: Tolstrup, K., Andersen, S.B., Boelt, B., Buus, M., Gylling, M., Holm, P.B., Kjellson, G., Pedersen, S., Østergaard, H. and Mikkelsen, S.A.. Report from the Danish Working Group on the Co-existence of Genetically Modified Crops with Conventional and Organic Crops. Ministry of Food, Agriculture and Fisheries, Danish Institute of Agricultural Sciences. DIAS Report Plant Production no. 94, 275 pp, 2003. Tolstrup, K., Andersen, S.B., Boelt, B., Gylling, M., Holm, P.B., Kjellson, G., Petersen, S., Østergaard, H. and Mikkelsen, S.A.. Supplementary Report from the Danish Working Group on the Co-existence of Genetically Modified Crops with Conventional and Organic Crops. Update of the 2003 Report. Ministry of Food, Agriculture and Fisheries, Faculty of Agricultural Sciences. DJF Plant Science no. 131, 107 pp, 2007 **AT**: Angevin, F., E.K. Klein, C. Choimet, A. Gauffreteau, C. Lavigne, A. Messéan, and M.J. M. 2008. Modelling impacts of cropping systems and climate on maize cross-pollination in agricultural landscapes: The MAPOD model. European Journal of Agronomy 28:471-484. Langhof, M., B. Hommel, A. Husken, J. Schiemann, P. Wehling, R. Wilhelm, and G. Ruhl, 2008b. Two year field study on maize gene flow over large distances. In: Breckling B., Reuter, H. & Verhoeven, R. (2008) Implications of GM-Crop Cultivation at Large Spatial Scales. Theorie in der Oekologie 14.Frankfurt, Peter Lang Ingram J. 2000. The separation distances required to ensure cross-pollination is below specified limits in non-seed crops of sugar beet, maize and oilseed rape. Plant Varieties and Seeds, 13: 181-199 Bannert, M. and Stamp, P., 2007. Cross-pollination of maize at long distance. Europ. J. Agronomy, 27: 44-51.
0.2%	150 m		
0.3%			
0.4%			
0.5%			
0.6%			
0.7%			
0.8%			
0.9%		200m[1]/150m[2]/300m[3]	

1 for fields < 5 ha

2 for fields > 5 ha

3 for contracted non-GM production

1.5. Analysis of the data for grain maize

The ECoB has analysed the data and provided justifications. The submitted data were adjusted to allow science-based comparison. The additional "safety margins", if applied by the TWG members, were removed as they were not justified by supporting data.

For further comparisons data were selected/adjusted as follows:

Proposal submitted by the member nominated by the United Kingdom:

- to allow comparison the proposed isolation distances necessary to comply with a given admixture level were re-calculated for 1 ha field (100 m depth) and 50% GM maize in a landscape; 98% confidence level was chosen.

Proposal submitted by the member nominated by Greece:

- to allow comparison the proposed isolation distances necessary to comply with a given admixture level were re-calculated for 1 ha field (100 m depth) and 50% GM maize in a landscape; 98% confidence level was chosen;

Proposal submitted by the member nominated by Ireland:

- data from the NIAB Report to DEFRA, indicated as a scientific background for the proposal, were taken into account; arbitrary safety margins added by the Irish member were removed.

Proposal submitted by the member nominated by France:

- data for the smallest (<5 ha) fields was chosen for further analysis (as a worst case scenario).

Proposal submitted by the member nominated by Germany:

- to allow comparison the proposed isolation distance necessary to comply with a 0.9% admixture level was adjusted for a 1 ha field (100 m depth); according to data presented by Langhof et al. (2009) in most cases a 50 m isolation distance is sufficient to limit the outcrossing level to below 0.9%. Longer distances were necessary in the case of small fields (50 m depth)

The proposal submitted by the Austrian member was not taken into account, as the publication by Ingram, indicated as a background, is based mostly on experiments with open-pollinated varieties and the other proposed distances do not correspond with the distances in papers indicated as justification.

The table below shows the summary of adjusted, scientifically justified proposals for isolation distances for grain maize.

	UK, EL	FR	IE	D	DK	Range
0.1%	241 m	300 m	105 m	300 m–500 m		105 to 500 m
0.2%	116 m	150 m	84 m		150 m	84 to 150 m
0.3%	73 m	100 m	72 m			72 to 100 m
0.4%	49 m	50 m	65 m			49 to 65 m
0.5%	37 m	50 m	60 m			37 to 60 m
0.6%	28 m	20 m	55 m			20 to 55 m
0.7%	23 m	20 m	50 m			20 to 50 m
0.8%	19 m	20 m	46 m			19 to 46 m (50 m)[18]
0.9%	15 m	20 m	44 m	50 m		15 to 50 m

The range shown in the right column of the above table was chosen as a proposal for isolation distances for grain maize. The values in the table were rounded to 5 m according to the decision of TWG members.

18 In order to keep consistency between the proposals for isolation distances necessary to comply with 0.9%-0.7% admixture levels 50 m, instead of 46 m, was adopted.

2. Whole plant use

In the case of whole plant use cross-pollination affects the grain composition only. Therefore the distances recommended to manage cross-pollination differ from those for grain maize.

2..1. Proposals of TWG members based on large data sets of field experiments analysed with statistical tools

Only four TWG members made specific proposals for whole plant use. Three proposals were based on modelling approach, the fourth on data sets of field experiments. The overview of the proposals is shown in the table below.

