DIAS report

Plant Production no. 94 • November 2003

Report from the Danish Working Group on the Co-existence of Genetically Modified Crops with Conventional and Organic Crops

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Ministry of Food, Agriculture and Fisheries
Danish Institute of Agricultural Sciences

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1. Conclusion

- This evaluation concerns co-existence of crops grown under Danish growing conditions. In other countries other measures may be necessary to ensure co-existence.

- Co-existence of GM crops with conventional and organic crops will, require care during production and specific control measures which are additional to the requirements of good farming practice.

- In principal co-existence of many crops is possible at the stipulated or presupposed threshold values, when there are moderate levels of GM crops, by using the recommended control measures. However, a few outcrossing crops and/or crops with long seed persistence in the soil are exceptions to this rule.

- For the crops maize, beet, potatoes, barley, wheat, triticale, rye, oats, lupin, field beans and peas, the Working Group finds that co-existence can be ensured at the existing threshold values for foods and feed in the presence of a moderate GM production and with the recommended control measures.

- If the GM growing of these crops becomes more extensive, further measures and regulations such as greater segregation, may become necessary.

- In order to ensure a particularly low GM content below the detection limit (~ 0.1 %) in organic crops, which the Working Group has assumed is the threshold value for organic production, further measures, as suggested, will be necessary in these crops.

- For the crops oilseed rape, grasses and clover, which are cross-pollinated and/or have long seed survival in the soil, the Working Group estimates that co-existence will need more rigorous control measures as recommended in the report.

- The Working Group is presently unable to recommend control measures that may ensure co-existence at the stipulated or presupposed threshold values for the following crops and production scenarios:

    - Seed production of hybrid oilseed rape. The cultivated area for oilseed rape hybrid seed production is less than 30 ha, corresponding to approx. 5 % of the oilseed rape seed growing area in 2002.

    - Organic grass seed production with extensive use of GM grasses. Organic grass seed production is approx. 1,600 ha in 2002 or approx. 3 % of the grass seed area.

- Organic white clover seed production. The area is approx. 600 ha in 2002 or approx. 16 % of the white clover seed production.

- Conventional and organic clover/grass pastures. The area of grass-clover fields is approx. 223,000 ha in 2002, corresponding to approx. 8 % of the agricultural area.

- The measures suggested by the Group to ensure compliance with the requested threshold values are based on:

  - The existing Danish regulations on certified seed production.

  - Information contained in Danish and foreign reports, scientific publications, model analyses and case studies.

- The Working Group has analysed the importance of the extent of GM crops in oilseed rape, maize and potatoes in a relevant Danish case study. Under the given preconditions, the analysis shows that there is a limited need of adjustments in the crop rotation. There is, however, a considerable need for information exchange and dialogue with neighbours.

- There will be large variations between both crops and individual farms in the expenses incurred in complying with threshold values.

- The extra costs in the primary production for complying with the given threshold value for adventitious presence are at 0-2 % of the total costs of growing crops of maize (for silage), potatoes, cereals, field pea, field bean and lupin for both conventional and organic production.

- For oilseed rape, beet, grassland legumes and forage and amenity grasses, the extra costs are at 3-9 % of the total costs of growing in conventional production, whereas they are at 8-21 % of the total costs of growing in organic production. Here, organic oil seed rape (approx. 900 ha) and organic production of grass seed (1,600 ha) and clover seed (800 ha) show the highest costs. It must be noted that calculations of the costs of the proposed control measures are also made in the cases where the Working Group did not find that the suggested control measures would ensure co-existence.

- For selected cases regarding oilseed rape, sugar beets and wheat, the Working Group has carried out analyses of the next stages in the production chain. The calculated extra costs for ensuring separation later on in the processing chain vary from a few per cent for sugar to about 24 % by using GM wheat in feed mixtures. In the production of a deep-frozen consumer product, the costs of ensuring separation are estimated at 6-7 % of the total costs as calculated without costs of raw materials.

- Some of the extra costs mentioned above will, however, probably occur in any case, independently of a Danish introduction of GM crops. This is due to the EU labelling regulations and the need for increased traceability and separation of productions, *e.g.* at import of foods and feed.

- Based on the complexity of the subject and the limited experience which is available concerning co-existence and handling of GM crops, the Group suggests that:

  - The introduction of control measures for ensuring co-existence, if required, is effected with a continuously updated evaluation of the control measures, and that initiatives are decided upon and implemented for shorter terms of years.

  - A training course is introduced for farmers who grow GM crops - possibly as part of the farmer's education.

- Finally, it is suggested that a monitoring, research and development programme is implemented. A close interaction between monitoring, research and development will contribute to providing the existing need for knowledge with regard to re-evaluation and refinement of the control measures for ensuring co-existence.

2. Summary

The tasks of the Working Group

The Working Group was established in July 2002 under the "Mandate for the work with the co-existence strategy" with the remit of:

- Undertaking a scientific evaluation of the possible sources of dispersal from genetically modified crop production to conventional and organic production.
- Evaluating the extent of dispersal and the need for control measures.
- Identifying and evaluating possible control measures for ensuring co-existence of genetically modified production with conventional and organic production systems.

Status

- Gene technology is a relatively new method, which among other things may be used in the breeding of new plant varieties.
- A few GM crops are grown in small areas in the EU today and GM maize is commercially grown in Spain. In Denmark no GM crops are grown commercially, but there have been experimental releases for a number of years.
- The marketing of GM crops is regulated by the EU, but since 1998 no new marketing applications for GM plants have been approved. For the time being, new applications are risk assessed scientifically without any authorisations for marketing being granted up to now.
- The scale of GM cropping of soybean, cotton, maize and oilseed rape particularly in the United States, Canada, China and Argentina is extensive (21 % of the total cropping area of these crops in 2002).
- There have been several cases of genetically modified organisms (GMOs) appearing in conventional and organic crops and products. Imported seed is now controlled for their GM content.
- It is considered that a detection limit for GMOs of about 0.1 % is realistic and practical with the existing analytical and sampling methods, though this will vary slightly with crop type.
- The regulations for organic farming prescribe that GMOs must not be used in the production.
- While the Working Group has carried out this evaluation, the EU has been debating a proposal regarding the approval and labelling of GM foods and feed, including a threshold value for the adventitious presence of GMOs below which labelling will not be required. Up to now, the threshold value for food for the labelling of GMO content has been 1 %. In November 2002, political agreement was reached in the EU on a threshold value of 0.9 % for foods and feed. The EU finally passed this proposal in July 2003. Thresholds for GM in certified seed are currently being discussed.

- The Danish Ministry of Food, Agriculture and Fisheries has worked out an overall Danish strategy for co-existence in June 2003, primarily based on the work of this Working Group.

The Group was especially inspired by:

- The report "The consequences of genetically modified crops for organic farming" published in Danish by DARCOF (Kjellsson & Boelt, 2002).
- The joint European report by JRC/IPTS 2002: "Scenarios for co-existence of genetically modified, conventional and organic crops in European agriculture". In this report, groups of experts evaluated the complex problems of co-existence for oilseed rape, maize and potato crops, and used simulation models to illustrate the main issues.

In addition to this, other available reports have formed part of the Group's work.

Based on the above, and taking into account the actual range of GM plants and varieties on offer, the Working Group does not expect that GM crops will be grown extensively in Denmark within the immediate future.

Based on the present experiments with GM crops and the applications for marketing, the Group infers that, initially, the GM crops most likely to be grown in Denmark are oilseed rape, maize and beet. The GM crop characteristic most likely to be used first is herbicide tolerance to facilitate weed control. However, other GM crops and characteristics are also likely to be introduced subsequently.

Threshold values

The EU is currently debating the threshold values (upper threshold values) for the adventitious presence of GM material in seed from individual crops. The Commission has presented a working paper containing threshold values of 0.3-0.7 % for seed, depending on crop. The working document has taken the current threshold value of 1 % for the labelling of GMO content in foods as its starting point.

While the Working Group has been working, the EU has passed a threshold value of 0.9 % for the labelling of GMOs in foods and feed.

If the proposed threshold values are changed in the final proposal, this will change the preconditions for co-existence and hence many of the conclusions of the Working Group's report.

The Working Group's evaluations

Genetically modified crops are not permitted in organic farming. The Group's evaluations regarding organic production are therefore based on the assumption that seed not containing GMOs ("GMO-free" seed) is used. It is further assumed that adventitious presence must be kept below the present detection limit (~0.1 %) as no specific threshold value for organic farming has been passed.

However, it appears from the EU Commission's recommendation of 23 July 2003 on guidelines for co-existence of GM crops and conventional and organic farming that it is the Commission's view that seed lots containing GM seeds below the seed threshold values may be used in organic farming as long as the regulation of organic farming does not stipulate a threshold value for the adventitious presence of GMOs.

If agreement is reached on a EU level on this interpretation of the regulations and if the proposed threshold values of 0.3-0.7 % for seed are passed, this will altogether mean a change of the assumptions on which the Group's work was based. Such a situation may therefore result in changes of the Group's conclusions regarding organic farming.

The Group's evaluations and estimates for the production as far as the first stage of distribution show that co-existence is possible as a principal rule and at moderate levels of GM cropping, based on the proposed threshold value for the end product. This takes into account the possibility of adventitious presence occurring in the subsequent stages of production. As appears from the examination of the individual crops, the margin that is available in the subsequent stages of production varies somewhat among the crops.

Extended precautions are, however, required for oilseed rape, grasses and clover, particularly with respect to co-existence with organic production. In certain cases these crops represent exceptions to the principal rule mentioned above. These exceptions are mentioned below.

Regarding seed production of hybrid varieties of oilseed rape, present knowledge does not indicate measures to ensure an adventitious presence below the proposed threshold value for conventional seed production and below the detection limit for organic production. The cropping area for seed growing of hybrid oilseed rape in Denmark was about 30 ha in 2002, which corresponded to about 5 % of the total oilseed rape seed growing area.

Due to the extensive distribution of grasses, both within and outside agricultural land, the Group has not been able to suggest control measures to ensure a GM dispersal that does not exceed the threshold values after using GM varieties for some time. This will primarily be important for maintaining a GM content below the detection limit in organic grass seed production. The area of organic grass seed in 2002 was about 1,600 ha or about 3 % of the grass seed production.

However, knowledge of the sources for adventitious presence of GM at field, farm and regional levels is currently very inadequate. The Group suggests that, prior to or together with the GM introduction, studies are initiated to determine gene dispersal from different sources, especially in relation to GM grasses being used for several years. The results of these studies may provide the basis of a reappraisal of the necessary control measures, *e.g.* after 3-5 years of studies.

Regarding white clover organic seed production as well as both conventional and organic clover grazing fields, it is currently not possible to suggest control measures in order to meet requirements concerning adventitious presence in the final product. Among other things, this is due to great uncertainty regarding the extent of gene dispersal between seed fields and grazing fields and the long survival time of clover seeds in soil. It should be noted that there are only a very limited number of scientific studies of this subject and that only a small part of these were carried out with the objective of co-existence.

The area with organic white clover seed is about 600 ha in 2002, which corresponds to about 16 % of the white clover seed production, while the area of conventional and organic clover /grass pastures is about 223,000 ha, which corresponds to about 8 % of the total agricultural area. White Clover also exists outside agricultural systems as a wild species, which also hybridises with cultivated forms so that transgenes can spread to and from these wild species.

The vegetable seed production is a small specialist production with very large biological and cultivation differences between the different species. The Working Group has chosen not to deal thoroughly with the question of co-existence regarding these crops but gives some general reflections of the co-existence problems for selected vegetable seed crops.

Biological background

Whichever crop is grown, be it conventional, organic or genetically modified, genes will always to some extent be dispersed to other crops.

The major sources of dispersal, as identified by the Group, are through:

- Seed (and propagating material, *e.g.* tubers).
- Pollen.
- Straw (containing seed).
- Seed within the crop rotation (the seed bank of the soil).
- Volunteers and feral plants.
- Sowing and harvesting machines.
- Transport equipment and storage.

The extent of dispersal depends on, *e.g.*:

- Crop biology including choice of variety.
- The extent of the growing.
- The size, position and shape of the fields.
- Weather conditions
- Human handling.

- Existence of wild relatives.
- Pollinating insects.

The dispersal can, however, be reduced by adopting various crop-dependent control measures. The most important control measures are:

- Control and safeguarding of seed.
- Separation distances, buffer zones and the size of the field.
- Cropping intervals (years between the same species of crops on the same field).
- Control of volunteers and possible wild relatives.
- Cleaning of sowing, harvesting and transport equipment, as well as stores and the control of the use of straw.

It is assumed in the report that the introduced GM varieties have been approved for marketing according to existing legislation. It is also assumed that these GM varieties do not have a general competitive capacity that considerably exceeds the competitive capacity of the corresponding non-GM varieties.

Uncertainties

The problems presented are complex and affected by many different factors. As existing knowledge in this area is limited, there are varying degrees of uncertainty associated with the evaluations and estimates of the Group. The Group has endeavoured to take these uncertainties into account in its assessment of the control measures required.

Monitoring, research and development programme

Based on the uncertainties mentioned above, the Group suggests that introduction of GM crops and the establishment of co-existence measures takes place with a continuously updated evaluation of the control measures. A continuously updated evaluation of control measures is especially relevant to crops with a higher potential for outcrossing and/or seeds with a long survival in soil such as oilseed rape, grass and clover. This implies that measures are initially passed and implemented for a 3-5-year period and constantly reviewed.

It is further suggested that a monitoring, research and development programme should be implemented. This programme should be implemented regardless of the speed of the actual GM introduction. Through such a programme, the consequences of the established control measures may be explained and adjustments made accordingly. A close interaction is needed between the monitoring, research and development programmes to cover the existing need for knowledge with regards to a continuous reappraisal and refinement of the control measures.

Examination of the crops

In connection with the work the Group has chosen to give the highest priority to the crops where a certain GM growing is to be expected in Denmark within a few years.

The Group based its evaluation of each crop on the following three scenarios:

0 % scenario:

- No GM varieties of this crop are grown in Denmark. Adventitious GM presence is, however, possible through the import of seed from areas where GM crops are grown or through cross-border pollination.

10 % scenario:

- A situation with a moderate growing of the GM crop in which GM varieties are grown on 10 % of the crop area.

50 % scenario:

- A situation with extensive cultivation of a GM crop. This corresponds to the development in countries such as Canada, where GM oilseed rape now constitutes more than 50 % of the total area cultivated with oilseed rape.

It has not been possible, however, within the given time frame, for the Working Group to thoroughly analyse the significance of the extent of growing for each individual crop. Only some of the crops have therefore been divided into 10 % and 50 % scenarios. As a principal rule the two scenarios have been treated together.

Where the Group has suggested control measures to minimise the presence of GM material in conventional or organic crops, these have been based on:

- Existing Danish regulations on certified seed production.
- Foreign and Danish reports, scientific papers, model analyses and case studies.

The Group assumes that "good farming practice" is used, as described in the report. As regarding control measures, basic measures (close to regulations on certified seed) and extended measures (approaching the regulations for basic or pre-basic seed) respectively are used. In addition more stringent control measures are used for certain crops.

The significance of the extent of growing and the need for neighbour information
The significance of growing GM crops was examined for oilseed rape, maize and potatoes in an actual Danish case area of 10 x 10 km in the County of Viborg based on scenarios, which correspond to moderate and to extensive growing of the GM crop in the area.

The analysis for the area shows that even in an area with relatively small farms the need for adjustments in the cropping plan is limited in order to comply with the separation distances.

However, the analysis also shows that separation distances in order to grow GM and non-GM crops in co-existence mean that only in relatively few cases will the growers in this area be able to grow a GM crop independently of their neighbouring farms. Consequently, there will be a great need for contact between neighbouring farms. However, adjustments in the cropping plan will only be necessary in the relatively few cases in which the neighbour grows a corresponding non-GM crop. However, on rare occasions, local conditions may mean that it will not be possible for a grower to grow GM oilseed rape if the farm is surrounded by conventional or organic oilseed rape in that year.

The conclusions are based on a relatively limited number of analyses and only a single area. The results are therefore not representative of Denmark as a whole. Due to the relatively small farms in the area, it is estimated that – as a principal rule – it will be more difficult to ensure co-existence in this area than in Denmark as a whole. Therefore, there is a need for a larger number of similar analyses showing the consequences of separation distances in other regions that have different crop distributions and farm and field structures.

The financial evaluation

The Group has calculated the extra costs that will be incurred in the primary production in order to comply with threshold values in the scenarios.

The costs for complying with the given threshold values of adventitious GM presence are for the crops maize (for silage), potatoes, grain, field pea, broad bean and lupin 0-2 % of the total growing costs for both conventional and organic production. For oilseed rape, beets, feed and lawn grasses, and grass field legumes, the costs are 3-9 % of the total growing costs for conventional production whereas they are 8-21 % of the total growing costs for organic production. Here, organic oilseed rape (about 900 ha) and organic production of grass seed (about 1,600 ha) and clover seed (about 800 ha) show the largest costs.

It must be noted that calculations of the costs of the proposed control measures were also carried out in the cases where the Working Group did not estimate that the proposed control measures would currently ensure co-existence.

The calculations show that the present farm management and agricultural system has a strong influence on the expected costs at the individual farms. Farms with specialised productions, such as certified seed, already work today within sets of regulations, which largely use the control measures on compliance and the threshold values that are suggested in the report.

The Group does not make any recommendations as to who should cover the extra expenses incurred if GMOs are adventitiously found and who should cover expenses in connection with any monitoring and control. Neither does it make any recommendations as to who should meet the expenses in connection with regulations on separation distances, buffer zones, etc. These questions are included in the Government's strategy for co-existence.

The costs of ensuring separation between non-GM and GM products by grain merchants and in the processing sectors are illustrated by selected production chains covering both foods and feed production.

As appears from the examples, a safe separation of non-GM products and GM products by grain merchants and in the processing sectors is possible in practice but the costs of separation are significantly affected by the nature of the products and the complexity of the production chains.

Regarding sugar, the production chain is relatively simple and the product has a long life. The extra costs of separation will in this case be a few per cent. Rapeseed oil is a product with a limited storage life and a more complex production chain and the extra costs of separation will be about 14 %. The agricultural merchants sector and the production of feed mixtures constitute a complex production chain with many stages and checkpoints. The extra costs of ensuring separation will here typically be about 24 % as illustrated for a GM feed wheat. In connection with production of a finished frozen consumer product, the extra costs are estimated at 6-7 % of the total costs as calculated without costs for raw materials. The extra costs were added to the GM production line in all the cases described.

It must, however, be noted that some of the calculated extra costs will probably occur in any case and independently of a Danish introduction of GM crops. This is due to the EU labelling regulations and the need for increased trace ability and separation of production lines at import of foods and feed. Finally, it must be noted that the production volume will also have a major influence on the costs.

Areas where new knowledge is needed

New knowledge appears continuously, and similar evaluation work has also been initiated in other European countries.

The Swedish Government has, inspired by the first version of the Danish report on co-existence, published its co-existence report in June 2003: “Samexistens i fält mellan genetiskt modificerede, konventionella och ekologiska gröder”.

Chapter 4.6 of our report contains a survey of a number of relevant, recently published reports.

The Group suggests that such reports and analyses are progressively included in a Danish evaluation of the problems, *cf.* the proposal of a continuously updated evaluation and adjustment of control measures for ensuring co-existence.

It is apparent that ensuring co-existence will, in most cases require extra care during production, good farm management, and an increased need for neighbour information as well as mutual understanding. The Group therefore suggests that a training course in co-existence should be made compulsory for farmers who grow GM crops – possibly as part of the farmer's licence to grow GM crops.

Much of the Group's work is based on foreign experiences and model calculations, and thus makes many assumptions in the evaluations and estimates. Only a few specific Danish experiments or model calculations exist regarding co-existence of GM crops with conventional and organic crops respectively.

Consequently, there is a need for improved knowledge with regard to:

- Plant characteristics in relation to the competitive capacity and the necessary control measures.
- Conditions affecting pollination.
- The extent of pollen dispersal, including the effect of field size.
- The potential for cross-pollination with wild relatives and volunteers.
- The presence of volunteers as weeds, including the survival period in the seed bank.
- Comparison between genetic and morphological characteristics for determination of varietal purity/GM presence.
- The effect of buffer zones.
- The importance of the extent of crop cultivation for the control measures to be adopted.
- The development of cropping systems to maintain varietal purity in seed fields.
- The development of models and decision support systems.
- Holistic analyses of the economic consequences of GM crop cultivation.

It is suggested that the need for new knowledge in these areas should be covered by establishing the monitoring, research and development programme mentioned above. The results of this programme would be used for a continuously updated evaluation of the control measures for ensuring co-existence.

Individual crop groups

Oilseed rape (see also Table 2.1)

Reproduction

Oilseed rape is both self-pollinated and cross-pollinated by wind and insects. In the case of hybrid varieties, seed production (multiplication) takes place using a technique with very extensive cross-pollination. Production crops of hybrid varieties grown in Denmark are assumed to resemble self-fertile varieties with respect to pollen production and cross-pollination. Varietal associations are not grown in Denmark at present. Two crop types are grown: Winter oilseed rape (sown in the autumn) and spring oilseed rape (sown in the spring).

Crop area, Denmark, 2002

Conventionally grown winter oilseed rape (production):	75,000 ha
Conventionally grown spring oilseed rape (production):	6,000 ha
Conventionally grown oilseed rape (seed):	600 ha [1)]
Conventionally grown oilseed rape in total:	81,600 ha
Organically grown winter oilseed rape (production):	800 ha
Organically grown spring oilseed rape (production):	80 ha
Organically grown oilseed rape (seed):	10 ha
Organically grown oilseed rape in total:	890 ha
Oil seed rape in total:	83,000 ha

1) This approximate figure consists of 478 ha winter oilseed rape and 84 ha spring oilseed rape. Seed production of hybrid varieties of winter oilseed rape and spring oilseed rape is about 5 % (less than 30 ha) and 0 % respectively of the respective areas.

Most important sources of dispersal

Dispersal can take place via sown seed, seeds lost at harvest and surviving in the seed bank of the soil, and seeds dispersed through handling and transport, as well as via pollen dispersal.

Adventitious presence

Seed: 0 % scenario with foreign GM growing:

- Adventitious presence is possible via imported seed for seed production (basic seed).
- It should be possible to keep the adventitious presence in conventional seed production below 0.3 % provided that the basic seed used is "GM free".
- It should be possible to keep the adventitious presence in organic seed below the detection limit provided that the basic seed used is "GM free".

Seed: 10 % and 50 % scenarios:

- It should be possible to keep the GM presence in conventional seed production of self-fertile varieties below 0.3 % through requirements on use of GM free basic seed, more rigorous separation distances and control of volunteer plants plus possibly separate harvesting of non-GM field marginal zones or the choice of squared fields (this does not apply to hybrid varieties, however).
- For seed production of hybrid varieties, it is not possible with present knowledge to recommend crop separation distances and cropping intervals, which can ensure a GM-content below 0.3 %. Large separation distances are recommended, but seed testing of all seed lots for adventitious presence before certification can make seed production possible.
- It is suggested that cropping intervals between seed production of GM oilseed rape and non-GM oilseed rape should, as a starting point, be at least 8 years.
- In organic seed production, it should be possible to keep the adventitious presence at about 0.1 % through more stringent regulations on "GM free" basic seed, increased distance to GM oilseed rape fields, possibly separate harvesting of the organic field margin, regulations on field size and shape, complete control of all volunteer plants in the area around the organic farm plus limitations on machinery used jointly with GM producers. To ensure that the produced seed has an adventitious presence of less than 0.1 %, it must be tested for GM-content.
- For seed production of organic hybrid varieties, it is not possible with present knowledge to recommend crop separation distances and cropping intervals, which can ensure compliance with levels of adventitious presence below the detection limit.
- It is suggested that cropping intervals between seed production of GM oilseed rape and organic oilseed rape should, as a starting point be at least 12 years.

Production: 0 % scenario with foreign GM growing:

- Adventitious presence is possible via imported seed.
- It should be possible to comply with the threshold value in conventional production.
- It should also be possible to keep the content in organic production below the detection limit provided that the seed used is "GM free".

Production: 10 % and 50 % scenarios:

- It should be possible to keep the GM content in products from conventional fields below 0.9 % through more stringent separation distances and control of volunteer plants plus possibly separate harvesting of non-GM field marginal zones or the choice of squared fields.
- It should be possible to keep adventitious presence in organic fields at about 0.1 % through more stringent regulations on "GM free" seed, increased distance to GM oilseed rape fields, possibly separate harvesting of the organic field margin,

regulations on field size and shape, complete control of all volunteer plants around the GM field plus limitations on machinery used jointly with GM producers.

- It is suggested that cropping intervals between production of GM oilseed rape and conventional oilseed rape should, as a starting point, be at least 8 years, and between GM oilseed rape and organic oilseed rape at least 12 years.

Need for further knowledge

- Data on seed persistence and dispersal at field level, including an extensive description of the composition and dynamics of seed banks, for example using DNA markers.
- Data on the extent and significance of dispersal by machinery, in order to quantify this dispersal route, for example using DNA markers.
- Data and models for studying pollen dilution of GM pollen in a non-GM field as a function of distance from the source field as well as field sizes and shapes. Implications of separate harvesting of field margins for GM content in seeds of the remaining crop.
- Data on the importance of honeybees in pollen dispersal between oilseed rape fields within the foraging range of honeybees and across large distances by moving honey bee colonies, for example, between GM winter oilseed rape and non-GM spring oilseed rape.
- A continued collaboration with INRA to adjust the GENESYS model to Danish conditions. This requires the measurements of many of the biological parameters for oilseed rape under Danish conditions.
- Monitoring of dispersal from future GM fields in order to continuously review and adjust control measures.

Maize (see also Table 2.2)

Reproduction

Maize is an annual and is mainly cross-pollinated by wind. The male flowers normally develop first. Bees can collect the pollen but do not transport it to female flowers, as these have no nectar.

Crop area, Denmark, 2002

Conventionally grown maize:	93,000 ha
Conventionally grown maize seed:	None
Organically grown maize:	3,300 ha
Organically grown maize seed:	None
Maize in total:	96,000 ha

Maize constitutes 3.6 % of the Danish cultivated area, and the area is expected to increase by 10-15 % in 2003. Growing takes place primarily in Jutland and in Funen. Organic maize constitutes 2.2 % of the area at organic farms. The average field size for maize crops is 4.6 ha.

Maize seed for the Danish marked is produced especially in France and Germany. Nearly all maize grown in Denmark is harvested for maize silage before maturity.

Most important sources of dispersal
Seed and pollen dispersal. Maize is extremely reluctant to shed seeds naturally.

Adventitious presence
Seed:
- There is no conventional or organic maize seed production in Denmark.

Production: 0 % scenario with foreign production of GM seed:
- The threshold value is expected to be 0.5 % for the presence of GM maize in conventional seed in the EU.
- As maize is not multiplied in the crop rotation, no problems are expected regarding keeping the GM maize content below 0.5 %.
- A maximum adventitious GM presence of about 0.1 % may be achieved in organic maize production provided that GM free seeds with corresponding specifications for GM content are used.

Production: 10 % scenario:
- In conventional farming, a separation distance of 200 m is proposed for growing GM maize for silage. This corresponds to the regulations for the seed production of certified seed with a purity of 99.8 %. However, a necessary prerequisite is that the GM maize is heterozygote for the gene spliced in, that is to say that only half the GM maize pollen contains the gene that is spliced in.
- It is also a part of the evaluation that the maize grains are at most 50 % of the finished silage product and that a thorough cleaning of the harvest machines takes place between harvesting GM maize and non-GM maize. Under these preconditions, it should be possible to keep the total GM presence in a conventional maize field, which is at a distance of 200 m from a GM maize field, at a maximum content of 0.7 % (0.2 % from pollination from neighbouring fields and 0.5 % from the seed). No further measures in the form of cropping interval after GM cultivation should be necessary.
- As regards organic farming, it is estimated that the GM presence through pollination from neighbouring GM maize fields can be reduced to ~0.1 % through a separation distance of 300 m, and if “GM free” seed is used, the final GM presence can be maintained at ~0.1 %.

Production: 50 % scenario:
Organic and conventional farming

- The maize cropping area is increasing and is concentrated around the cattle farms in Jutland. It is to be expected that at the 50 % scenario problems may arise to meet the necessary separation distances in regions with an extensive cultivation of maize. As a result of this, further control measures may become necessary in the form of buying seed with a lower GM content, plus agreements with neighbours concerning the disposition of fields.
- It is emphasised that the GM presence in a non-GM maize field due to pollination from a GM maize field will depend to a very great extent on the mutual dimensions of the two fields and especially on the depth of the non-GM maize field in the direction away from the GM maize field.

Need for further knowledge
There is a need for

- Measurements of the dispersal of maize pollen under Danish climatic conditions.
- Studies of the effect of different field sizes and shapes on the total adventitious presence.

This knowledge should subsequently be used for developing computer models that can be used by the individual farmer and advisers as a planning tool.

Beet (see also Table 2.3)

Reproduction
Cross-pollination mainly by wind. Beets are mainly used for the production of sugar; a minor part is used for feed.

Crop area, Denmark, 2002

Conventionally grown sugar beets:	55,000 ha
Conventionally grown fodder beets:	10,000 ha
Conventionally grown beet seed:	63 ha
Organically grown fodder beets:	70 ha
Organically grown sugar beets:	140 ha
Organically grown beet seeds:	None
Beet in total:	65,000 ha

Beet cultivation constitutes 2.4 % of the total cultivated area. Only 0.3 % of the beet crop is organically grown. Production of beet seeds takes place primarily in Southern Europe.

Most important sources of dispersal

The largest risk for dispersal is from GM presence in imported seed. Cultivated beet can cross with wild beet species, such as the sea beet. The seed of all types of beet can persist for long periods in the soil. The occurrence of bolters and weed beet can be a serious source of adventitious presence.

Adventitious presence

Seed: 0 % scenario with foreign GM growing:

- Conventional seed is mainly imported
- There is no Danish organic seed production

Seed: 10 % and 50 % scenarios:

- In conventional seed cultivation, it is expected that the use of controlled basic seeds and a separation distance of 2,000 m, a crop rotation of 8 years and cleaning of machinery and transport equipment will make it possible to maintain a GM content <0.3 % in conventional seed production.
- By using “GM free” seed and at a separation distance of 2,000 m, a crop rotation of 8 years and cleaning of machinery and transport equipment, it is expected that a GM content of ~0.1 % can be maintained in organic seed production.

Production: 0 % scenario with foreign GM growing:

- In conventional farming, the import of certified beet seed is expected to result in a GM content of <0.3 % of the crop with no special measures.
- Through effective control of organic seed production, it is expected that a GM content ~0.1 % can be maintained with no special measures.

Production: 10 % and 50 % scenario:

- Irrespective of the cropping system, it is recommended that weed beets and bolters both in and outside the fields should be effectively removed to avoid GM dispersal from these.
- In conventional beet crops, a GM content below 0.4 % is considered achievable, primarily through the use of certified seed and through the cleaning of machinery and transport equipment. Increased crop separation distances (50 m) will, to a smaller extent, reduce the level of dispersal.
- In organic beet crops, it is expected that the GM content can be kept ~0.1 %, primarily through the use of “GM free” seed, the control of bolters and the cleaning of field machinery and transport equipment and to a smaller extent through increased crop separation distances (100 m) and cropping intervals (5 years) after GM growing.

Need for further knowledge

- The incidence of annual weed beets in Denmark needs to be examined.

- The significance of pollination systems and the chromosome composition of beet varieties on outcrossing frequencies should be analysed for a range of beet varieties and types.
- Knowledge of the probability of cross-pollination by GM pollen into (male-sterile) seed production fields in relation to distance from GM pollen source and the area of surrounding non-GM pollinator barrier plants.

Potato (see also Table 2.4)

Reproduction

Potato has the ability to reproduce vegetatively as well as by true seed in some cases. In Denmark, potato is grown and propagated as an annual crop from seed potatoes (actually clonal tubers) and not via "true seeds" as in some developing countries.

Crop area, Denmark, 2002

Conventionally grown potatoes for human consumption:	12,000 ha
Conventionally grown potatoes for starch production (potato flour):	20,000 ha
Conventionally grown seed potatoes:	4,000 ha
Organically grown potatoes for human consumption:	750 ha
Organically grown potatoes for starch production:	15 ha
Organically grown seed potatoes:	130 ha
Potatoes in total:	37,000 ha

In Denmark, potatoes are grown on about 1.4 % of the agricultural area. Organic production constitutes 2.5 % of the total potato production or 0.6 % or of the organic area. Potato growing is more intense locally and especially in Central and Western Jutland where it constitutes up to 13 % of the area in some municipalities. Denmark exports half of its seed potatoes.

Most important sources of dispersal

From adventitious GM-presence in seed potatoes (tubers), volunteer tubers (ground-keepers) and true seeds in soils, as well as tubers remaining in field machinery, transport equipment and stores. Pollen dispersal between crops and establishment of seed plants and tubers is another possibility in certain cases.

Adventitious presence

Seed (seed potatoes): 0 % scenario with foreign GM growing:

- The only source of adventitious presence will be imported seed, which would have to be controlled if they originate from areas where GM potatoes are grown. The proposed threshold value for seed potatoes in EU is 0.5 %.
- In organic farming, the use of tested seed from areas where no GM potatoes are grown will minimise likelihood of GM presence.

Seed (seed potatoes): 10 % and 50 % scenarios:

- The production of potato seed in Denmark already has legal constraints regarding crop separation distances, cropping intervals, deployment of machinery, *etc*. The present level of varietal impurity allowed is 0-0.05 %, depending on class. The testing is, however, based on morphological characteristics and not on genetic analysis.
- In conventional farming, it is expected that GM presence in Danish seed potatoes can be kept at a very low level through controlled use of seed, control of ground-keepers, separation distances to GM potatoes and an increased cropping interval for certified seed potatoes. A conversion from GM potato growing to non-GM potato seed production necessitates the introduction of an increased cropping interval for the fields.
- For organic seed potatoes, it is estimated that adventitious GM content can be kept below ~0.1 % with the additional measure of using organic seed potatoes in all classifications and provided that the above-mentioned cropping interval between production of GM potatoes and organic seed production in a field is increased further.

Production: 0 % scenario with foreign GM growing:

- The only source of GM presence would be foreign seed potatoes, see above section on seed.

Production: 10 % and 50 % scenarios:

- There is already a regulation that seeds in Danish potato production have to be replaced regularly and that farm-saved seed must be for own use only.
- In conventional farming, these regulations, supplemented by separation distances to GM potatoes and combined with a varied crop rotation and control of ground-keepers, as well as the cleaning of machinery according to good farming practice, should keep GM presence at a low level. A cropping interval between production of GM potatoes and conventional potato production in a field is deemed to be necessary.
- In organic farming, it is expected that with the use of further slightly more stringent measures, it will be possible to keep the level of GM content ~ 0.1 %, as long as tested organic seed potatoes with organic origins are used in all preceding classes.

Production: 50 % GM scenario:

- A large distribution of GM potatoes in areas with intensive growing of potatoes will not make it impossible to comply with separation distances and other control measures, but will necessitate much communication between neighbours.

Need for further knowledge

- Studies of the extent of the problems with volunteers and ground-keepers in Denmark in the light of the mild winters in recent years.
- Danish studies of pollen dispersal and cross-pollination, including the dispersal by insects and the extent of over-wintering of true seeds and volunteers originating from them.

Barley, wheat, oats and triticale (see also Table 2.5)

Reproduction

The varieties are primarily self-pollinating, although triticale has some cross-pollination. In Denmark, mainly triticale varieties with a high degree of self-pollination are grown.

Crop area, Denmark, 2002

Conventionally grown barley:	809,000 ha
Conventionally grown wheat:	574,000 ha
Conventionally grown triticale:	25,000 ha
Conventionally grown oats:	46,000 ha
Organically grown barley:	20,000 ha
Organically grown wheat:	7,600 ha
Organically grown triticale:	2,300 ha
Organically grown oats:	8,500 ha
Totally:	1,492,400 ha

The 4 cereals cover about 1,492,000 ha when grown to ripeness or about 56 % of the cultivated area in Denmark. In addition there is grain and mixed seed for wholecrop production, which altogether covers about 82,000 ha grown conventionally and about 16,000 ha which is organic. Altogether this is about 59 % of the cultivated area. The average size of a field is largest for winter wheat with 6.1 ha and smallest for oats with 3.7 ha. For spring barley it is 4.2 ha.

Most important sources of dispersal
Through adventitious GM content in seed, transmission by volunteers and through straw, volunteers and admixtures in connection with crop handling.

Adventitious presence
Seed: 0 % scenario with foreign GM growing:
- No problems are expected with respect to meeting the threshold for adventitious GM presence in seed of less than 0.5 %.
- No problems are expected with respect to maintaining the GM presence in organic seed below the detection limit.

Seed: 10 % and 50 % scenarios:
- It should still be possible to comply with the threshold of 0.5 % for GM content in grain seed and to keep the level below the detection limit in organic seed production, provided analyses are performed regarding the GM presence in all basic seed lots.

Production: 0 % scenario with foreign GM growing:
- The only source of adventitious GM presence is imported seed.
- No problems are expected regarding keeping the GM content in conventional production below 0.5 %.
- Neither should there be any problems in keeping the GM content in organic production below the detection limit.

Production: 10 % and 50 % scenarios:
- It should be possible to keep the GM presence in conventional production below 0.6 %.
- It will still be possible to keep the GM content in organic production below the detection limit. The maintenance of the threshold values will require an effective segregation throughout the production system.

Need for further knowledge
- The importance of sources of GM presence originating from volunteers, harvesting, transport, and storage operations, respectively, is less well documented. Here are (for evaluation of GM presence due to harvesting, transport, and storage operations) used estimated values based on rape, which has far smaller seeds and a quite different volunteer biology than the cereals.
- The ability of cereals to survive as volunteers and form part of the soil seed bank is also insufficiently understood.

Rye (se also Table 2.6)

Reproduction

Rye is wind-pollinated, and in Denmark there are no other species with which it can cross-pollinate.

Crop area, Denmark, 2002

Conventionally grown rye (grain):	43,000 ha
Conventionally grown rye (wholecrop, silage):	6,000 ha
Conventionally grown rye (seed):	1,600 ha
Organically grown rye (grain):	2,500 ha
Organically grown rye (wholecrop, silage):	2,300 ha
Organically grown rye (seed):	500 ha
Rye in total:	56,000 ha

Rye constitutes 1.6 % of the cultivated area. Organic growing of rye constitutes about 12.5 % of the total production of rye. In organic farming, rye for grain constitutes 2.2 % and rye for wholecrop 1.5 %. Growing rye is especially frequent in North Jutland, Mid Jutland, and North Zealand, where it covers 5-16 % of the cultivated area in some municipalities. A few rye varieties are hybrids. In Denmark only 65 ha are used for seed production of hybrid rye and that is exclusively in the form of seed production for certified seeds.

Most important sources of dispersal

- Dispersal to neighbouring fields through pollen.
- The seeds normally persist less than a year in the soil. Rye does not appear as a weed in the crop rotation and is therefore not expected to propagate in the field.
- Rye does not cross-pollinate with weeds or other cultivated plants in Denmark.
- A significant proportion of rye production, especially in organic production, is harvested before reaching ripeness and is used as wholecrop.

Adventitious presence

Seed: 0 % scenario with foreign GM growing:

- The threshold value for adventitious presence of GM rye in conventional seed has not been decided but will probably be 0.3-0.5 %. GM rye could be introduced via imported seed, but as rye does not multiply in the crop rotation, there will be no problems in the Danish seed production of conventional varieties.
- It will be possible for organic farmers to achieve a lower GM content ~0.1 % if they use seed with corresponding specifications.

Seed: 10 % and 50 % scenarios:

- As a starting point, it is recommended that growers comply with the separation distances and cropping intervals that are stated for seed production. However, it should be stressed that no knowledge of GM rye seed multiplication is available.

Production: 0 % scenario with foreign GM growing:

- Unexpected presence of GM rye will solely be a result of its presence in seed, as rye cannot multiply in the crop rotation. The threshold value for adventitious GM presence in conventional seed is expected to be 0.3-0.5 %, *i.e.* considerably below the threshold value of 0.9 % in the end product.
- In organic rye production, a GM content of ~0.1 % can be achieved by purchasing seed with corresponding specifications for the content of GM rye.

Production: 10 % scenario:

- In conventional farming, the general recommendation for the production of certified seed from open-flowering varieties is a separation distance of 250 m. According to experience from the production of certified seed, this should ensure a very low cross-pollination percentage through pollen dispersal.
- According to experience from the production of open-flowering certified varieties, a separation distance of 250 m to a GM rye field will ensure a very low GM presence in organic growing. A precondition for this level is that “GM free” seed is used.

Production: 50 % scenario:
Organic and conventional farming

- In 2002, the total rye area was only 1.6 % of the cultivated area, 12.5 % of which was cultivated organically. However, there are regions, where there is a relatively high concentration of rye. It should therefore be expected that problems to comply with the necessary separation distances could arise under a 50 % GM scenario. As a result of this, further control measures may become necessary in the form of using seed with a lower GM content and agreements between neighbours on the location of GM and non-GM crops.

Need for further knowledge

- Knowledge about the potential crossing percentages of GM rye in non-GM rye fields is limited.
- Knowledge about pollen dispersal under Danish climatic and field conditions as well.
- An evaluation is needed of the possibilities of control measures in the form of the planning of field spacing and field size. These studies can be made relatively easily if a number of trial plots are planted with rye, which through crossing with rye in surrounding fields, causes a morphological change that is easy to see, *e.g.* a change in the shape or colour of the seed. This information can subsequently be used for

developing computer models for predicting adventitious presence under a number of different production conditions.

Forage and amenity grasses (see also Table 2.7)

Reproduction

Grasses are mainly cross-pollinating (wind) with the exception of smooth stalked meadow grass, which is self-fertile.

Denmark is the largest producer of grass seed in the EU with more than 40 % of the total EU grass seed production. Denmark is also the world's largest exporter of grass seed and is one of the few countries in the world to establish organic grass seed production.

Perennial rye grass is the most commonly used grass species in grazing fields, and it constitutes also by far the largest area in the production of seeds. The seed production of perennial rye grass is mainly located in Western Denmark, partly because of larger amounts of precipitation and partly because this production to some extent can be combined with animal husbandry. The seed production of red fescue and smooth-stalked meadow grass is primarily located in Eastern Denmark.