	EL	IE	UK	AT	Evidence used to justify proposal
0.1%	200 m	172 m	116 m	300m[1]/200m[2]	**EL**: Grains are at maximum 50% of the dry weight; the distances proposed are half of the distances proposed for grain maize **IE:** The distances are based on the NIAB 2006 Report to DEFRA The 'UK Farm Scale Evaluations'.-Table 4, page 33. The distances are based on non-GM fields of a depth of 100 m (about 1ha in size). Additional safety margins of 50% for thresholds in the range 0.3% to 0.9%, and safety margins of 100% for thresholds in the range 0.1% to 0.2% were added. **UK**: Grains are at maximum 50% of the dry weight; the distances proposed are equal to the distances proposed for half of the requested GM content in grain maize **AT**: Henry C, Morgan D and Weekes R. 2003. Farm scale evaluations of GM crops: monitoring gene flow from GM crops to non-GM equivalent crops in the vicinity (contract reference EPG 1/5/138). Part I: Forage Maize. Central Science Laboratory / Centre for Ecology and Hydrology / Defra, UK. Angevin, F., E.K. Klein, C. Choimet, A. Gauffreteau, C. Lavigne, A. Messéan, and M.J. M. 2008. Modelling impacts of cropping systems and climate on maize cross-pollination in agricultural landscapes: The MAPOD model. European Journal of Agronomy 28:471-484. Bannert, M. and Stamp, P., 2007. Cross-pollination of maize at long distance. Europ. J. Agronomy, 27: 44-51. Ingram J. 2000. The separation distances required to ensure cross-pollination is below specified limits in non-seed crops of sugar beet, maize and oilseed rape. Plant Varieties and Seeds, 13: 181-199" to the column "Evidence used to justify proposal"
0.2%	100 m	130 m	49 m		
0.3%	50 m	80 m	28 m		
0.4%	35 m	68 m	19 m		
0.5%	25 m	60 m	13 m		
0.6%	20 m	53 m	1 m		
0.7%	15 m	47 m	0 m		
0.8%	12.5 m	42 m	0 m		
0.9%	10m	39 m	0 m	150m[1]/100m[2]	

1 for fields < 5 ha

2 for fields > 5 ha

2.2. Analysis of the data for whole plant use

The ECoB has analysed the provided data and justifications. The submitted data were adjusted to allow science-based comparison. The additional "safety margins", if applied by TWG members, were removed as they were not justified by supporting data.

For further comparisons data were selected/adjusted as follows:

Proposal submitted by the member nominated by Greece:

- according to the original submission the proposed distances are half of distances for grain maize

Proposal submitted by the member nominated by Ireland:

- data from the NIAB Report to DEFRA, indicated as a scientific background for the proposal, were taken into account; safety margins added by Irish member were removed.

The proposal submitted by the Austrian member was not taken into account, as the publication by Ingram, indicated as a background, is based mostly on experiments with open-pollinated varieties and the other proposed distances do not correspond with the distances in papers indicated as justification.

The table below shows the summary of adjusted, scientifically justified proposals for isolation distances for whole plant use.

	EL	IE	UK	Range of proposals
0.1%	120.5 m	86m	116 m	86 to 120.5 m
0.2%	58 m	65m	49 m	49 to 65 m
0.3%	36.5 m	53m	28 m	28 to 53 m
0.4%	24.5 m	45m	19 m	19 to 45 m
0.5%	18.5 m	40m	13 m	13 to 40 m
0.6%	14 m	35m	1 m	1 to 35 m
0.7%	11.5 m	31m	0 m	0 to 31 m
0.8%	9.5 m	28m	0 m	0 to 28 m
0.9%	7.5 m	26m	0 m	0 to 26 m

The range shown in the right column of the table above was chosen as a proposal for isolation distances for whole plant use. The values in the table were rounded to 5 m according to the decision of TWG members.

European Commission

EUR 24509 EN — Joint Research Centre — Institute for Prospective Technological Studies

Title: European Coexistence Bureau (ECoB). Best Practice Documents for coexistence of genetically modified crops with conventional and organic farming – 1. Maize crop production

Authors: Marta Czarnak-Kłos, Emilio Rodríguez-Cerezo

Luxembourg: Publications Office of the European Union
2010

EUR — Scientific and Technical Research series — ISSN 1018-5593
ISBN 978-92-79-16558-0
doi:10.2791/4619

Abstract

The European Coexistence Bureau (ECoB) was created in 2008 by DG AGRI and the JRC to implement the Agriculture Council conclusions of 22 May 2006 in which the Council invited the Commission to engage in works related to coexistence in close cooperation with Member States and stakeholders. Among others the Council invited the Commission to identify the best practices for technical segregation measures and to develop crop-specific guidelines for coexistence regulations while leaving Member States necessary flexibility to adapt the recommendations to their specific climatic and agricultural conditions.

ECoB, located in the premises of JRC Institute of Prospective Technological Studies, consists of a Secretariat (formed by permanent JRC staff and seconded national experts) and crop-specific technical working groups consisting of technical experts nominated by interested Member States. Currently one technical working group is active, dealing with maize crop production.

The management practices for maize crop production proposed in this Best Practice Document (BPD) are the result of a consensus building process which started in October 2008. The ECoB Secretariat was responsible for collection of inputs from technical experts and exchange of information between them, analysis of the collected data and preparation of drafts of the Best Practice Document for consultation. This Best Practice Document was adopted by consensus within the EcoB in May 2010.

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LF-NA-24509-EN-C

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Publications Office

ISBN 978-92-79-16558-0

9 789279 165580