Crop area, Denmark, 2002

Conventional grass/clover pastures in crop rotation:	189,000 ha
Permanent pasture:	137,000 ha
Set-aside areas with grass:	192,000 ha
Conventional seed production (various grass species):	63,000 ha
Organic grass/clover pastures in crop rotation:	34,000 ha
Organic permanent pasture:	20,000 ha
Organic seed production (various grass species):	1,600 ha
Organic set-aside areas with grass:	4,000 ha

Grass areas including grass set-aside areas constitute about 640,000 ha in total or about 24 % of the agricultural area.

Grasses are very widespread in recreational areas – *i.e.* golf courses, sports grounds, parks and private lawns. The grass area for these purposes is about 15,000 ha, and the area is increasing. Due to the widespread distribution of grass in farming, recreational areas and in natural/unfarmed areas, it will be of great importance to carry out a thorough evaluation of the characteristics of GM varieties in relation to their dispersal and survival capacity. It will be a requirement that GM varieties cannot displace existing species and cultivars by having a greater competitive capacity. Herbicide resistant GM grass varieties have been developed for use on golf courses.

Most important sources of dispersal
Seed, pollen, seedlings (volunteers), hybridisation with other cultivated and weed grass species, as well as harvesting machines, and transport of seeds and hay.

Adventitious presence
Seed (seed production): 0 % scenario with foreign GM growing:

- Foreign seed lots are propagated in Denmark. If these lots contain GM seed, additional measures should be implemented.
- It is expected that it will be possible to comply with an adventitious presence of GM seed of <0.3 % and <0.1 % for conventional and organic production respectively at a seed production in keeping with the Ministerial order on field seeds.

Seed (seed production): 10 % and 50 % scenarios:

- At moderate distribution of GM varieties, it is expected that further measures must be implemented in conventional seed production in order to comply with an adventitious presence of GM plants of <0.3 %. These additional measures will be use of "GM free" basic/certified seed or seed with a very low GM content, compliance with increased separation distances, increased cropping intervals (dependent on the survival capacity of the grass species in the soil and on the possibilities of controlling volunteers).
- At extensive growing of GM varieties, additional measures may prove necessary to achieve a GM content of <0.3 %. These measures may include use of buffer zones in the form of a zone of bare soil/spring-sown crop/cutting and separation of field margin at harvest, guidelines for the control of volunteers and guidelines for the sequence of crops, as well as the control of grass weeds in the crop rotation.
- At moderate distribution of GM varieties, a precondition of achieving a GM content of below ~0.1 % in organic seed production will be that the field can be established by using organic seed ("GM free") as well as by compliance with separation distances to GM seed fields and compliance with a cropping interval of 5-7 years, in which volunteers are effectively controlled. In addition machinery, drying plants, and stores should be cleaned carefully, and machinery should not be used jointly with GM growers.
- At an extensive growing of GM varieties, it is expected that it will be necessary to monitor contributions to admixtures from field boundaries, recreational areas, grazing fields, the soil seed bank and long-distance pollen dispersal as a result of local circumstances and environmental conditions (wind direction during flowering, *etc.*). It is therefore recommended that the certified seed should be tested for GM presence.

Production (grass field in crop rotation): 0 % scenario with foreign GM growing:

- There is a limited import of fodder grass seed.

- Certified seed is used in connection with the establishment of production fields, and there should be no problems in complying with an adventitious GM presence of <0.8 % in conventional production and below ~0.1 % in organic production. The latter, however, subject to the use of "GM free" seed.

Production (grass fields in crop rotation): 10 % and 50 % scenarios:

- In connection with distribution of GM varieties it should be possible to comply with a level of adventitious presence of <0.8 % through the use of certified seed at field establishment. It is recommended that grass plants are effectively controlled at the end of the crop and to control any grass volunteers in the intervening crops. However, it is a prerequisite that the GM varieties commercialised do not possess a competitive capacity significantly exceeding the capacity of non-GM varieties.
- The maintenance of organic production fields with a GM content of <0.1 % is conditional upon access to organic or conventional "GMO free" (controlled) seed. If there are GM fields within the current separation distances, any flowering seed stems must be removed by grazing or mowing.

Need for further knowledge

Due to the widespread distribution of grass in both cultivated and in uncultivated areas as well as in recreational areas, it is considered necessary to combine different control measures in order to avoid adventitious presence of GM material at field, farm and regional levels. It is therefore relevant to initiate studies to determine:

- The importance of flowering biology on gene dispersal.
- The degree of invasion, establishment and introgression of genes/plants into perennial or permanent grass swards depending of the nature of the sward and its management.
- The effect of separation distance combined with different plant densities in both donor and receptor field.
- The importance of seed dispersal and the possibilities of controlling volunteer plants in different cropping systems/crop sequences.
- The importance of gene dispersal at a regional level (seed fields, production fields, field boundaries, recreational areas, set-aside fields, *etc.*) and the effect of buffer zones.
- Gene dispersal at field, farm and regional levels through monitoring the introduction of varieties with identifiable characteristics (both morphological and genetic).

The development of cropping systems to ensure varietal purity in seed production fields would be of great importance in maintaining Denmark's position as the leading exporter of conventional and organic grass seed.

Grassland legumes (see also Table 2.8)

Reproduction
White and red clover is almost completely self-incompatible and is cross-pollinated mostly by insect-pollination with honeybees and naturally occurring bumblebees. White clover can also reproduce vegetatively by virtue of development of rooting stem offshoots. Lucerne is also cross-pollinated (insect-pollinated).

Denmark is the largest producer of white clover seed in the EU, and about 80 % of the total white clover seed production in the EU is located in Denmark. White clover is used extensively in organic farms.

Clover (especially white clover) is widely distributed in both cultivated and uncultivated areas. Moreover, white clover in grass mixtures is being introduced into recreational areas. Due to the large distribution of white clover it is of very great importance to carry out a thorough evaluation of the characteristics of GM varieties in relation to their distribution and survival capacity. It is a requirement that GM varieties do not have a competitive capacity significantly exceeding the competitive capacity of non-GM plants.

GM white clover is being developed, and GM lucerne has been developed.

Crop area, Denmark, 2002

Conventional clover in mixtures with grass:	189,000 ha
Conventional white clover (seed production):	2,852 ha
Conventional red clover (seed production):	381 ha
Organic clover in mixtures with grass:	34,000 ha
Organic set-aside:	34,000 ha
Organic white clover (seed production):	554 ha
Organic red clover (seed production):	246 ha
Conventional lucerne (forage production):	2,400 ha
Conventional lucerne (seed production):	6 ha
Organic lucerne (forage production):	800 ha
Organic lucerne (seed production):	0 ha

It is estimated that white clover is present in the majority of rotational grass fields, about 223,000 ha or about 8 % of the total Danish agricultural area. About 18 % of this is organic.

Most important sources of dispersal

Seed, pollen, seed (hard seeds), hybridisation with wild relatives and weeds (lucerne), harvest machinery, and transport of seed.

Adventitious presence

The threshold value for the adventitious GM presence in conventionally produced clover and lucerne seed has not been established. The following estimates have been based on an expected threshold of 0.3 % for conventional seed and ~0.1 % (the detection limit) for organic seed.

Clover

Seed: 0 % scenario with foreign GM growing:

- It is expected that it will be possible to comply with a GM content of <0.3 % in conventional seed production and <0.1 % in organic seed production in accordance with the Ministerial Order on seed purity.

Seed: 10 % and 50 % scenarios:

- At a moderate distribution of GM varieties, it is expected that additional measures must be initiated in order to achieve a GM content of <0.3 %. These additional measures consist of larger separation distances and increased cropping intervals.
- On the current basis of knowledge, no guidelines can be produced that will ensure organic clover seed production (especially white clover) has a GM content under the detection limit (~0.1%) if GM white clover is grown in Denmark. This is due to:
  - Pollinating insects being able to disperse pollen from GM fields across very large distances (up to 5 km).
  - The presence of dormant seeds contributing to maintaining volunteers in intervening crops.
  - White clover being widely distributed in organic farms (in the form of grazing fields, fertility building crops and seed crops).
  - The difficulty of preventing flowering of white clover by mowing.
  - The difficulty of controlling white clover in organic farming.

Production (grass-clover fields): 0 % scenario with foreign GM growing:

- Certified seed is used in the establishment of production fields, and no problems are expected in maintaining an adventitious presence <0.8 % in conventional production.
- It is anticipated that it will be possible achieve a threshold of below ~0.1 % in organic production fields provided that organic "GM free" seed is used for establishing the crop, that the recommended separation distances are complied with and that the proposed cropping interval is used. At present, the supply of organic white clover seed is insufficient.

Production (grass-clover fields): 10 % and 50 % scenarios:

- If there is extensive use of GM varieties in conventional production, it is currently not possible to recommend measures, which will ensure an adventitious GM presence below the threshold value in perennial grazing fields.
- If there is moderate use of GM varieties, it is currently not possible to recommend control measures to ensure a GM presence of below ~0.1 %.

Lucerne

Seed:

- There is only a small amount of seed production of lucerne in Denmark.

Production: 0 % scenario with foreign GM growing:

- It is anticipated that it will be possible to maintain an adventitious presence of GM plants of <0.8 % in conventional production without introducing additional control measures.
- It is anticipated that it will be possible to maintain an adventitious presence of GM plants below ~0.1 % in organic production without introducing additional control measures.

Production: 10 % and 50 % scenarios:

- It is anticipated that it will be possible to maintain an adventitious presence of GM plants of <0.8 % in conventional production by using certified seed for crop establishment.
- It is anticipated that it will be possible to maintain an adventitious presence of GM plants of <0.1 % in organic production by using organic or conventional "GM free" seed for crop establishment.

Need for further knowledge

Due to the widespread distribution of white clover in the cultivated and in uncultivated areas, it is considered necessary to combine different measures in order to minimise adventitious presence of GM material at field, farm and regional levels.

- There is a need for further studies of the degree of invasion, establishment and introgression of genes/plants into perennial or permanent clover/grass swards depending of the nature of the sward and its management.
- Clover persists for a very long time in the soil - especially because of its ability to develop hard seeds. Initiatives to prevent/reduce the presence of hard seeds should be developed. Factors that influence the persistence of hard seeds should be studied to develop a model for predicting the presence of hard seed in the soil, in relation to cropping intervals and conversion time.
- In the long term, gene dispersal in clover at the regional level (clover seed fields, grass-clover leys, field boundaries, *etc.*) will be important for the level of adventitious

presence. Therefore a monitoring programme to determine the extent of this gene dispersal should be initiated.

- The development of cropping systems to maintain varietal purity in seed fields will be of great importance to maintain Denmark's position as the leading clover seed producer in the EU both in conventional and in organic seed production.
- The possibility of making voluntary, regional agreements on the placing of GM white clover fields in relation to organic farms and pasture should be examined which take account of white clover being widespread in both conventional and organic farms and seed production taking place in areas using clover in pastures.

Field pea (see also Table 2.9)

Reproduction
Self-pollinating with a small amount of insect pollination. Peas do not form hybrids with other wild relatives in Denmark.

Field pea is usually grown for wholecrop or for grain, and is a source of protein for both animal and human consumption.

Crop area, Denmark, 2002

Conventionally grown grain peas:	26,000 ha
Conventionally grown pea seed:	8,000 ha
Conventionally grown silage peas:	12,000 ha
Conventionally grown green peas:	3,000 ha
Organically grown grain peas:	1,700 ha
Organically grown pea seed:	1,300 ha
Organically grown peas for silage:	4,000 ha
Organically grown green peas:	100 ha
Pea growing in total:	56,000 ha

Peas for different purposes comprise altogether 2.1 % of the agricultural area of which 13 % is organic.

Most important sources of dispersal
The main dispersal mechanism in peas is through seed. There is little risk of admixture in crop rotations as seed of field pea persists for only a short time in the soil. There is little risk of pollen dispersal as the majority of varieties are self-pollinating.

Adventitious presence

Seed: 0 % scenario with foreign GM growing:

- The use of conventional pea seed to supplement the need for organic seed will involve a small risk of GM adventitious presence, estimated, however, at maximum of 0.3 %.
- By using "GM free" seed, it is estimated that the GM presence in organic seed production will be ~0.1 % without using special control measures.

Seed: 10 % and 50 % scenarios:

- Use of certified seed, separation distances of 50 m and cleaning of machinery and transport equipment is expected to restrict the presence to a maximum of 0.3 % in conventional seed growing.
- By using "GM free" seed, separation distances of 50 m and cleaning of machinery and transport equipment, the GM presence in organic seed production is estimated at ~0.1 %.

Production: 0 % scenario with foreign GM growing:

- For conventional pea production, the GM presence is expected to be less than 0.3 % of the crop without special initiatives.
- For organic pea production, the GM presence is expected to be ~0.1 %with the use of organic certified seed and without special control measures.

Production: 10 % and 50 % scenarios:

- Increased monitoring may reduce presence to some extent. It is expected that the GM presence in conventional pea crops can be kept below 0.5 %, primarily through the use of certified seed, and to a lesser extent through the use of increased crop separation distances (10 m), as well as the cleaning of field machinery and transport equipment. It may also be appropriate to add a buffer zone.
- It is expected that the GM presence in organic pea production can be kept at ~0.1 %, primarily through the use of "GM free" seed, increased separation distances and through cleaning of field machinery and transport vehicles. It may also be appropriate to add a buffer zone.

Need for further knowledge

- The extent of cross-pollination by insects and the biological factors involved are not sufficiently researched. Additional knowledge on pollen dispersal by bees is necessary to establish effective isolation distances.

Field beans (faba beans) and lupin (see also Table 2.10)

Reproduction

The species are mainly cross-pollinated by insects, mostly bees. However, some species are also largely self-pollinating.

Crop area, Denmark, 2002

Conventionally grown field beans:	700 ha
(of this 309 ha seed)	
Organically grown field beans:	250 ha
(of this 136 ha seed)	
Field beans in total:	950 ha
Conventionally grown lupin:	550 ha
(of this 64 ha seed)	
Organically grown lupin:	1,600 ha
(of this 395 ha seed)	
Lupin in total:	2,150 ha

Organic production is about 27 % of the field bean area and about 74 % of the lupin area.

Most important sources of dispersal

Pollen, imported seed with adventitious presence, sowing and harvesting machinery, transport equipment, storage facilities and handling equipment.

Adventitious presence

Seed: 0 % scenario with foreign GM growing:

- It should be possible to keep the adventitious presence in conventional seed production below 0.3 %.
- It should also be possible to keep the presence in organic seed at ~0.1 %.

Seed: 10 % and 50 % scenarios:

- It should be possible to keep the GM content in seed in conventional production below 0.3 % with the present regulations on separation distance (400 m) and cropping intervals for production of basic seed.
- In order to keep the GM content in seed for organic production below ~0.1 %, it is suggested that the seed is produced in special isolated areas with no other cultivation of these species.

Production: 0 % scenario with foreign GM growing:

- It should be possible to keep the GM content in conventional production below 0.3 % provided that imported seed lots are checked for GM content.
- It will also be possible to keep the GM content in organic production below ~0.1 %, provided that only "GM free" certified seed is used for production.

Production: 10 % and 50 % scenarios:

- It should be possible to keep the adventitious presence in conventional non-GM production below 0.6 % with testing of imported seed, a separation distance of 400 m and a two-year cropping interval.
- The adventitious presence in organic productions can also be kept below ~0.1 % with testing of imported seed, a separation distance of 400 m, a two-year cropping interval between a GM crop and organic production and the exclusive use of organic certified seed in the production.

Need for further knowledge

- The extent of cross-pollination and of cultivar variation is less well documented.
- Further knowledge of the role of insects in pollen dispersal, the decline in dispersal with distance into the field and on pollination, may be necessary in order to better determine separation distances.

Vegetable seed production (spinach, carrot, cabbage, radish, etc.)

Reproduction

Spinach, carrot, cabbage and radish are cross-pollinated (wind and insects).

Crop area, Denmark, 2002

Conventionally grown carrot:	1,600 ha	*
Organically grown carrot:	300 ha	*
Carrot seed:	300 ha	
Conventionally grown spinach seed:	3,000 ha	
Organically grown spinach seed:	Small production	

* Year 2000

Altogether about 5,300 ha of different vegetables are grown in Denmark, corresponding to 0.2 % of the cultivated area.

Denmark is the world's largest producer of spinach seed, and varieties (both open-pollinated and hybrid varieties) are propagated by both Danish and foreign variety owners.

Most important sources of dispersal

Pollen and seed dispersal and hybridisation with related weed species.

Adventitious presence

A more detailed analysis species by species will be necessary in order to adjust control measures to specifically ensure co-existence of the individual species. In this report, the individual vegetable species are not considered in detail.

The variety owners' quality requirements for these crops are already very high, and the production of vegetable seed therefore already takes place in accordance with production guidelines that exceed the official requirements in terms of separation distance, cropping interval, *etc.*

However, the species mentioned above are all cross-pollinating, and it should be emphasised that, if adventitious GM presence is to be restricted, it will be necessary to initiate further measures in seed production. Measure to restrict GM presence include regulations on the use of tested seed, isolation distances, increased cropping intervals and the use of buffer zones.

In order to maintain organic vegetable production with a GM content below the detection limit, it is necessary to procure organic seed or conventional "GM free" seed of varieties that meet the production requirements of organic vegetable producers. Seed production in pollen-proof environments (*e.g.* plastic tunnels) could be a possible method.

Need for further knowledge

- More studies on pollen dispersal and seed dispersal in order to define specifications for separation distances and buffer zones in order to minimise GM admixture.
- Studies of systems for maintaining varietal purity in vegetable seed areas, including studies of production in pollen-proof facilities.

Table 2.1. Oilseed rape. Co-existence between genetically modified (GM), conventional and organic crops in Denmark. Summary of measures for the control of adventitious GM presence and estimated maximum presence levels.

Crop	Scenario			Cropping interval 1)	Used seed	Separation Distance 2)	Buffer zone 3)	Other measures ¤)	Estimated adventitious presence
Oilseed rape. Self-fertile/ hybrid.	0	Conventional	Seed multiplicat. self-fertile var.	6 yr 4)	∇∇∇	100 m	-		0-0.3 %
			Seed multiplicat. hybrid var.	6 yr 4)	∇∇∇	300 m			0-0.3 %
			Production 5)	∇	∇	∇	-		0-0.7 %
		Organic	Seed multiplicat. self-fertile var.	6 yr 4)	∇∇∇	100 m	-		~0.1 %
			Seed multiplicat. hybrid var.	6 yr 4)	∇∇∇	300 m	-		~0.1 %
			Production 5)	∇	∇∇∇	∇	-		~0.1 %
	+GM	Conventional	Seed multiplicat. self-fertile var.	8 yr	∇∇∇	300 m	Poss. 6 m	Control of volunteer plants and related weeds around boundaries to GM fields. Possibly regulations on field size and shape. Cleaning of jointly used machinery before use.	0-0.3 %
			Seed multiplicat. hybrid var.	8 yr	∇∇∇	1,000 m	-	Control of volunteer plants and related weeds around boundaries to GM fields. Possibly regulations on field size and shape. Cleaning of jointly used machinery before use. Testing of the produced seed for GM content required.	?
			Production 5)	8 yr	∇	150 m	Poss. 6 m	Control of volunteer plants around boundaries to GM fields. Possibly regulations on field size and shape. Cleaning of jointly used machinery before use.	0-0.8 %
		Organic	Seed multiplicat. self-fertile var.	12 yr	∇∇∇	500 m	Poss. 6 m	Complete control of volunteer plants and related weeds around boundaries to GM fields. Regulations on field size and shape. Limitations on joint use of machinery with GM producers/GM machine pools. Mandatory testing of the produced seed for GM content.	~0.1 %
			Seed multiplicat. hybrid var.	12 yr	∇∇∇	1,500 m	-	Complete control of volunteer plants and related weeds around boundaries to GM fields. Regulations on field size and shape. Limitations on joint use of machinery with GM producers/GM machine pools. Mandatory testing of the produced seed for GM content.	?
			Production 5)	12 yr	∇∇∇	500 m	Poss. 6 m	Complete control of volunteer plants around boundaries to GM fields. Regulations on field size and shape. Limitations on joint use of machinery with GM producers/GM machine pools.	~0.1 %
Present regulations on seed production (certified seed) of self- fertile/hybrid variety				6 yr 4)		100 m/ 300 m			

[¤)] More stringent control measures on GM farms.

- Complete control of oilseed rape volunteers on the whole farm and adjoining areas.
- Choice of crop rotation and soil treatment that minimise accumulation of GM seed in the seed bank.
- Complete cleaning of machinery after GM use of jointly used machinery
- Ensuring transport of GM oilseed rape in seed-tight containers.

Scenario 0	No GM plants of this crop are grown in Denmark. Seed can, however, be imported from other countries with a threshold of adventitious presence of 0.3 % for conventional seed for production. For organic seed, a corresponding level of less than 0.1 % is assumed.
Scenario + GM	GM plants of this crop are grown in Denmark. Both the 10 % and 50 % scenarios of GM cropping are included. It is assumed that, within a given season, there is no simultaneous cropping of the same GM and non-GM crop on the same farm.
[1)] Cropping interval	Years with other crops following a GM crop, or a crop with a significant GM presence, and until a conventional “GM free” or organic crop production of this crop can be take place in the same field again. Control of volunteers in the intervening period is assumed. Under the present regulations of certification, this means the period between growing the same species in a field.
[2)] Separation distance	The distance between a GM and the nearest non-GM crop that can cross-pollinate. The distances may be reduced in case of a larger area of non-GM field or buffer zone in the non-GM field.
[3)] Buffer zone	Field margins at the verge of non-GM field towards GM field. The margins are harvested separately.

[4)] 8 years between production of varieties with different content of erucic acid and/or glucosinolate.

[5)] It is assumed that hybrid varieties grown in Denmark resemble self-fertile varieties with respect to pollen production and cross-pollination.

The estimated GM presence covers the production as far as the first stage of distribution.

-	Not relevant.
∇	Good farming practice.
∇∇	Crop production: minimum requirement of certified seed. Seed production: higher class, *i.e.* pre-basic or basic seed.
∇∇∇	“GM free” seed (GM presence <0.1 %).

Table 2.2. Maize. Co-existence between genetically modified (GM), conventional and organic crops in Denmark. Summary of measures for the control of adventitious GM presence and estimated maximum presence levels.

Crop	Scenario			Cropping interval[1)]	Used seed	Separation distance[2)]	Buffer zone[3)]	Other measures	Estimated GM presence
Maize	0	Conventional	Seed multiplicat.	-	-	*	-		0-0.5 %
			Production	-	∇∇	-	-		0-0.5 %
		Organic	Seed multiplicat.	-	-	*	-		~0.1 %
			Production	-	∇∇∇	-	-	Seed from areas without GM crops	~0.1 %
	+GM (10 %)	Conventional	Seed Multiplicat.	-	-	*	-		0-0.5 %
			Production	-	∇∇	200 m	-	Cleaning of jointly used machinery	0-0.7 %
		Organic	Seed Multiplicat.	-	-	*	-		~0.1 %
			Production	-	∇∇∇	300 m	-	Cleaning of jointly used machinery	~0.1 %
	+GM (50 %)	Conventional	Seed Multiplicat.	-	-	*	-		0-0.5 %
			Production	-	∇∇	200 m	-	Cleaning of jointly used machinery	0-0.7 %
		Organic	Seed Multiplicat.	-	-	*	-		~0.1 %
			Production	-	∇∇∇	300 m	-	Cleaning of jointly used machinery	~0.1 %

* There is no seed production in Denmark

Scenario 0 — No GM plants of this crop are grown in Denmark. Seed can, however, be imported from other countries with a threshold of adventitious presence of 0.5 % for conventional seed for production. For organic seed, a corresponding level of less than 0.1 % is assumed.

Scenario + GM — GM plants of this crop are grown in Denmark. Both the 10 % and 50 % scenarios of GM cropping are included.
It is assumed that, within a given season, there is no simultaneous cropping of the same GM and non-GM crop on the same farm.

[1)] Cropping interval — Years with other crops following a GM crop, or a crop with a significant GM presence, and until a conventional “GM free” or organic crop production of this crop can be take place in the same field again. Control of volunteers in the intervening period is assumed. Under the present regulations of certification, this means the period between growing the same species in the field.

[2)] Separation distance — The distance between a GM and the nearest non-GM crop that can cross-pollinate.

[3] Buffer zone	Field margins at the verge of non-GM field towards GM field. The margins are harvested separately.

The estimated GM presence covers the production as far as the first stage of distribution.

-	Not relevant.
∇	Good farming practice.
∇∇	Crop production: minimum requirement of certified seed. Seed production: higher class, *i.e.* pre-basic or basic seed.
∇∇∇	"GM free" seed (presence <0.1 %).

Table 2.3. Beet. Co-existence between genetically modified (GM), conventional and organic crops in Denmark. Summary of measures for the control of adventitious GM presence and estimated maximum presence levels.

Crop	Scenario			Cropping interval[1)]	Used seed	Separation distance[2)]	Buffer zone[3)]	Other measures	Estimated GM presence
Fodder beet Sugar beet	0	Conventional	Seed multiplicat.	4 yr	∇∇	(1,000 m)	-		0-0.3 %
			Production	3 yr	∇∇	-	-		0-0.3 %
		Organic	Seed multiplicat.	4 yr	∇∇∇	(1,000 m)	-		~0.1 %
			Production	3 yr	∇∇	-	-		~0.1 %
	+GM (10 %)	Conventional	Seed multiplicat.	8 yr	∇∇	2,000 m	-	Cleaning of machinery and transport equipment Monitoring	0-0.3 %
			Production	3 yr	∇∇	50 m	-	Cleaning of machinery and transport equipment Monitoring	0-0.4 %
		Organic	Seed multiplicat.	8 yr	∇∇∇	2,000 m	-	Cleaning of machinery and transport equipment Monitoring	~0.1 %
			Production	5 yr	∇∇∇	100 m	-	Cleaning of machinery and transport equipment Monitoring	~0.1 %
	+GM (50 %)	Conventional	Seed multiplicat.	8 yr	∇∇	2,000 m	-	Cleaning of machinery and transport equipment Monitoring	0-0.3 %
			Production	3 yr	∇∇	50 m	-	Cleaning of machinery and transport equipment Monitoring	0-0.4 %
		Organic	Seed multiplicat.	8 yr	∇∇∇	2,000 m	-	Cleaning of machinery and transport equipment Monitoring	~0.1 %
			Production	5 yr	∇∇∇	100 m	-	Cleaning of machinery and transport equipment Monitoring	~0.1 %
Present regulations on certified seed				4/8 yr		800 m			

Scenario 0 — No GM plants of this crop are grown in Denmark. Seed can, however, be imported from other countries with a threshold of adventitious presence of 0.3 % for conventional seed for production. For organic seed, a corresponding level of less than 0.1 % is assumed.

Scenario + GM — GM plants of this crop are grown in Denmark. Both the 10 % and 50 % scenarios of GM cropping are included.
It is assumed that, within a given season, there is no simultaneous cropping of the same GM and non-GM crop on the same farm.

1) Cropping interval — Years with other crops following a GM crop, or a crop with a significant GM presence, and until a conventional "GM free" or organic crop production of this crop can be take place in the same field again. Control of volunteers in the

	intervening period is assumed. Under the present regulations of certification, this means the period between growing the same species in the field.
2) Separation distance	The distance between a GM and the nearest non-GM crop that can cross-pollinate.
3) Buffer zone	Field margins at the verge of non-GM field towards GM field. The margins are harvested separately.

The estimated GM presence covers the production as far as the first stage of distribution.

-	Not relevant.
∇	Good farming practice.
∇∇	Crop production: minimum requirement of certified seed.Seed production: higher class, *i.e.* pre-basic or basic seed.
∇∇∇	"GM free" seed (presence <0.1 %).

Table 2.4. Potato. Co-existence between genetically modified (GM), conventional and organic crops in Denmark. Summary of measures for the control of adventitious GM presence and estimated maximum presence levels.

Crop	Scenario			Cropping interval[1)]	Used seed	Separation distance [2)]*	Buffer zone[3)]	Other measures	Estimated GM presence
Potato	0	Conventional	Seed multiplicat.	3 yr	∇∇	15 m	-		0-0.5 %
			Production	∇	∇	-	-		0-0.5 %
		Organic	Seed multiplicat.	3 yr	∇∇∇	15 m	-	Seed from areas with no GM production	~0.1 %
			Production	∇	∇∇∇	-	-	Seed from areas with no GM production	~0.1 %
	+GM	Conventional	Seed multiplicat.	4 yr	∇∇	20 m	-	Control of volunteers, cleaning of machinery, etc.	0-0.5 %
			Production	3 yr	∇	20 m	-	Control of volunteers, cleaning of machinery, etc.	0-0.7 %
		Organic	Seed multiplicat.	5 yr	∇∇∇	20 m	-	Only organic seed, control of volunteers, cleaning of jointly used machinery, etc.	~0.1 %
			Production	4 yr	∇∇∇	20 m	-	Only organic seed, control of volunteers, cleaning of jointly used machinery, etc.	~0.1 %
Present regulations on certified seed				3 yr		15 m		Cleaning of jointly used machinery, etc.	

* If the GM species can be documented not to form flowers or to have male sterile flowers, the distance can be reduced to 2 m for production and to the normal separation distance for seed production.

Scenario 0	No GM plants of this crop are grown in Denmark. Seed can, however, be imported from other countries with a threshold of adventitious presence of 0.5 % for conventional seed for production. For organic seed, a corresponding level of less than 0.1 % is assumed.
Scenario + GM	GM plants of this crop are grown in Denmark. Both the 10 % and 50 % scenarios of GM cropping are included. It is assumed that, within a given season, there is no simultaneous cropping of the same GM and non-GM crop on the same farm.
1) Cropping interval	Years with other crops following a GM crop, or a crop with a significant GM presence, and until a conventional "GM free" or organic crop production of this crop can be take place in the same field again. Control of volunteers in the intervening period is assumed. Under the present regulations of certification, this means the period between growing the same species in the field.
2) Separation distance	The distance between a GM and the nearest non-GM crop that can cross-pollinate.
3) Buffer zone	Field margins at the verge of non-GM field towards GM field. The margins are harvested separately.

The estimated GM presence covers the production as far as the first stage of distribution.

-	Not relevant.
∇	Good farming practice.
∇∇	Crop production: minimum requirement of certified seed.Seed production: higher class, *i.e.* pre-basic or basic seed.
∇∇∇	"GM free" seed (presence <0.1 %).

Table 2.5. Barley, wheat, triticale, oats. Co-existence between genetically modified (GM), conventional and organic crops in Denmark. Summary of measures for the control of adventitious GM presence and estimated maximum presence levels.

Crop	Scenario			Cropping interval[1)]	Used seed	Separation distance[2)]	Buffer zone[3)]	Other measures	Estimated GM presence
Barley,	0	Conventional	Seed multiplicat.	1 yr	∇∇	0 m/ **T**20 m	-		0-0.5 %
Wheat,			Production	∇	∇	-	-		0-0.6 %
Oats,		Organic	Seed multiplicat.	1 yr	∇∇∇	0 m/ **T**20 m	-		~0.1 %
Triticale (T)			Production	∇	∇∇∇	-	-		~0.1 %
	+GM (10 %)	Conventional	Seed multiplicat.	1 yr	∇∇	0 m/ **T**50 m	-	Control of volunteers, cleaning of machinery	0-0.5 %
			Production	1 yr	∇	0 m/ **T**50 m	-	Control of volunteers, cleaning of machinery	0-0.6 %
		Organic	Seed multiplicat.	1 yr	∇∇∇	0 m/ **T**50 m	-	Control of volunteers, cleaning of machinery	~0.1 %
			Production	1 yr	∇∇∇	0 m/ **T**50 m	-	Control of volunteers, cleaning of machinery, only certified seed	~0.1 %
	+GM (50 %)	Conventional	Seed multiplicat.	1 yr	∇∇	0 m/ **T**50 m	-	Control of volunteers, cleaning of machinery	0-0.5 %
			Production	1 yr	∇	0 m/ **T**50 m	-	Control of volunteers, cleaning of machinery	0-0.6 %
		Organic	Seed multiplicat.	1 yr	∇∇∇	0 m/ T50 m	-	Control of volunteers, cleaning of machinery	~0.1 %
			Production	1 yr	∇∇∇	0 m/ **T**50 m	-	Control of volunteers, cleaning of machinery, only certified seed	~0.1 %
Present regulations on certified seed				1 yr		0 m/ **T**20 m			

Scenario 0	No GM plants of this crop are grown in Denmark. Seed can, however, be imported from other countries with a threshold of adventitious presence of 0.5 % for conventional seed for production. For organic seed, a corresponding level of less than 0.1 % is assumed.
Scenario +GM	GM plants of this crop are grown in Denmark. Both the 10 % and 50 % scenarios of GM cropping are included. It is assumed that, within a given season, there is no simultaneous cropping of the same GM and non-GM crop on the same farm.
1) Cropping interval	Years with other crops following a GM crop, or a crop with a significant GM presence, and until a conventional "GM free" or organic crop production of this crop can be take place in the same field again. Control of volunteers in the intervening period is assumed. Under the present regulations of certification, this means the period between growing the same species in the field.
2) Separation distance	The distance between a GM and the nearest non-GM crop that can cross-pollinate.
3) Buffer zone	Field margins at the verge of non-GM field towards GM field. The margins are harvested separately.

The estimated GM presence covers the production as far as the first stage of distribution.

-	Not relevant.
∇	Good farming practice.
∇∇	Crop production: minimum requirement of certified seed. Seed production: higher class, *i.e.* pre-basic or basic seed.
∇∇∇	"GM free" seed (presence <0.1 %).
T	Triticale

Table 2.6. Rye. Co-existence between genetically modified (GM), conventional and organic crops in Denmark. Summary of measures for the control of adventitious GM presence and estimated maximum presence levels.

Crop	Scenario			Cropping interval1)	Used seed	Separation distance2)	Buffer zone3)	Other measures	Estimated GM presence
Rye	0	Conventional	Seed multiplicat.	1 yr	∇∇	250/500*m	-		0-0.5 %
			Production	-	∇	-	-		0-0.5 %
		Organic	Seed multiplicat.	1 yr	∇∇∇	250/500*m	-		~0.1 %
			Production	-	∇∇∇	-	-		~0.1 %
	+GM (10 %)	Conventional	Seed multiplicat.	1 yr	∇∇	250/500*m	-		0-0.5 %
			Production	-	∇	250 m	-	Cleaning of jointly used machinery	0-0.6 %
		Organic	Seed multiplicat.	1 yr	∇∇∇	250/500*m	-		~0.1 %
			Production	-	∇∇∇	250 m	-	Cleaning of jointly used machinery	~0.1 %
	+GM (50 %)	Conventional	Seed multiplicat.	1 yr	∇∇	250/500*m	-		0-0.5 %
			Production	-	∇	250 m	-	Cleaning of jointly used machinery	0-0.6 %
		Organic	Seed multiplicat.	1 yr	∇∇∇	250/500*m	-		~0.1 %
			Production	-	∇∇∇	250 m	-	Cleaning of jointly used machinery	~0.1 %
Present regulations on certified seed				1 yr		250/500*m			

* Applies to rye hybrids.

Scenario 0 — No GM plants of this crop are grown in Denmark. Seed can, however, be imported from other countries with a threshold of adventitious presence of 0.5 % for conventional seed for production. For organic seed, a corresponding level of less than 0.1 % is assumed.

Scenario +GM — GM plants of this crop are grown in Denmark. Both the 10 % and 50 % scenarios of GM cropping are included. It is assumed that, within a given season, there is no simultaneous cropping of the same GM and non-GM crop on the same farm.

1) Cropping interval — Years with other crops following a GM crop, or a crop with a significant GM presence, and until a conventional "GM free" or organic crop production of this crop can be take place in the same field again. Control and monitoring of volunteers in the intervening period is assumed. Under the present regulations of certification, this means the period between growing the same species in the field.

2) Separation distance — The distance between a GM and the nearest non-GM crop that can cross-pollinate.

3) Buffer zone — Field margins at the verge of non-GM field towards GM field. The margins are harvested separately.

The estimated GM presence covers the production as far as the first stage of distribution.

- - Not relevant.
- ∇ Good farming practice.
- ∇∇ Crop production: minimum requirement of certified seed. Seed production: higher class, *i.e.* pre-basic or basic seed.
- ∇∇∇ "GM free" seed (presence <0.1 %).

Table 2.7. Forage and amenity grasses. Co-existence between genetically modified (GM), conventional and organic crops in Denmark. Summary of measures for the control of adventitious GM presence and estimated maximum presence levels.

Crop	Scenario			Cropping interval 1)	Used seed	Separation distance 2)*	Buffer zone 3)	Other measures ¤)	Estimated GM presence
*** Forage and amenity grasses**	0	Conventional	Seed multiplicat.	3 yr	∇∇	50-100 m	-		0-0.3 %
			Production	-	∇∇	-	-		0-0.8 %
		Organic	Seed multiplicat.	3 yr	∇∇∇	50-100 m	-		~0.1 %
			Production	-	∇∇∇	-	-		~0.1 %
	+GM	Conventional	Seed multiplicat.	5-7 yr	∇∇	300 m	2-5 m	Cutting of verges and other sources of dispersal Buffer Zone: Bare soil/spring-sown crops/cutting Complete control of grass plants in terminated seed fields Complete control of volunteers in intervening crops Cleaning of machinery, drying plant and store	0-0.3 %
			Production	1-2 yr	∇∇	-	-	Complete control of grass plants in terminated seed fields Complete control of volunteers in intervening crops	0-0.8 %
		Organic	Seed multiplicat.	5-7 yr	∇∇∇	300 m	2-5 m	Cutting of verges and other sources of dispersal Buffer Zone: Bare soil/spring-sown crops/cutting Cleaning of machinery, drying plant and store Mandatory GM analysis of the certified product	~0.1 %
			Production	5-7 yr	∇∇∇	-	-	Any grass stems are grazed or removed by cutting	~0.1 %
Present regulations on certified seed*				3 yr		50/ 100 m			

* The table has been composed for cross-pollinating forage and amenity grasses. The distance 50 m is for fields < 2 ha and the distance 100 m is for fields > 2ha. Other regulations regarding separation distance and varietal purity apply to meadow grass.

¤) More stringent control measures in connection with GM introduction:

- Compliance with separation distances to other crops and sources of pollen with which the GM seed field can cross-pollinate.
- Cutting flowering grass stems within the extent of the separation distance.
- Compliance with cropping interval of 5-7 years in seed fields (depending on the grass species and the possibilities of controlling plants from terminated seed fields and volunteers).
- Complete control of grass plants at the end of seed and pasture crops.
- Complete control of volunteers in intervening crops.
- Cleaning of machinery, drying plants and stores.
- No joint use of harvest machinery.
- Transport of GM seed in sealed containers.
- Re-evaluate the more stringent control measures (*e.g.* after 5 years).

Scenario 0	No GM plants of this crop are grown in Denmark. Seed can, however, be imported from other countries with a threshold of adventitious presence of 0.3 % for conventional seed for production. For organic seed, a corresponding level of less than 0.1 % is assumed.
Scenario +GM	GM plants of this crop are grown in Denmark. Both the 10 % and 50 % scenarios of GM cropping are included. It is assumed that, within a given season, there is no simultaneous cropping of the same GM and non-GM crop on the same farm.
1) Cropping interval	Years with other crops following a GM crop, or a crop with a significant GM presence, and until a conventional "GM free" or organic crop production of this crop can be take place in the same field again. Control of volunteers in the intervening period is assumed. Under the present regulations of certification, this means the period between growing the same species in the field. In a conversion from seed growing to production field, the same cropping intervals apply as for seed growing.
2) Separation distance	The distance between a GM and the nearest non-GM crop that can cross-pollinate.
3) Buffer zone	Field margins at the verge of non-GM field towards GM field. The margins are harvested separately.

The estimated GM presence covers the production as far as the first stage of distribution.

-	Not relevant.
∇	Good farming practice.
∇∇	Crop production: minimum requirement of certified seed.. Seed production: higher class, *i.e.* pre-basic or basic seed.
∇∇∇	"GM free" seed (presence <0.1 %).

Table 2.8. Forage legumes. Co-existence between genetically modified (GM), conventional and organic crops in Denmark. Summary of measures for the control of adventitious GM presence and estimated maximum presence levels.

Crop	Scenario			Cropping interval 1)	Used seed	Separation distance 2)	Buffer zone 3)	Other measures ¤)	Estimated GM presence
White and red clover		Conventional	Seed multiplicat.	3 yr	∇∇	50/100 m	-		0-0.3 %
White and red clover, lucerne			Production	-	∇∇	-	-		0-0.8 %
White and red clover	0	Organic	Seed multiplicat.	3 yr	∇∇∇	50/100 m	-		~0.1 %
White and red clover, lucerne			Production	-	∇∇∇	-	-		~0.1 %
White and red clover		Conventional	Seed multiplicat.	7 yr	∇∇	200 m	-	Procedures for bee pollination Complete control of clover plants in terminated seed fields Complete control l of volunteers in intervening crops after seed production Cleaning of machinery, drying plant and store	0-0.3 %
White and red clover, lucerne (L)			Production	1-2 yr	∇∇	-	-	Attempt to restrict clover flowering through intensive grazing or cutting Complete control of clover plants in terminated clover grass fields Complete control of volunteers in intervening crops after clover grass	? **L** 0-0.8 %
White and red clover	+GM	Organic	Seed multiplicat.	7 yr	∇∇∇	200 m	2-5 m	Procedures for bee pollination Buffer zone – bare soil Complete control of clover plants in terminated seed fields Complete control of volunteers in intervening crops after seed production Cleaning of machinery, drying plant and store Mandatory GM analysis of the certified product	?
White and red clover, lucerne (L)			Production	2 yr	∇∇∇	-	?	Attempt to restrict clover flowering through intensive grazing or cutting	? **L** ~0.1 %
Present regulations for certified seed				3 yr		50/100 m*			

* The distance 50 m is for fields < 2 ha and the distance 100 m is for fields > 2 ha.

¤) More stringent control measures in connection with GM introduction:

- Identification of a region in which GM production can be introduced gradually.
- Compliance with increased separation distances
- Removal of flowering white clover heads within the extent of the separation distance.
- Compliance with increased cropping interval.

- Complete control of clover plants at the end of seed and forage crops..
- Complete control of volunteers in intervening crops.
- Cleaning of machinery, drying plants and stores.
- No joint use of harvest machinery.
- Transport of GM seed in sealed containers.
- Re-evaluation of the more stringent control measures (*e.g.* after 5 years).

Scenario 0	No GM plants of this crop are grown in Denmark. Seed can, however, be imported from other countries with a threshold of adventitious presence of 0.3 % for conventional seed for production. For organic seed, a corresponding level of less than 0.1 % is assumed.
Scenario +GM	GM plants of this crop are grown in Denmark. Both the 10 % and 50 % scenarios of GM cropping are included. It is assumed that, within a given season, there is no simultaneous cropping of the same GM and non-GM crop on the same farm.
[1)] Cropping interval	Years with other crops following a GM crop, or a crop with a significant GM presence, and until a conventional "GM free" or organic crop production of this crop can be take place in the same field again. Control of volunteers in the intervening period is assumed. Under the present regulations of certification, this means the period between growing the same species in the field. In a conversion from seed growing to production field, the same cropping intervals apply as for seed growing.
[2)] Separation distance	The distance between a GM and the nearest non-GM crop that can cross-pollinate.
[3)] Buffer zone	Field margins at the verge of non-GM field towards GM field. The margins are harvested separately.

The estimated GM presence covers the production as far as the first stage of distribution.

-	Not relevant.
∇	Good farming practice.
∇∇	Crop production: minimum requirement of certified seed.. Seed production: higher class, *i.e.* pre-basic or basic seed.
∇∇∇	"GM free" seed (presence <0.1 %).

Table 2.9. Field pea. Co-existence between genetically modified (GM), conventional and organic crops in Denmark. Summary of measures for the control of adventitious GM presence and estimated maximum presence levels.

Crop	Scenario			Cropping interval[1)]	Used seed	Separation distance[2)]	Buffer zone[3)]	Other measures	Estimated GM presence
Field pea	0	Conventional	Seed multiplicat.	2 yr	∇∇	1 m	-	-	0-0.3 %
			Production	2 yr	∇	-	-	-	0-0.3 %
								-	
		Organic	Seed	2 yr	∇∇∇	1 m	-	-	~0.1 %
			Production	2 yr	∇∇∇	-	-	-	~0.1 %
	+GM (10 %)	Conventional	Seed multiplicat.	2 yr	∇∇	50 m	-	Cleaning of machinery and transport equipment	0-0.3 %
			Production	2 yr	∇∇	10 m	-	Cleaning of machinery and transport equipment	0-0.5 %
		Organic	Seed	2 yr	∇∇∇	50 m	-	Cleaning of machinery and transport equipment	~0.1 %
			Production	2 yr	∇∇∇	50 m	-	Cleaning of machinery and transport equipment	~0.1 %
	+GM (50 %)	Conventional	Seed	2 yr	∇∇	50 m	-	Cleaning of machinery and transport equipment	0-0.3 %
			Production	2 yr	∇∇	10 m	-	Cleaning of machinery and transport equipment	0-0.5 %
		Organic	Seed	2 yr	∇∇∇	50 m	-	Cleaning of machinery and transport equipment	~0.1 %
			Production	2 yr	∇∇∇	50 m	-	Cleaning of machinery and transport equipment	~0.1 %
Present regulations on certified seed				2 yr		1 m			

Scenario 0 — No GM plants of this crop are grown in Denmark. Seed can, however, be imported from other countries with a threshold of adventitious presence of 0.3 % for conventional seed for production. For organic seed, a corresponding level of less than 0.1 % is assumed.

Scenario +GM — GM plants of this crop are grown in Denmark. Both the 10 % and 50 % scenarios of GM cropping are included. It is assumed that, within a given season, there is no simultaneous cropping of the same GM and non-GM crop on the same farm.

1) Cropping interval — Years with other crops following a GM crop, or a crop with a significant GM presence, and until a conventional "GM free" or organic crop production of this crop can be take place in the same field again. Control of volunteers in the intervening period is assumed. Under the present regulations of certification, this means the period between growing the same species in the field.

2) Separation distance — The distance between a GM and the nearest non-GM crop that can cross-pollinate.

3) Buffer zone — Field margins at the verge of non-GM field towards GM field. The margins are harvested separately.

The estimated GM presence covers the production as far as the first stage of distribution.

-	Not relevant.
∇	Good farming practice.
∇∇	Crop production: minimum requirement of certified seed.. Seed production: higher class, *i.e.* pre-basic or basic seed.
∇∇∇	"GM free" seed (presence <0.1 %).

Table 2.10. Field (Faba) bean and lupin. Co-existence between genetically modified (GM), conventional and organic crops in Denmark. Summary of measures for the control of adventitious GM presence and estimated maximum presence levels.

Crop	Scenario			Cropping interval[1)]	Used seed	Separation distance[2)]	Buffer zone[3)]	Other measures	Estimated GM presence
Field bean, Lupin	0	Conventional	Seed multiplicat.	-	∇∇	200/100m	-		0-0.3 %
			Production	-	∇		-		0-0.3 %
		Organic	Seed multiplicat.	-	∇∇∇	200/100m	-		~0.1 %
			Production	-	∇∇∇		-		~0.1 %
	+GM (10 %)	Conventional	Seed multiplicat.	2 yr	∇∇	400 m	-	Control of volunteers and stray populations	0-0.3 %
			Production	2 yr	∇	400 m	-	Control of volunteers and stray populations, cleaning of machinery	0-0.6 %
		Organic	Seed multiplicat.	2 yr	∇∇∇	400 m	-	Control of volunteers and stray populations	~0.1 %
			Production	2 yr	∇∇∇	400 m	-	Control of volunteers and stray populations, only certified seed, cleaning of machinery	~0.1 %
	+GM (50 %)	Conventional	Seed multiplicat..	2 yr	∇∇	400 m	-	Control of volunteers and stray populations	0-0.3 %
			Production	2 yr	∇	400 m	-	Control of volunteers and stray populations, cleaning of machinery	0-0.6 %
		Organic	Seed multiplicat.	2 yr	∇∇∇	400 m	-	Control of volunteers and stray populations	~0.1 %
			Production	2 yr	∇∇∇	400 m	-	Control of volunteers and stray populations, only certified seed, cleaning of machinery	~0.1 %
Field bean – present regulations on certified seed				2 yr		200 m			
Lupin – present regulations on certified seed				2 yr		100 m			

Scenario 0 — No GM plants of this crop are grown in Denmark. Seed can, however, be imported from other countries with a threshold of adventitious presence of 0.3 % for conventional seed for production. For organic seed, a corresponding level of less than 0.1 % is assumed.

Scenario +GM — GM plants of this crop are grown in Denmark. Both the 10 % and 50 % scenarios of GM cropping are included. It is assumed that, within a given season, there is no simultaneous cropping of the same GM and non-GM crop on the same farm.

1) Cropping interval — Years with other crops following a GM crop, or a crop with a significant GM presence, and until a conventional "GM free" or organic crop production of this crop can be take place in the same field again. Control of volunteers in the intervening period is assumed. Under the present regulations of certification, this means the period between growing the same species in the field.

2) Separation distance — The distance between a GM and the nearest non-GM crop that can cross-pollinate.

[3] Buffer zone	Field margins at the verge of non-GM field towards GM field. The margins are harvested separately.

The estimated GM presence covers the production as far as the first stage of distribution.

-	Not relevant.
∇	Good farming practice.
∇∇	Crop production: minimum requirement of certified seed.. Seed production: higher class, *i.e.* pre-basic or basic seed.
∇∇∇	"GM free" seed (presence <0.1 %).

3. Introduction

In June 2002, the Danish Minister for Food, Agriculture and Fisheries took the initiative in preparing a strategy of co-existence of genetically modified, conventional and organic crops. The strategy was to be worked out in co-operation with the Ministry of the Environment and be completed at the end of the year.

A Working Group, a Strategy Group and a Contact Group were set up in connection with this task. The Ministry of Food, Agriculture and Fisheries asked the Danish Institute of Agricultural Sciences represented by Søren A. Mikkelsen to act as Chairman and to manage the secretariat of the Working Group and to set up the Group according to the mandate.

Based on the conclusion in the first draft of the Working Group's report of 9 January 2003 and the subsequent Expert hearing at Christianborg Palace on 21 January 2003, in February 2003 the Minister decided that the work on the evaluation should continue until August 2003 with a view to revising and updating the report.

Mandate for the work with the co-existence strategy
the Working Group

Background
Commercial production of GM crops presents the agricultural industry with a number of challenges and possibilities. It is important for the confidence of consumers and the agricultural industry that these challenges and possibilities are handled on a well-examined basis and in a dialogue with the public.

On 29 May 2002, the Danish Parliament (Folketing) passed an amendment of the Act on Environment and Gene Technology. Accordingly, the following provision is inserted in §13, subsection 3: "The Minister for Food, Agriculture and Fisheries lays down regulations that within the framework of EU legislation severely restricts the risk of dispersal to other fields, including organic fields".

An initiative was therefore taken in preparing a strategy of co-existence of genetically modified, conventional and organic crops.

Aim
The aim of the work is to describe possibilities and conditions of a commercial use of the gene technology in agriculture that supports the free choice of consumers and the potential of current production systems. Further, the work is to establish a basis for decisions that may

constitute the starting point of regulation. Finally, it is the intention that the strategy is prepared in a continuous dialogue with the public.

Possibilities and conditions of co-existence of genetically modified, conventional and organic crops must be analysed and evaluated. The aim is partly to examine whether the co-existence of new and present productions require special measures and initiatives as a necessary prerequisite. Further, possible measures must be identified and evaluated. On the basis of a scientific evaluation, scenarios of co-existence are worked out that take Danish conditions as their starting point.

For this work, a Working Group, a Strategy Group and a Contact Group have been appointed.

The tasks of the Working Group
The Working Group is charged with:

- *Performing a scientific evaluation of sources of dispersal from genetically modified productions to conventional and organic productions.*
- *Evaluating the extent of dispersal and the need of control measures.*
- *Identifying and evaluating possible control measures to ensure co-existence of genetically modified, conventional and organic production systems.*

The evaluation is to be carried out for each crop and should include the phases of the agricultural production in which there is a possibility of dispersal. Dispersal and control measures are to be evaluated under varying admixture levels. The evaluation is to take its starting point in an admixture level of 0, which corresponds to the complete separation of the production systems. The Group should lay down an upper limit of admixture levels and a suitable number of intervals for the use in the evaluation. The consequences for business economics of implementing the different admixture levels are to be evaluated. The evaluation is carried out on the basis of Danish conditions and on the basis of the knowledge that is available regarding this subject.

Organisation of the work
A Working Group is set up, consisting of the Danish Institute of Agricultural Sciences, the Danish Plant Directorate, the Danish Research Institute of Food Economics, National Environmental Research Institute, Denmark, and scientists from the Royal Veterinary and Agricultural University and Risø National Laboratory. The Danish Institute of Agricultural Sciences is in charge of the work and provides secretariat functions.

The aim of setting up the Working Group is to ensure an adequate scientific analysis of the dispersal problems and possible control measures that take Danish conditions as their starting points.

The Working Group is to submit its subreport to the Strategy Group in December 2002.

Subsequently, the Strategy Group may involve the Working Group in the additional work as required.

The Working Group involves the Contact Group in accordance with the task specification for this Group.

The evaluation is initiated by mid-2002 and finished in December 2002

The Working Group was set up in July 2002 and consists of:

- Søren A. Mikkelsen, Danish Institute of Agricultural Sciences, chairman
- Karl Tolstrup, Danish Institute of Agricultural Sciences, secretary
- Preben Bach Holm, Danish Institute of Agricultural Sciences
- Birte Boelt, Danish Institute of Agricultural Sciences
- Merete Buus, Danish Plant Directorate
- Hanne Østergård, Risø National Laboratory
- Gøsta Kjellsson, National Environmental Research Institute, Denmark
- Sven Bode Andersen, the Royal Veterinary and Agricultural University
- Morten Gylling, Danish Research Institute of Food Economics.

In addition, Svend Pedersen, the Danish Plant Directorate, participated in the meetings and contributed to the report, and Rikke Bagger Jørgensen, Risø National Laboratory, contributed to chapter 10.2.

Tommy Dalgaard and Inge T. Kristensen, Danish Institute of Agricultural Sciences have contributed with maps of Denmark illustrating field data and crop distribution, and Jens Abildtrup, Danish Research Institute of Food Economics has contributed chapter 4.5 "The importance of the distribution of GM crops illustrated through a case study in Denmark".

The Working Group decided that the evaluation should be restricted to:

- Danish plant production of significant agricultural crops and seed growing of selected vegetables, but no fruit, berries or forest trees.

- Calculations regarding business economics comprising primary production, *i.e.* multiplication up to and including vegetable production (first stage of distribution).

> The general calculations regarding business economics therefore do not include agricultural commerce, the processing industry, retail trade, *etc*. In four selected cases (sugar, rapeseed oil, feed wheat, and an actual food product), however, calculations of costs further on in the production chain were made.

The Group does not make any recommendation on who should cover extra costs in connection with a possible adventitious admixture of GM or who should cover any costs that may be incurred in connection with monitoring and control. Neither does it make any recommendations on where costs should be placed in connection with separation distances, buffer zones, *etc*. These questions are included in the Ministry of Food, Agriculture and Fisheries' Strategy for co-existence of genetically modified, conventional and organic crops, June 2003.

The product prices used for calculating the costs of the primary productions are assessed on the basis of present average prices and cannot be used to predict the future price movement and future mutual price relations between different types of products.

The assumed future development regarding GM distribution rests on expectations based on the present trends.

Due to the time frame under which the Working Group was working, it was not possible to conduct own studies. In connection with the work, a study tour was arranged to NIAB, Cambridge, the United Kingdom and INRA, Paris, France. Information obtained during this tour is included in the material presented by the Working Group.

The Working Group presented the 1st edition of its report of 9 January 2003 at an Expert Hearing arranged by the Ministry of Food, Agriculture and Fisheries at Christiansborg Palace on 21 January 2003. Apart from the Working Group, there were contributions from Dr Jeremy Sweet, NIAB, and Dr John Killpatrick, ADAS, England, and Dr Natalie Colbach, INRA, France.

As part of the continued evaluation, the Working Group presented its "Report from the Working Group regarding co-existence of genetically modified and organic crops, January 2003" at "Round Table on research results relating to co-existence of GM and non-GM crops" in Brussels on 24 April 2003. The Round Table was arranged by the EU Commission in a co-operation between DG-Research and DG-Agriculture.

In addition, the Working Group held a two-day seminar on the continued work on co-existence with a broad scientific participation in May 2003. Dr Geoff Squire, Scottish Crop Research Institute, gave several talks on British research regarding co-existence, including the extensive field trial programme: "Farm-scale Evaluation Programme".

The subject area that is dealt with in the evaluation is complex and comprises many different scientific problems, which are affected by a large number of environmental factors. Further, existing knowledge on this subject is very limited. As a result, the Working Group's report comprises mainly assessments and estimates that are based on available knowledge and the Working Group's scientific insight. The given assessments and estimates therefore involve a varying degree of uncertainty.

The continued evaluation work

Based on the conclusions in the first version of the report of the Working Group and in the subsequent Expert Hearing at Christiansborg Palace, the Minister for Food, Agriculture and Fisheries decided - as mentioned above - that the work on the evaluation should continue until August 2003 with a view to elaborating and updating the report.

The work was carried out by the existing Working Group and by four task groups who refer to the Working Group. With a view to a continued dialogue and openness concerning the work, a number of resource persons were involved.

The continued work comprised a more thorough analysis of the crops oilseed rape, grass and clover. Extended financial analyses and updating and extension regarding monitoring and significance of the distribution of GM crops were also included.

The oilseed rape task group consists of:

- Hanne Østergård, Risø National Laboratory (chairman)
- Karl Tolstrup, Danish Institute of Agricultural Sciences
- Christian Andreasen, the Royal Veterinary and Agricultural University
- Christian Damgaard, National Environmental Research Institute, Denmark
- Ilse Ankjær Rasmussen, Danish Institute of Agricultural Sciences
- Rikke Bagger Jørgensen, Risø National Laboratory.

Attached resource persons were:

- Jens Abildtrup, Danish Research Institute of Food Economics
- Henrik Brødsgaard, Danish Institute of Agricultural Sciences
- Morten Gylling, Danish Research Institute of Food Economics
- Peter Kryger Jensen, Danish Institute of Agricultural Sciences
- Morten Greve Pedersen, DLF-TRIFOLIUM
- Johannes Thulesen, Organic Denmark
- Christian Haldrup, Danish Agricultural Advisory Service
- Katrine H. Madsen, the Royal Veterinary and Agricultural University.

The grass task group consists of:

- Birte Boelt, Danish Institute of Agricultural Sciences (chairman)

- Karl Tolstrup, Danish Institute of Agricultural Sciences
- Hans Chr. Ellegaard, Danish Plant Directorate
- Gøsta Kjellsson, National Environmental Research Institute, Denmark
- Peter Kryger Jensen, Danish Institute of Agricultural Sciences.

Attached resource persons were:

- Niels Christian Nielsen, DLF-TRIFOLIUM
- Arne Larsen, DLF-TRIFOLIUM
- Christian Haldrup, Danish Agricultural Advisory Service
- Henrik Refsgaard, Organic Denmark.

The clover task group consists of:

- Birte Boelt, Danish Institute of Agricultural Sciences (chairman)
- Karl Tolstrup, Danish Institute of Agricultural Sciences
- Henrik Brødsgaard, Danish Institute of Agricultural Sciences
- Kristian Kristensen, Danish Institute of Agricultural Sciences
- Gøsta Kjellsson, National Environmental Research Institute, Denmark
- Per Kudsk, Danish Institute of Agricultural Sciences.

Attached resource persons were:

- Hans Chr. Ellegaard, Danish Plant Directorate
- Arne Larsen, DLF-TRIFOLIUM
- Vibeke Meyer, DLF-TRIFOLIUM
- Christian Haldrup, Danish Agricultural Advisory Service
- Henrik Refsgaard, Organic Denmark.

The economy task group consists of:

- Morten Gylling, Danish Research Institute of Food Economics (chairman)
- Karl Tolstrup, Danish Institute of Agricultural Sciences
- Janus Søndergaard, Danish Research Institute of Food Economics
- Søren Marcus Pedersen, Danish Research Institute of Food Economics
- Jens Abildtrup, Danish Research Institute of Food Economics
- Tommy Dalgaard, Danish Institute of Agricultural Sciences.

Attached resource persons were:

- Flemming L. Jensen, Danish Crown
- Erik Knudsen, Danisco Sugar
- Henrik Brinch-Pedersen, Danish Institute of Agricultural Sciences
- Steen Bisgaard, Danisco Seeds
- Søren Nilausen, DLG.

- Ingolf Nielsen, Agrova Food / Dan Olie
- Søren Villumsen, DLG
- Hemming Van, Daloon
- Susanne Pedersen, Daloon
- Arne Schmidt, Daloon.

European Conference
As a follow-up to the work of the Working Group, DIAS is holding the : "1st European Conference on the Co-existence of Genetically Modified Crops with Conventional and Organic Crops – **GMCC-03**" in Helsingør on 13 and 14 November 2003.

The conference is especially directed at scientists and advisers in the area of crop growing and takes place in a co-operation with KVL, NERI, Risø National Laboratory, the Danish Plant Directorate, FOI, and the foreign institutions: NIAB, United Kingdom, INRA, France, BBA, Germany, and the University of Manitoba, Canada. The conference receives financial support from the Danish Ministry of Food, Agriculture and Fisheries.

4. Scientific background

4.1 GM – Genetic modification

Plant breeders have through time invented a number of methods of making their work more effective and creating new varieties with improved characteristics of cultivation, quality and resistance.

Through so-called traditional methods, plant characters and their genes have been transferred, and selected. A much-used traditional method for introducing new genes or traits is by creating hybrids with wild species followed by repeated backcrosses to cultivated varieties alternating with multiplication and selection in order to create varieties with desirable characteristics. These programmes may take generations to accomplish and it is difficult to assess in advance whether the results will be worth the effort.

The molecular biological techniques (gene technology), which are a supplement to the traditional breeding methods, are developing rapidly. Modern methods are used partly for identification of plant varieties and the genetic code of other organisms, and partly for purification of individual genes and research into their function.

Through the technique of genetic modification (GM), also called genetic engineering, individual genes can be transferred from one organism to another. Genetic engineering has primarily been using Agrobacterium bacteria for transformation or a method of particle bombardment.

The inserted genes often consist of:

- A gene coding for a desired characteristic.
- Auxiliary genes that are to contribute to the introduction of the gene sequence.
- Marker genes so that it is possible later to select the plant cells that have received the genes.

With the present genetic engineering technique the foreign gene is inserted at random. But it is to be expected that the technique will be refined so that the insertion will become more targeted in the future. The genetically engineered cells are propagated and regenerated in plants that are propagated in their turn. The plants that are most suitable for production purposes are selected in the field in experimental trials. Those are called GM plants, GM varieties, GM crops, etc. In this way, the development period is shortened with respect to the traditional breeding and crossing programmes, and the species barriers can be overcome.

Subsequently, the individual GM plant varieties must be subjected to experimental trial and testing before a decision can be made on a possible approval for marketing. In this report it is assumed that the GM crops have been through an official procedure of approval.

4.2 Distribution of GM crops

Worldwide, GM crops were not produced commercially on a larger scale until 1996. The area has increased from 1.7 mill. ha in 1996 to about 58.7 mill. ha in 2002.

About 99 % of the global GM crop area is divided among the USA, Canada, Argentina and China. Mainly soybean, maize, cotton and oilseed rape are grown. Crops such as potatoes are grown on much smaller areas.

The area of the most important GM crops and the GM share of the global area appear in Table 4.1. Half the world's production of soybean and a fifth of cotton are based on GM crops.

Table 4.1. GM crop areas in 2001 and 2002 for soybean, maize, cotton and oilseed rape.

Crop	GM area 2001 (mill. ha)	GM area 2002 (mill. ha)	Change 2001-2002	GM area share of the total global area (per crop)
Soybean	33.3	36.5	+ 10 %	51 %
Maize	9.8	12.4	+ 27 %	9 %
Cotton	6.8	6.8	-	20 %
Oilseed rape	2.7	3.0	+ 11 %	12 %
Total	52.6	58.7	+ 12 %	21 %

Source: James, 2002.

The development of the area under GM soybean, GM maize and GM oilseed rape shows an increase from 2001 to 2002 while the area under cotton is static. Table 4.2 shows the extent of GM production of maize, soybean and oilseed rape in countries with a significant GM production of these crops. In the USA the share of GM soybean has increased further to 80 % and the share of GM maize has increased to 38 % in 2003. In the EU, GM maize was produced in Portugal, France and Spain. In 2001 20-25,000 ha of insect resistant maize was produced in Spain, which corresponds to 4-5 % of the production (Brookes, 2002). Generally, an increase in the GM production is expected in the countries that already have the largest GM crop areas.

Table 4.2. Share of GM area in the individual countries of the total cultivated area for soybean, maize and oilseed rape in 2002.

Country	Crop		
	Soybean*	**Maize**	**Oilseed rape**
USA	75 %	34 %	50 %**
Canada	60 %	50 %	65 %
Argentina	99 %	22 %**	-

Source: www. transgen.de

*: In addition, substantial areas of GM soybean are cultivated illegally in Brazil.

**: 2001 figures.

The special characteristics of the main GM crops and their relative share in 2002 are shown in Table 4.3. The most common traits were herbicide tolerance and insect resistance, by themselves or in combination.

Table 4.3. The area of the most common GM crops in 2002 according to their characteristics and the relative share of these.

Crop	**Mill. ha**	**Relative share**
Herbicide tolerant soybean	36.5	62 %
Insect resistant maize	7.7	13 %
Herbicide tolerant oilseed rape	3.0	5 %
Herbicide tolerant maize	2.5	4 %
Insect resistant cotton	2.4	4 %
Herbicide tolerant cotton	2.2	4 %
Herbicide tolerant/insect resistant cotton	2.2	4 %
Herbicide tolerant/insect resistant maize	2.2	4 %
Total	58.7	100 %

Source: James, 2002.

Figure 4.1 on experimental releases and information about marketing applications in the EU shows the possibility of introducing and producing GM crops in the EU within a few years. This particularly applies to oilseed rape and maize but also potatoes, beet, cereals and several other important crops that are at the experimental stage.

The crops that may be the first candidates are likely to possess herbicide tolerance, insect resistance, or special constituents such as starch or proteins (Figure 4.2).

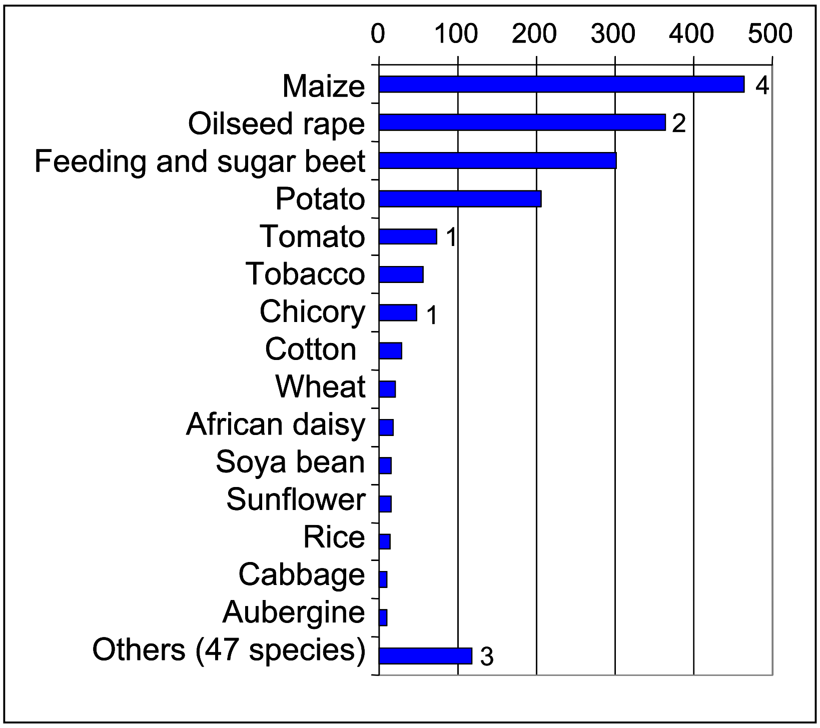

Figure 4.1. The most commonly used GM crops in experimental releases in the EU. Number of separate applications for experimental releases from 1991 to April 2002 inclusive is shown horizontally. Altogether there were 1,762 applications for experimental releases in this period (Kjellsson & Boelt, 2002). The number of GM crops approved for marketing is shown to the right of the columns (see Table 1 in the Annex for details).

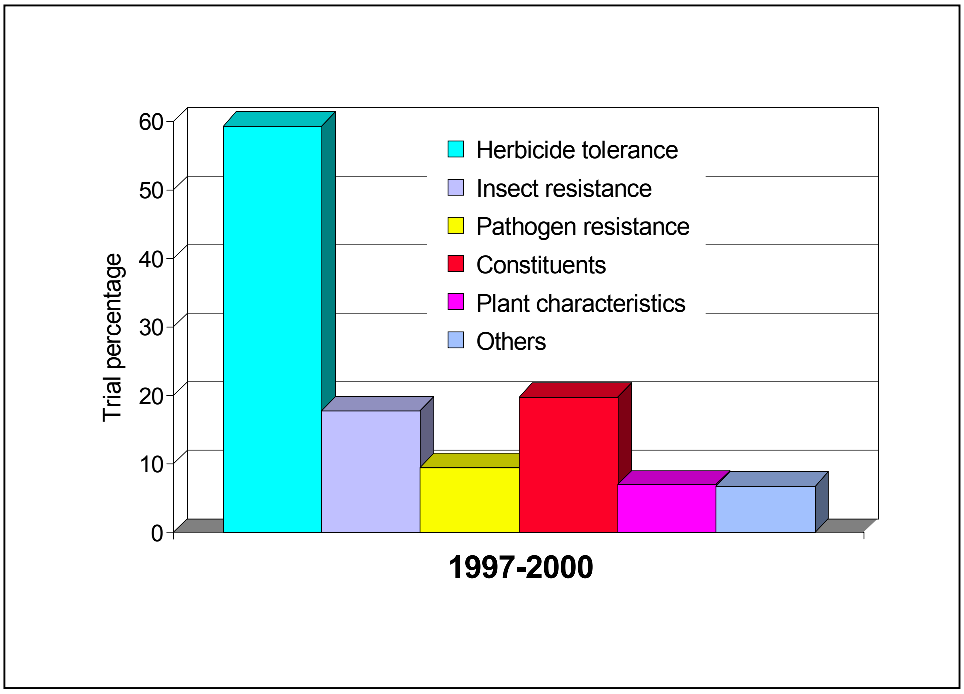

Figure 4.2. Characteristics of the genetically modified crops in EU experimental releases during 1997-2000. As a GM crop may have several GM characteristics, the sum of the percentages is larger than 100 (Kjellsson & Boelt, 2002).

4.3 Plant characteristics

It is expected that the development of herbicide and insect resistant varieties will continue in the years to come. For example, herbicide tolerant wheat is reportedly close to being introduced in the USA.

A development is under way from these so-called 1st generation plants with one or two inserted characteristics, such as herbicide tolerance and insect and disease resistance, towards 2nd and 3rd generation plants with several inserted genes and plant characteristics. This development is especially clear in the USA and Canada but is also beginning to be seen in European experimental releases. The number of GM characteristics in EU experimental releases has also risen during recent years.

Thus, about one fourth of the experimental releases in 2001 had between 3 and 7 different inserted characteristics (Kjellsson and Boelt, 2002).

Plant characteristics expected to be developed through genetic modification are:

- Increased tolerance to drought, frost and salt.
- Changed chemical composition of the plant product of *e.g.* proteins, lipids, starch and vitamins for industrial use or as improved foods.
- Production of drugs, *e.g.* vaccines, hormones and enzymes.
- Materials such as: wood pulp, lignin and plastics.
- Built-in weed control resulting from secondary constituents (chemical bio-weapons).
- Inducable characteristics, which are not activated until desired, such as insect resistance and no flowering or seed setting.
- Traits for decontaminating polluted soil and effective use of plant nutrients.
- Elimination of natural, toxic substances and allergenic substances

Due to the relatively high costs of development, the development is primarily expected to take place in crops with a high earning potential, whether it is crops with large production area or crops in which a few processing companies are involved. The value of any derived products may also be of great importance.

The risk assessment of applications for permission to market GM plants, which is carried out by the authorities in the EU, is performed according to the so-called "case-by-case" principle. It means that in connection with each marketing application the authorities evaluate the specific risks that may be involved with the species and gene combination in question. For example, it is not expected that a herbicide tolerant GM plant has an increased survival capacity in situations where the herbicide in question is not used. However, there may be an improved competitive capacity in GM plants with traits such as insect resistance or fungal disease resistance.

In the present report it is assumed that the GM plants concerned are approved for marketing according to current legislation, so that the GM varieties used do not have a competitive capacity that significantly exceeds that of the corresponding non-GM varieties. It is also expected that the conditions of the marketing authorisation take account of risks to human health.

Whether GM varieties will be developed and produced in the future - and the time scale - primarily depends on whether the environmental and agricultural impacts of the modified crops are acceptable. In addition it will depend upon the producers' acceptance of the product, the costs of the product, the market and likely economic return and particularly the reaction of consumers.

4.4 Production practice

In 2002 the Danish agricultural area constituted about 2.68 million ha. The farmland areas are dominated by barley and wheat, which comprise more than half of the area. Whole crop cereals, grass for feed and cattle pasture are considerable but of much smaller area. In addition to this, a number of smaller but economically important crops, such as oilseed rape, grass seed, beets, peas, potatoes, *etc*., are produced for different purposes, such as feed, foods and industry (DIAS, 2003).

Organic crop production is characterised by extensive production of grass/clover leys and permanent grassland plus legumes used as animal feed (The Danish Plant Directorate, 2003). This is due to the relatively large number of organic dairy farms.

In organic farming, GMOs must not be used apart from veterinary drugs produced by use of GMOs. Synthetic chemical crop-protecting agents must not be used against weeds, pests and diseases. The latter often necessitates an intensive mechanical weed control by harrowing and inter-row weeding in organic crop production. In conventional agriculture, reduced soil treatment is increasingly used. Such trends may have an influence on the soil seed bank and on a possible dispersal of GM to subsequent crops (see chapter 8).

Current organic farming and its development are to a certain extent dependent on the use of conventional products in the form of seed, animal feed and manure. Thus, using conventional, non-fungicide-treated seed is allowed at present provided that organic seed of the desired crop does not exist or is not a variety worth producing. This may also affect the future adventitious GM presence in these crops (see chapter 8).

In principle, there are innumerable crop rotations in Denmark, adjusted to the current requirements of the individual farm. Broadly, however, a typical crop rotation may be attached to the dominant cultivation sectors, cattle farming, pig farming and plant production. These will in their turn vary somewhat according to difference in soil type (clay-sand) and according to animal density (especially in cattle farming) and whether on full-time or part-time farms.

The distribution of field sizes in Denmark appears from Table 4.4. The areas were assessed based on the support per hectare scheme (DIAS, 2003). About 41 % of the total area is small fields of less than 5 ha. If fields of up to 10 ha are included, they constitute about 93 % of the fields and about 73 % of the area. Fields larger than 20 ha constitute about 8 % of the total area.

Organic and the conventional farms are almost the same average size, 48 ha and 53 ha, respectively. A disproportionate number of organic farms are small: about 11 % of them are smaller than 5 ha while only about 2 % of all Danish farms are smaller than 5 ha. The small organic farms constitute, however, only 0.6 % of the total organic area (Statistics Denmark ref. in The Danish Plant Directorate, 2003).

Table 4.4. Fields in Denmark, classified according to size.

Area in ha	Total area		Number of fields	
	1,000 ha	%	(1,000)	%
0-4.99	1,093.8	41	519.8	75
5-9.99	876.6	32	129.8	18
10-19.99	505.8	19	38.9	6
20<	205.1	8	7.2	1
Total	2,681.3	100	695.7	100

Source: DIAS, 2003

The average field size based on applications for support per hectare is 3.9 ha. The area varies from crop to crop and at the same time comprises a very large variation. The field size for winter wheat, an average field area of 6.1 ha, varies between 0.01 and 130 ha. However, certain reservation must be made about the average field areas because many fields that are divided by old boundaries are farmed as one with the same crop.

The field size varies from 2 ha up to 18 ha depending on where the field is located in Denmark (Figure 4.3). In several municipalities in East Zealand, in Lolland-Falster and in East Jutland, it is approximately 6-7 ha. The largest field sizes are found in East Jutland and in the eastern parts of the islands. The smallest fields are found in West Jutland, North Jutland and North Zealand.

The size and shape of the field will have a great importance for the pollen dispersal to and from the field. A small GM field will have a relatively small dispersal to larger conventional and/or organic fields. On the other hand, small fields will be much exposed to pollen spreading from large fields (see chapter 8).

Organic production is widespread in North Zealand and Jutland with up to 36 % of the area. In south Jutland it is primarily with forage crops for dairy cattle. A higher share is fund in municipalities near to Copenhagen, but here the agricultural area is negligible. There is none at all or a very small organic production in other municipalities such as in the County of Storstroem (Figure 4.4.).

Another factor that may greatly influence co-existence is the farm management at the individual farm whether it has GM production, GM free conventional production or organic production.

As a starting point, this report generally assumes "good farming practice" as described by the Danish Farmers' Association and Danish Family Farms Union, 2000.

The Working Group defines "good farming practice" in crop production as:

- Compliance with cropping practice, including compliance with time limits for spraying, application of fertilizers and manure, as well as spraying, and manure free zones in accordance with the current legislation.

- Management of volunteers and wild oats and the cleaning of machinery in connection with seed production in accordance with the current legislation.

- Bookkeeping of accounts for fertilizer, manure and spraying records in accordance with the current legislation.

- Entering into a good dialogue with neighbours with adjoining production areas.

- Trading with quality seed and cereal processors who take care to avoid mixing seed lots.

- Choosing varieties and establishing crop rotations that also take problems with weeds into account, also including volunteers, diseases and pests.

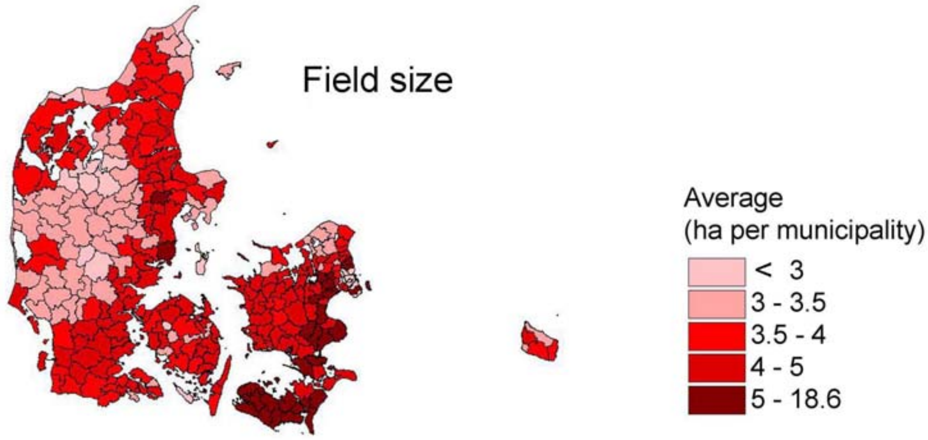

Figure 4.3. Distribution of field size in Denmark, 2002. (Dalgaard & Kristensen, 2003).

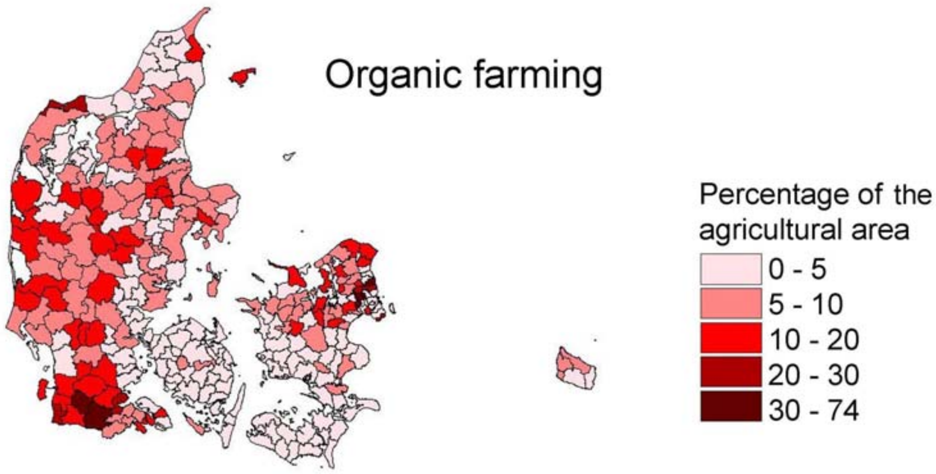

Figure 4.4. Distribution of organic crop production in Denmark, 2002. (Dalgaard & Kristensen, 2003).

4.5 The importance of the distribution of GM crops illustrated through a case study in Denmark

The size of the farms and the location of the fields are relevant to the ability to comply with the separation distances required when GM crops are produced. Field size and form determine the extent of the border between fields on the same and neighbouring farms. A farm with a large area and its fields situated close together will thus have relatively fewer fields bordering on the fields of a neighbouring farm. The converse will be true for small fragmented farms.

The importance of the location of the fields in relation to each other has not been studied previously under Danish conditions. In order to get an estimate of how a GM crop producer may have to make adjustments in crop production to comply with the separation distances suggested in the report, a geographical analysis was carried out based on the actual farm and field structure in a selected area in the County of Viborg (Abildtrup & Gylling, 2003).

As regards the crops oilseed rape, maize and potatoes, we estimated how often the separation distances will not be complied with under different assumptions of the distribution of the crop and the share of GM crops in relation to non-GM crops.

Due to regional differences in the farm and field structure in Denmark, the results are only representative of farms in the same area or with the same structure as the one selected.

The need for cultivation adjustments in order to comply with separation distances of GM crop production will depend on the following factors:

- The size of the separation distances.
- The area distribution of the crop.
- The distribution of GM crops compared with non-GM crops.
- The organic crop area (assuming that specific separation distances apply to organic fields).
- Farm size and the location of the fields.
- Field sizes and shapes.

Method of analysis:

1. The farms (crop production, pig farming, cattle farming) in the area that are to grow the crops selected in the analysis were selected.
2. The farms that are to grow GM crops were selected through computer simulation.
3. The simulations were repeated a number of times.
4. The average number of fields that does not comply with the separation distances was estimated.

The area

Facts about the area (see Figure 4.5)

- The area is 10 x 10 km and is located in the Municipalities of Bjerringbro and Hvorslev in the County of Viborg.

- The area was selected because it is the only area in Denmark for which the field and farm structure was digitised and exists in an accessible format. The digitising took place on the basis of data from 1998 and was carried out by the Danish Institute of Agricultural Sciences (ARLAS, 2003).

- Sixty-five % of the area is used for agricultural purposes. (Area for agricultural purposes in the country as a whole: 66 %). The crop distribution does not differ significantly from the crop distribution in the County of Viborg.

- The share of permanent grass is high (10 % in the area compared with 5 % in Denmark).

- A total of 508 farms are registered in the area. These farms have a total area of 8,990 ha. This means that the average of the cultivated area per farm is just 18 ha, which is very low. The average farm size for all of the country was about 44 ha/farm in 1998 and about 53 ha/farm in 2002.

- The reason for the low average farm size is a large number (250) of very small farms with less than 5 ha of farmland mostly not registered in the General Farm Register. If these farms are excluded from the calculation, farms average about 33 ha in area.

Table 4.5. Farm and field structure in 1998 for the case area compared with the County of Viborg and all of the country[1].

	Total	Farms > 5 ha	County of Viborg	Denmark
Number of fields	3,041	2,640	75,409[1]	695,134[1]
Area (ha)	8,990	8,645	257,640	2,685,027
Number of farms	508	266	7,146	61,426
Field size (ha/field)	3.0	3.3	3.4[1]	3.9[1]
Farm size (ha/field)	17.7	32.5	36.1	43.7

[1] Field size and number of fields for the county and all of the country are based on data from 2002.

Sources: Statistics Denmark (1999), ARLAS (2003) and our own calculations.

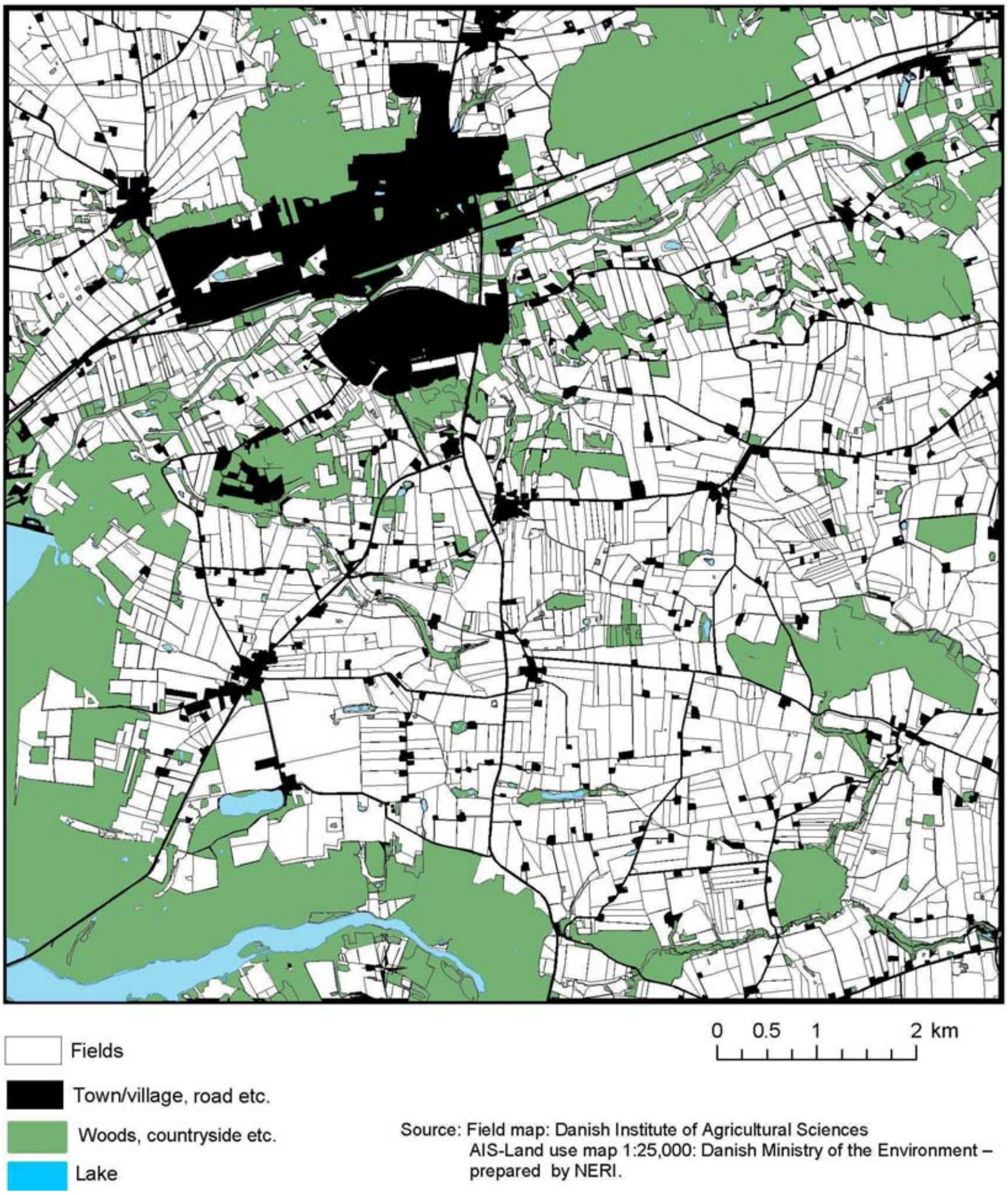

Figure 4.5. Map of the case area in the Municipalities of Bjerringbro and Hvorslev.

The need for farm adjustments

For oilseed rape, maize and potatoes, transgression of the separation distances is estimated under the assumption:

- That 2.5 % or 5.0 % of the cultivated area is used for oilseed rape, 2.5 % of the area is used for maize and that 5 % or 10 % is used for producing potatoes. The analysis was carried out with up to 10 % of the area with potatoes, as potato production is relatively widespread in Central Jutland (where highest, it constitutes 13 % of the area in the Municipality of Ikast).

- That 10 % and 50 %, respectively, of the crop area is cultivated using a GM variety.

It is important to stress that the results described all are average figures and that there may be large local variations in the consequences of the separation distances.

Oilseed rape
Assumptions in the analysis:

- Only the crop production and pig farms in the area grow oilseed rape.
- Winter oilseed rape forms part of a 6-years crop rotation.
- Not all crop producing farms grow winter oilseed rape, but the probability of a farm producing winter oilseed rape increases with the area of the farm corresponding to the distribution of farms with oilseed rape in Denmark.
- The average field size of oilseed rape producing farms is at about 4.5 ha.
- The probability of a oilseed rape producer choosing a GM oilseed rape is independent of farm size.
- Separation distance: 150 m +/- 50 m.
- Organic oilseed rape production is not included in this analysis.

Table 4.6. Transgression of separation distances in winter oilseed rape with separation distance of 150 m.

Oilseed rape area of cultivated area	Share of area with GM oilseed rape of total oilseed rape area		Oilseed rape area		Number of oilseed rape fields	GM fields that do not comply with separation distances	
	Scenario (%)	Realised[1)] (%)	(ha)	(%)[1)]		% of GM oilseed rape fields	% of all oilseed rape fields
2.5 %	10	10.8	131	2.3	32	10	1.1
	50	50.5	153	2.4	32	6.2	2.7
5 %	10	12.2	310	4.9	68	15	1.9
	50	53.3	324	5.1	72	12	5.7

1) The oilseed rape area and the share with GM oilseed rape deviate from the size corresponding to the analysed scenarios. This is due to the fact the analysis is based on the random simulation and a finite number of simulations.

Table 4.7. Transgression of separation distance in oilseed rape with separation distances of 100, 150 and 200 metres at 5 % winter oilseed rape area and 50 % GM oilseed rape area.

Separation distances	Share of area with GM oilseed rape of total oilseed rape area		Oilseed rape area		Number of oilseed rape fields	GM fields that do not comply with separation distances	
	Scenario (%)	Realised (%)	(ha)	(%)		% of GM oilseed rape fields	% of all oilseed rape fields
100 m	50	53.3	324	5.1	72	8.2	4.1
150 m	50	53.3	324	5.1	72	12	5.7
200 m	50	53.3	324	5.1	72	15	7.5

There were 0 to 9 fields that did not comply with the separation distance in the scenario with the 5 % oilseed rape area and 50 % of the rape share as GM. The variation is caused by differences in the dispersal of the GM crop growing farms in the studyarea. If the farms producing a GM crops lie relatively close together, the probability of a neighbour producing a non-GM crop will be smaller.

Maize

Assumptions in the analysis:

- Maize is only produced on cattle farms with crop rotations for silage production.

- Cattle farms with more than 35 ha of cultivated area are all assumed to produce maize in a crop rotations, with maize grown every three years.

- The probability of a maize producer choosing a GM maize is assumed to be independent of farm size.

- Separation distance: 200 m.

- In organic maize, a separation distance of 300 m is suggested. Organic maize production is, however, not included in this analysis.

Table 4.8. Transgression of the separation distance of 200 m in GM maize production.

Maize area of cultivated area	Share of area with GM maize of total maize area		Maize area		Number of maize fields	GM fields that do not comply with separation distances	
	Scenario (%)	Realised (%)	(ha)	(%)		% of GM maize fields	% of all maize fields
2.5 %	10	8.2	164	2.6	46	6.1	0.6
	50	46	164	2.6	46	3.6	1.6

Only 6 % and 4 % of the GM maize fields would not comply with the separation distances at 10 % and 50 %, respectively, of the GM maize crop area. Even though the separation distance for maize is 200 m, the number of transgressions of the separation distances is smaller than for rape with separation distances of 150 metres. This is caused by the maize area being more concentrated at the farms with silage production.

Potatoes

Assumptions in the analysis:

- Potatoes are produced on the crop production farms and pig farms in a crop production rotation.
- Potatoes form part of the crop rotation every four years.
- Not all farms produce potatoes, but the probability of producing potatoes increases with the farm area.
- The probability of a potato producer choosing a GM potato variety is assumed to be independent of farm size.
- Separation distance: 20 m.

Table 4.9. Transgression of the separation distance of 20 m in potatoes.

Potato area of cultivated area	Share of area with GM potatoes of total potato area		Potato area		Number of potato fields	GM fields that do not comply with separation distances	
	Scenario (%)	Realised (%)	(ha)	(%)		% of GM potato fields	% of all potato fields
5 %	10	10.6	337	5.3	77	12	1.2
	50	48.5	361	5.7	82	5.4	2.7
10 %	10	10.7	663	10.5	158	19	2.0
	50	50.6	650	10.3	153	9.6	4.8

In order to comply with the separation distances of 20 m, at a distribution of GM potatoes of 10 % and 50 % of the potato area, a potato producer who grows GM potatoes and is located in a potato intensive area (10 % of the area with potatoes) must make crop rotational adjustments for 19 % and about 10 % of the potato fields, respectively. A usable alternative to relocating crops from fields that do not comply with the separation distances would be to cultivate a buffer zone of up to 20 m with another crop or to set this zone aside.

Organic oilseed rape
To illustrate the problems in producing organic oilseed rape, Figure 2 shows the distribution of oilseed rape fields in the "case area":

Assumptions in the scenario:

- Extensive oilseed rape production (6.4 % of the agricultural area).
- Six % of the oilseed rape area is cultivated organically and 56 % is cultivated with a non-GM oilseed rape.
- A buffer zone of 500 m is drawn around the fields with organic oilseed rape.
- A buffer zone of 150 m is drawn around the fields with non-GM oilseed rape.

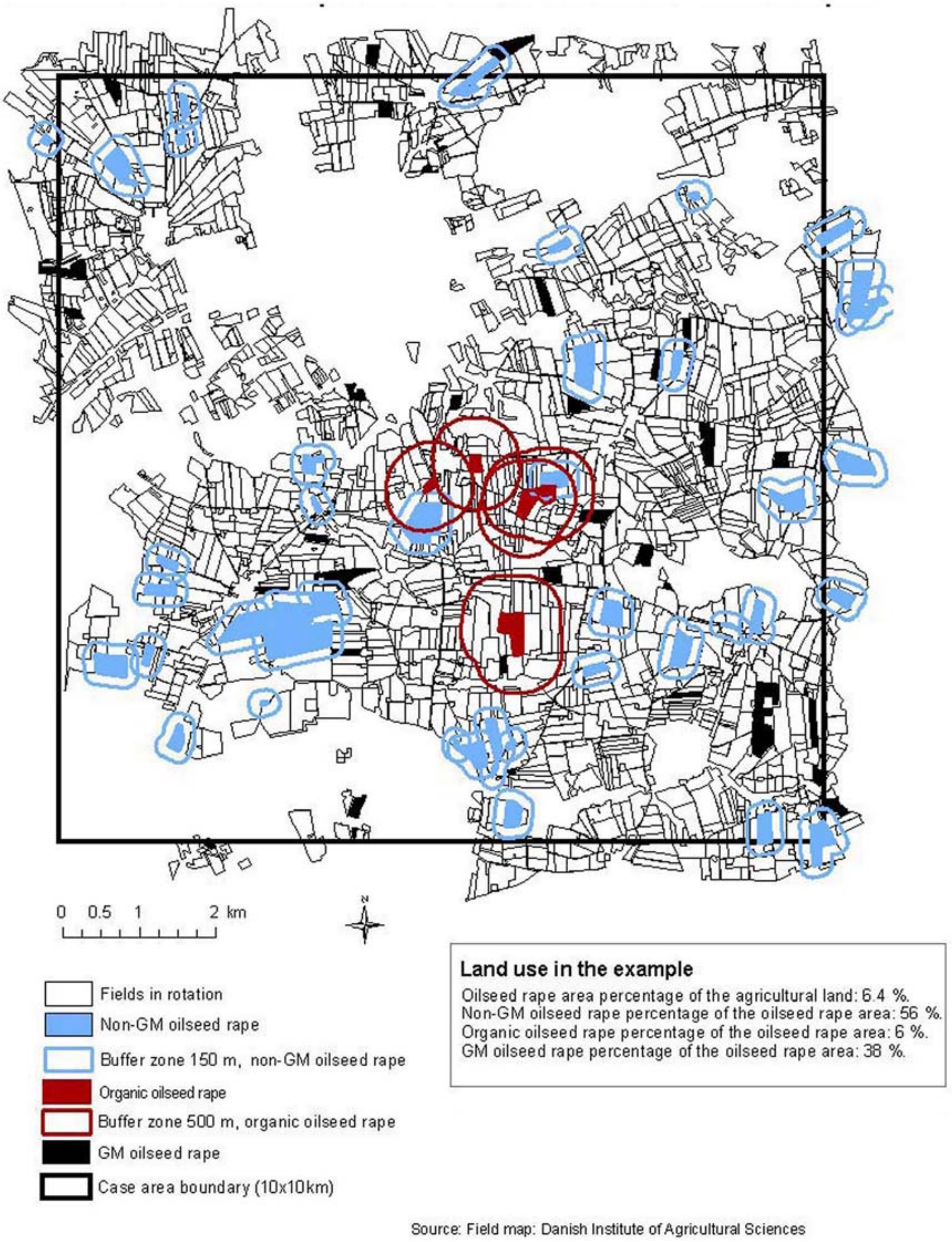

Figure 4.6. Localisation of oilseed rape fields in the case area with extensive organic oilseed rape production (Abildtrup & Gylling, 2003).

The map in Figure 4.6 shows that despite the relatively widespread production of non-GM oilseed rape and organic rape, there are still large areas that are not affected by the buffer zones and that therefore can be cultivated with a GM oilseed rape and comply with the separation distances. There may, however, be farms, which will have a very limited freedom on where to plant GM oilseed rape.

A special “worst case” scenario will arise if for example a relatively well-structured farm of about 40 ha wanted to grow GM oilseed rape and all the neighbours want to grow organic oilseed rape. In that case it will not be possible to comply with the separation distances, even with the best possible coordination with the neighbours. Local problems may thus arise in such cases where a producer cannot grow GM oilseed rape as a result of the separation distances. This is, however, unlikely, as the organic oilseed rape area is very limited.

The need for contact with neighbours
Based on the farm and field structure of the case area, the number of fields is worked out in which a GM crop producer may choose his crop rotation independently of the neighbouring farms.

The analysis shows that only 4-8 % of the fields could be cultivated independently of neighbouring farms at separation distances of 100 m between GM crops and corresponding non-GM crops. If the separation distance is increased, the number of "free" fields is more than halved. It may be concluded that there will be an increased need for coordination with neighbouring farms, as only few fields may be cultivated independently of the neighbouring farms at separation distances of more than 100 metres. However, it must be stressed that the number of fields that can be cultivated independently of neighbouring farms will be higher in other areas that are not characterised by a large number of small farms.

Conclusion

- The need for adjustments in the crop rotations of oilseed rape, maize and potatoes in order to comply the separation distances is limited in the analysed scenarios.

- At separation distances of 150 metres and an oilseed rape area share of 5 % of the agricultural area of which half is GM oilseed rape, only 12 % of the GM oilseed rape fields do not comply with the separation distances if there is no farm adjustment.

- Stipulated separation distances mean that the producers in an area only in relatively few cases may grow a GM crop independently of their neighbouring farms. There will be a high requirement for contact between neighbouring farms. However, it will only be in a relatively few cases, where a neighbour intends to grow a similar non-GM crop, that farm adjustments will be necessary.

- However, in a few cases local conditions may make it impossible for a grower to grow a GM crop, *e.g.* when the proposed GM oilseed rape field is surrounded by non-GM oilseed rape.

- The conclusions are based on a relatively limited number of analyses and only one case area. The results are therefore not representative of Denmark as a whole.

- As the area generally has smaller farms and fields than Denmark on average, the estimated need of adjustments would probably be higher than for Denmark as a whole.

- Similar analyses are needed of the consequences of separation distances in other regions with a different crop distribution and farm and fields structure from those of the case area. In connection with the introduction of GM crops, the development of GIS-based models will be valuable to advisers and farmers in connection with decision-making and the co-existence problems.

4.6 Available literature and experience for the report

Both before the start of the evaluation and during the work of the Working Group, a number of reports were published on related subjects. The Working Groups has especially made use of

- The DARCOF report in Danish language "Konsekvenser af Genmodificerede afgrøder for økologisk jordbrug" (The consequences of genetically modified crops for organic farming) (Kjellsson & Boelt, 2002).

- The European report from JRC/IPTS, (Bock *et al.*, 2002): "Scenarios for co-existence of genetically modified, conventional and organic crops in European agriculture".

- The European Environment Agency report: "Genetically modified organisms (GMO's). The significance of gene flow through pollen transfer" by Eastham & Sweet, 2002.

In addition, the Working Group's work is to a large extent based on existing knowledge from multiplication of seed of the individual crops (see chapter 6).

As regards the dispersal of GM material, the Group's knowledge on Danish conditions is based on the experience that was obtained in this country from experimental releases and small-scale experiments. For example in 1999, demonstration experiments with GM fodder beet were carried out in Denmark in 14 different areas. The area sizes for those experiments varied between 0.3 and 3 ha.

In addition, scientific publications were used that are specific to the individual crops as well as experience from a study trip to NIAB, Cambridge, England, and INRA, France respectively.

Literature
The DARCOF report (Kjellsson & Boelt, 2002) contains a survey of the consequences of GM crops for organic farming under Danish conditions. It discusses among other things:

- The special conditions of organic farming, *e.g.* with regard to the supply of seed, manure and feed.

- Dispersal routes and control measures to control possible GM dispersal.

- Possibilities of control and risk assessment regarding GM plants.

- Problems regarding the individual crops, which are of varying extent.

The joint European JRC/IPTS report (Bock *et al.*, 2002) is based on expert opinion and computer models. The study comprises 3 crops: winter oilseed rape for seed and production, maize and potatoes and scenarios with 10 % and 50 % GM production in selected areas in France, Italy, the United Kingdom and Germany. It is emphasised in the report that reservations must be made about the resulting absolute figures, because the applied GENESYS and MAPOD models of oilseed rape and maize, respectively, were not adjusted on the basis of practical field data. Neither can they be transferred directly to other areas and conditions. The calculations are, however, suitable for relative comparisons. In addition, there are a number of suggestions on which control measures may be used with regard to the individual farm.

The JRC/IPTS report evaluates whether co-existence is possible in a region under the conditions described. The conclusion is that co-existence depends on *inter alia*: crop, farming system and field size. The study also shows that the share of GM crops that is produced in a region is an important factor for adventitious presence. Further, it is found that basic control measures for preventing dispersal ought to be employed immediately at the introduction of a GM crop.

The results are discussed at length in chapters 10.2, 10.3 and 10.5 in this report for oilseed rape, maize and potatoes, respectively.

The Evaluation Group had several working documents, reports, scientific publications, and expressions of opinion from a variety of sources at its disposal, including:

- "Genetically modified organisms (GMO's). The significance of gene flow through pollen transfer" by Eastham & Sweet (2002), which reviews information on the existing knowledge of gene dispersal in the crops oilseed rape, maize, beet, potato, wheat, barley, fruit and berries. Among other things, the report evaluated the probability of pollen dispersal in the above-mentioned crops.

- “Opinion of the scientific committee on plants concerning the adventitious presence of GM seeds in conventional seeds” (Scientific committee on plants, 2001). Evaluations by the standing scientific committee on plants regarding adventitious presence of GM seeds in conventional seeds.

- “ESTO study on co-existence of GM, conventional and organic crops” (ESTO, 2002, draft).

- “Gene stacking” (ORSON, 2002) describes experience from a journey to Canada to gather experience regarding accumulation of herbicide tolerance genes in oilseed rape volunteers. The report makes suggestions for possible control measures in future growing of herbicide tolerant oilseed rape in Great Britain.

- “Seeds of doubt” from the organic “Soil Association” (2002) describes the situation of growing GM crops in the USA. The report is based on interviews with American farmers who are very critical of GM growing and the obtained results.

- “Let the facts speak for themselves” from a number of American interest groups, among them “American Soybean Association”. This comments and argues against the points of criticism raised by the report mentioned above (Nill, 2002).

- “The farm level impact of using Bt maize in Spain”, discusses experience from Spanish farmers’ growing of insect resistant maize (Brookes, 2002). Calculations were made of contribution margins as well as evaluations of effect in different regions.

- “Adoption of Bioengineered Crops”, published by USDA (Fernandez-Cornejo, 2002). The report is based on questionnaire studies and provides a survey of the expected distribution of herbicide tolerant and insect resistant GM soybean, cotton and maize in the USA in the next few years. The financial results that were achieved through the use of these crops are described.

- The report “Bleibt in Deutschland bei zunehmenden Einsatz der Gentechnik in Landwirtschaft und Lebensmittelproduktion die Wahlfreiheit auf GVO-unbelastede Nahrung erhalten“ by the Forschungsinstitut für biologischen Landbau Berlin e.V. and Öko-Institute e.V. (Beck *et al*., 2002) deals with the possibility of GM dispersal in all production and distribution stages and discusses different control measures and possibilities based on different cropping scenarios.

- “Comparative Environmental Impacts of Biotechnology-derived and Traditional Soybean, Corn, and Cotton Crops” by “the Council for Agricultural Science and Technology” (Carpenter, 2002).

- “Plant Biotechnology: Current and Potential Impact for Improving Pest Management In U.S. Agriculture. An Analysis of 40 Case Studies” by the National Center for Food and Agricultural Policy, USA (Gianessi *et al*., 2002).

- “Memorandum” by Greenpeace (2002) outlines the views of the organisation regarding co-existence, dispersal and threshold values.

- “Monitoring large-scale releases of genetically modified crops (EPG 1/5/84) incorporating report on project EPG 1/5/30: monitoring releases of genetically modified crop plants” (Norris & Sweet, 2002) presents the results of the monitoring of the experimental releases of GM oilseed rape in Great Britain between 1994 and 2000.

- (“Farm Scale Evaluations”). A three-year programme growing herbicide tolerant oilseed rape, GM beet and GM maize was carried out at farm level in Great Britain. The three-year programme is now finished, but the results were not yet fully analysed and published. So only the set up could be considered in this report. A new link from DEFRA October 2003 is www.defra.gov.uk/environment/gm/fse/

- “Samexistens i fält mellan genetiskt modificerede, konventionella och ekologiska gröder” Jordbruksverket, 2003. The Swedish Government, inspired by the 1st edition of the Danish report, prepared a co-existence account dealing with evaluations of oilseed rape, beets and potatoes.

- “Round table on research results relating to co-existence of GM and non-GM crops”. The European Commission, 2003. The latest research results and evaluations regarding co-existence in connection with introduction of genetically modified maize and oilseed rape were presented and discussed at a round table discussion arranged by the European Commission on 24 April 2003.

- “Plant biotechnology: Potential impact for improving Pest Management in European Agriculture” (Gianessi *et al*., 2003). Based on case studies with different GM characteristics in maize, beets and potatoes, the economic potential of the crops in Europe is evaluated.

- “GM Science Review. First report. An open review of science relevant to GM crops and food based on the interest and concerns of the public” (GM science review panel, 2003). A British discussion of the subject, which also includes environmental evaluations and cost-benefit analyses of the consequences of growing GM plants.

- “Review of GMOs under research and development and in the pipeline in Europe” prepared by ESTO, JRC and IPTS represented by Lheureux *et al*. (2003). The report provides a survey of the research and the development of GM crops and the expectations to the future growing of those crops in Europe.

- “Dispersal of maize, wheat and rye pollen. Institute of Plant Sciences. Swiss Federal Institute of Technology” by B. Feil & J.E. Schmid (2002). The study presents different aspects of the dispersal of maize, wheat and rye pollen, including a survey of applied separation distances in different countries.

- “Co-existence of genetically modified and non-genetically modified crops” by Christey & Woodfield (2001) includes an evaluation of the co-existence problems for New Zealand’s agriculture in connection with introduction of GM crops. The evaluations include oilseed rape, clover and potatoes.

- “GM crops in Europe – planning for the end of the moratorium” published by PG-Economics (2003). The report studies – based on the current regulations for the EU and the characteristics that are developed – the potential of the distribution of a number of GM crops in Europe.

Regarding the debate on co-existence and ethical aspects the homepage www.biotik.dk may be consulted.

Further literature could be found at the homepage for the “1st European conference on the Co-existence of Genetically Modified Crops with Conventional and Organic Crops”, 2003: www.agrsci.dk/GMCC-03/ where there is a survey of co-existence studies prepared by IPTS.

5. Legislative status

A survey of the existing and future EU legislation on GMOs with relevance to the co-existence problem is presented below in the form of a time line. It comprises:

- Experimental planting and marketing of GMOs.
- Ban on using GMOs in organic farming.
- Traceability and labelling of GMOs.
- GMOs in foods and feed.
- Adventitious admixture of GM seeds in conventional seeds.

1990:	The EU passes a directive (90/220) that regulates experimental release and marketing of GMOs in the EU.
1993 and onwards:	Gradual transfer of the marketing part in the release directive to specific legislation – *inter alia* to the seed legislation.
1994:	The EU approves marketing of a genetically modified plant (GM plant) for the first time: tobacco.
Up to 1999:	27 applications for approval for marketing of GM plants in the EU have been submitted. A total of 14 applications have been approved, comprising tobacco, oilseed rape, soybean, chicory, maize, carnations (see Annex 1).
1998:	A blocking minority, consisting of France, Italy, Greece, Luxemburg and Denmark (and later Austria) passes a moratorium on the approval for marketing of new GM plants. Since then no new GM plants have been approved for marketing in the EU. A condition of revoking the moratorium is that regulations on traceability and labelling are introduced first - in a continuation of a revised release directive.
1999:	EU ban on using GMOs in organic farming.
2000:	Admixture of GM oilseed rape in oilseed rape seed lots from Canada is detected in several EU countries, among them Denmark. In consequence, the EU Standing Committee on Seeds passes an action plan to monitor conventional seed for GM seed contamination.

17 April 2001:	The revised release directive (2001/18) becomes effective. The directive must be implemented in national law on 17 October 2002 at the latest.
4 July 2001:	A working document on adventitious presence of GM seeds in conventional seed is submitted to the Standing Committee on Seeds. In the document, threshold values for labelling of conventional seed are laid down. The working document is continuously revised. A final proposal is expected in September 2003.
25 July 2001:	The EU Commission presents two proposals to the European Parliament and the Council of Ministers for: 1) A Regulation on traceability and labelling of GMOs and traceability of food and feed products produced from GMOs. With this regulation, GMO traceability is ensured through all of the production and distribution chain. 2) A Regulation on genetically modified food and feed. With this regulation, requirements of approval of GM feed are introduced. In addition, the approval of GM foods is transferred from the Novel Foods Regulation.
29 May 2002:	The Danish Parliament (Folketinget) passes an amendment of the Act on environment and gene technology. The revised Act implements the new release directive. Into the Act is inserted a provision that the Minister for Food, Agriculture and Fisheries lays down regulations that, within the framework of EU legislation, severely restrict the risk of dispersal to other fields, including organic fields. Based on the Act, the Ministry of Food, Agriculture and Fisheries initiates the work regarding co-existence between GM crops, conventional, and organic crops.
3 July 2002:	First reading in the European Parliament of the proposal for a Regulation on traceability and labelling of GMOs and traceability of food and feed products produced from GMOs. The Parliament passes 30 amendments to the proposal by the Commission.
3 July 2002:	First reading in the European Parliament of the proposal for a Regulation on genetically modified food and feed.

The Parliament passes 111 amendments to the proposal by the Commission.

17 October 2002: The old release directive of 1990 is revoked. According to a provision in the new release directive (2001/18) all applications for approval for marketing that are not yet decided according to the old directive must be complemented so that they comply with the requirements in this new directive.

28 November 2002: The Council of Ministers reaches political agreement on a common position on the proposal for a Regulation on genetically modified food and feed. Among other things, the Council passes a threshold value of 0.9 % for labelling GM food and GM feed for approved GMOs. The proposal is sent back to the European Parliament for its second reading.

January 2003: For the first time since 1999 the EU Commission sends two applications for approval for marketing of genetically modified plants to the member states, one for maize and one for oilseed rape.

2 July 2003: Second reading in the European Parliament of the proposal for a Regulation on genetically modified food and feed. The threshold value of 0.9 % for labelling of GM foods and GM feed is maintained. In addition, a provision on laying down guidelines on co-existence is inserted (amendment of the release directive).

2 July 2003: Second reading in the European Parliament of the proposal for a Regulation on traceability and labelling of GMOs. The proposal is adopted with a few amendments.

22 July 2003: The Council of Ministers adopts the proposals for the Regulations on genetically modified food and feed and on traceability and labelling of GMOs, respectively.

23 July 2003: The EU Commission publishes its “Recommendation 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”.

(Annex 2 contains a list of the legislation referred to in this chapter).

6. Seed production and threshold values

6.1 Present regulations on seed production

In connection with the question of setting threshold values for adventitious presence of GM seed, it is relevant to mention the already existing regulations regarding varietal purity in the production (growing) of certified seeds for sowing.

In connection with the production of seeds for sowing, a number of quality requirements are laid down in the EU directives on the marketing of seed. These requirements include threshold values for admixture of seeds not true to variety and minimum distances to areas with other varieties of the same species (see Tables 6.1 and 6.2). These requirements must be met for the seeds to be certified.

Only the production of seeds for marketing is affected by the requirements. Farm saved seed is not affected.

The requirements issued by the statutory instruments apply to seed of fodder plants, beet, oil and fibre plants, cereals and vegetables. Compliance with the requirements is controlled by certification and includes requirements that:

- Seeds are multiplied according to the existing regulations.

- The seed lot complies with the stipulated minimum standards on purity, germination capacity and varietal purity that apply to the marketing of seeds within the EU.

- The variety is on an official list of varieties.

Higher national standards apply to production and the marketing of cereal seeds in Denmark.

6.2 Multiplication, certification and inspection

When breeders produce a new variety, a condition of multiplication and marketing of seed of the new variety is that it is included in the official variety list. One of the conditions of inclusion is that the variety is morphologically distinct from other varieties in characters such as time of ear emergence/flowering, type of ear, colour of the flower, *etc*.

Multiplication of a variety is necessary for marketing. After breeding there is only a small amount of seed of the new variety, which cannot meet the expected demand. Therefore the seed is multiplied to ensure appropriate seed supply and is under official control by the

Danish Plant Directorate. Among other things, they inspect to ensure that the multiplication does not result in a change of the varietal purity through cross-pollination or admixture of another variety.

Seed is multiplied in a set hierarchy of generations:

- Breeders material.
- Pre-basic seed.
- Basic seed.
- Certified seed 1st generation (C1).
- Certified seed 2nd generation (C2).

C1 and C2 seed are for final/farmer usage. Not all species can be multiplied to the C2 generation. All fields that are sown for seed production in one of the generations mentioned above must be under official or authorised control.

Crop inspectors check cross-pollinating species to ensure that minimum distances to other pollen sources are complied with. Self-pollinating species are checked that neighbouring fields do not impose a risk of admixture of another species or variety at harvest (Tables 6.1-6.2). In addition, the presence of other varieties in the crop is checked.

After harvest the seed crop is delivered to the registered seed company that cleans it. The crop is sealed in lots that are identified by a reference number. For each lot, a sample must be analysed for germination capacity and purity by either an official or an authorised laboratory. Seed lots are only certified if the analysis shows that the quality standards are met.

In addition, a sample must be submitted for official control of varietal purity. The Danish Plant Directorate carries out this test by sowing and inspecting plots at their experimental farm.

Varietal purity requires that the number of plants not being true to variety shall not exceed the minimum quality standards (Table 6.1). In the varietal purity test the same characteristics are used as mentioned concerning variety testing.

Table 6.1. Quality requirements in seed production of agricultural plants: Minimum distance to areas with other varieties of the same species, maximum presence of other varieties and interval between production of varieties of the same species on the same area.

	Crop	Basic seed			Certified seed (C1)		
		Minimum distance	Presence of other varieties	Cropping Interval	Minimum distance	Presence of other varieties	Cropping Interval
Self-pollinating	Barley	0 m	≤ 0.1 %	1 yr	0 m	≤ 0.3 %	1 yr
	Wheat	0 m	≤ 0.1 %	1 yr	0 m	≤ 0.3 %	1 yr
	Oats	0 m	≤ 0.1 %	1 yr	0 m	≤ 0.3 %	1 yr
	Triticale (self-pollinating)	50 m	≤ 0.3 %	1 yr	20 m	≤ 1 %	1 yr
	Meadow grass; one-cloned varieties (apomictic)	1 m	≤ 1 per 20 m^2	5 yrs	1 m	≤ 6 per 10 m^2	3 yrs
	Field pea	1 m	< 0.3 %	2 yrs	1 m	< 1 %	2 yrs
	Soybean	1 m	< 3 %		1 m	< 5 %	
Cross-pollinating	Rye	300 m	≤ 1 per 30 m^2	1 yr	250 m	≤ 1 per 10 m^2	1 yr
	Rye; hybrids	600/1,000 m	≤ 1 per 30 m^2	1 yr	500 m	≤ 1 per 10 m^2	1 yr
	Maize; inbred lines & simple hybrids	200 m	≤ 0.1 %	2 yrs	200 m	≤ 0.2 %	1 yr
	Maize; open pollinating	200 m	≤ 0.5 %	2 yrs	200 m	≤ 1 %	2 yrs
	Oilseed rape; self-fertile	200 m	<0.1 %; <0.3 % (feed)	6 yrs[1)]	100 m	<0.3 %; <1 % (feed)	6 yrs[1)]
	Turnip-rape; self-fertile	500 m	<0.1 %; <0.3 % (feed)	6 yrs[1)]	200 m	<0.3 %; <1 % (feed)	6 yrs[1)]
	Oilseed rape & turnip rape; hybrids	500 m	< 0.1-5 %[2)]	6 yrs[1)]	300 m	< 10 %	6 yrs[1)]
	Other *Brassica*-species	800 m	Sufficient var. purity.	16 yrs/8 yrs	500 m	Sufficient var. purity	16 yrs/8 yrs
	Beet	1,000 m	Sufficient var. purity	8 yrs[3)]	800 m	Sufficient var. purity	8 yrs[3)]
	Grassland legumes**	200 m	≤ 1 plant per 20-30 m^2	5 yrs[4)]	50/100 m*	≤ 1-6 plants per 10 m^2	3 yrs
	Lupin	200 m	≤ 1 plant per 30 m^2	2 yrs	100 m	≤ 1 plant per 10 m^2	2 yrs
	Broad bean	400 m	0.3 %	2 yrs	200 m	1 %	2 yrs
	Potato	50 m/25 m[5) 6)]	0.0 %	4 yrs/3 yrs[6)]	15 m[5)]	0.05 %	3 yrs

[1)]: Between seed production of varieties with different content of erucic acid and/or glucosinolates 8 years, however. [2)]: Hybrids in which male sterility is used: Male constituent < 0.1 %, female constituent < 1 %. Hybrids in which self-sterility is used: Inbred line < 2 %; single hybrid < 5 %. [3)]: Compared with former beet seed production. 4 years compared with former production of beet for feed or industrial use. [4)]: For grassland legumes 7 years, however. [5)]: These distances are laid down due to the risk of virus transmission. [6)]: Pre-basic and basic seed potatoes respectively. * 50m at field sizes < 2 ha, 100 m at fied sizes > 2 ha.
** including both grasses and clover; for smooth-stalked meadow grass, however, see above.

Table 6.2. Quality requirements in seed production of vegetables: Minimum distance to areas with other varieties of the same species.

Crop	Basic seed	Certified seed
Leaf beet and garden beet		
From any pollen sources of the genus *Beta*	1,000 m	1,000 m
From pollen sources of the same subspecies, different variety group	1,000 m	600 m
From pollen sources of the same subspecies, same variety group	600 m	300 m
Brassica species		
From sources of foreign pollen liable to cause serious deterioration in varieties of *Brassica* species	1,000 m	600 m
From other sources of foreign pollen liable to cross with varieties of *Brassica* species	500 m	300 m
Industrial chicory		
From other species of the same genera or subspecies	1,000 m	1,000 m
From another variety of industrial chicory	600 m	300 m
Other species		
From sources of foreign pollen liable to cause serious deterioration in varieties of species as a result of cross-fertilisation	500 m	300 m
From other sources of foreign pollen liable to cross with varieties of species as a result of cross-fertilisation	300 m	100 m

Generally, vegetable seed is not certified but is sold as standard seed. Standard seed – just as certified seed – must meet certain standards of germination and purity. Fields for production of standard seed are not officially inspected, and the varietal purity test in the field plot test is only carried out as a random sampling from 2 % of the standard seed lots.

It implies in all species that the lot itself most probably will have been sold when the results of the variety testing is available because the test requires assessment of the sample throughout a growing season.

Apart from the risk of cross-pollination, there is a risk of admixture of other varieties at sowing, harvesting, storing and cleaning. Great care on the part of growers and companies is required. The individual companies have laid down guidelines for their growers and workers on how to avoid admixture. The results of the varietal purity test in 2002 are shown below to illustrate how many lots are rejected in the varietal purity test by the Danish Plant Directorate:

Table 6.3. Result of the varietal purity test 2002 by the Danish Plant Directorate.

Species/group of species	Category	Number of assessed lots	Number of lots that do not meet the standard	% rejected lots
Grasses	Pre-basi	34	7	20.1
	Basic	387	13	3.4
	C1	1,165	50	4.3
Grassland legumes	Pre-basic	1	0	0
	Basic	9	0	0
	C1	34	0	0
Field pea and broad bean	Pre-basic	61	0	0
	Basic	45	2	4.4
	C1	150	0	0
	C2	47	0	0
Oilseed rape*	Basic	24	0	0
	C1	13	0	0
Cereals	Pre-basic	165	11	6.7
	Basic	207	11	5.3
	C1	915	30	3.3
	C2	1,028	13	1.3

*No lots of pre-basic seed were produced.

For cereals, the share of seed lots that are rejected is reduced during multiplication from pre-basic seed to C2.

For grasses the number of rejected lots cover a large variation among species. For smooth-stalked meadow grass (*Poa pratensis*) and hard fescue (*Festuca lemanii*) there are years in which more than 20 % of the seed lots do not meet the standards whereas there are fewer seed lots with aberrant types in meadow fescue (*F. Pratensis*) and red fescue (*F. rubra*).

6.3 Use of morphological versus genetic characteristics to determine varietal purity or adventitious presence

Much experience exists on varietal purity in connection with multiplication of certified seed, and minimum distances have been established for the different crops to ensure a certain varietal purity, *i.e.* an upper limit of plants not true to variety. These minimum distances thus constitute a knowledge basis, which may be used for formulating minimum distances between GM, conventional and organic crops.

The assessment of varietal purity has, however, until now mainly been based on morphological characteristics such as the differences in leaf and ear characteristics in cereals. These morphological characteristics can be determined by single genes or by the interaction between different genes. A variety that displays homogeneous morphological characteristics may in reality consist of several lines that are not genetically identical but can only be distinguished by a genetic analysis.

In cereals – especially maize – a number of studies of pollen dispersal have been carried out based on the colour or shape of the grain. Those characteristics have a simple genetic basis. The experience achieved was subsequently used in the formulation of the certification regulations for maize.

Potatoes are grown as clones and are therefore genetically homogeneous within the variety. However, measurable differences that are conditional on genetics can be found between different clones of the same variety.

Analyses were performed to determine the relationship between morphological characteristics and different methods for genetic analyses in grasses. Generally, the relation between morphological characteristics and the used genetic analyses was found to be poor, but for plants with a common genetic basis the genetic and biochemical methods of analyses were in keeping with the morphological recordings.

An unambiguous conclusion for all plant species is not possible, due to the existing differences among species. It is, however, generally presumed that an assessment of varietal purity, based on morphological characteristics, would to some extent underestimate the degree of adventitious presence. The Evaluation Group has taken this factor into account in its recommendation of control measures.

6.4 GM content in seed

According to the existing EU regulation on novel foods, which among other things include GM foods, a threshold value of 1 % has been set under which the labelling of GM content in food is not necessary.

To meet that labelling requirement, the EU Standing Committee on Seeds and Propagating Material for Agriculture, Horticulture and Forestry (Standing Committee on Seeds) is working on a proposal for setting threshold values of GM content in the production of conventional seed. The provisions on threshold values will be included in the directives on the marketing of seed. The consequence will be that seed with a GMO content exceeding the threshold value must be labelled when sold.

Since the production of seed comes before the production of food in the production chain, these threshold values must be set so that it is possible to meet the threshold values for the labelling of food and so that a number of possibilities of admixture on the way from seed to food is taken into account (pollination, admixture during harvest, transport, storage, *etc*.).

As the risk of pollination with foreign pollen depends on whether the plant is cross- or self-pollinating, the Commission's working document suggests different threshold values for the different species included in the document (Table 6.4). The suggestion comprises the species for which GM plants have been developed for marketing so far.

Based on an earlier edition of the working document, which at that time contained all species, it is expected that the threshold value for adventitious presence in cross-pollinated species such as rye, most grasses, and clover is to be 0.3 %, for self-pollinating species like wheat, barley and oats 0.5 % and for field peas 0.7 %. The threshold values will, however, first be finally decided when GM plants of these species are close to marketing.

Table 6.4. Proposal for threshold values for adventitious presence of GM seed in conventional seed (from the working document "SANCO/1542/02July2002").

Species	**Maximum adventitious presence of GM seed**
Oilseed rape	0.3 %
Maize, beet, potato, cotton, tomato, chicory	0.5 %
Soybean	0.7 %

At the meeting of the Council of Ministers on 22 July, 2002, the proposal for Regulation on Genetically Modified Food and Feed was agreed upon. Consequently, the threshold value for labelling of GM foods and GM feed for adventitious GMO presence is to be 0.9 %. The EU Commission is consequently expected to submit a proposal for GM threshold values in seed for debate in the Standing Committee on Seeds based on the latest working document of 2 July, 2002.

7. Monitoring and analytical methods

7.1 Monitoring

The Directive 2001/18/EC on the deliberate release into the environment of genetically modificed organisms contains regulations concerning the monitoring of genetically modified organisms that have been approved for marketing. Such monitoring is to uncover any unwanted consequences of the release of the GM plant on the environment and on human and animal health (monitoring of environmental effects).

There also has to be a monitoring of the effect of the control measures that are to ensure the co-existence of genetically modified, conventional and organic crops as suggested in this report (monitoring of effects of cultivation).

Though the objective of the two forms of monitoring is different, there is still a certain overlap in the parameters monitored. For example, pollen dispersal is studied both in relation to monitoring unwanted environmental effects and in relation to co-existence.

Post marketing monitoring according to the release directive (2001/18/EC)
Applications for marketing consent must include a plan for monitoring of the marketed GMO. The applicant is responsible for performing the monitoring and for reporting the results to the EU Commission and to the competent authorities in the member states.

The general principles of the framing of the monitoring plan are described in Annex VII of the release directive. These were later extended, leading to the Council's resolution of 3 October 2002 (2002/811/EC) that lays down guidelines for the elaboration of the plan.

The monitoring objectives are, 1., to confirm the environmental risk assessment (ERA) on any direct, indirect, immediate or delayed, adverse effects of the GMO on human health and the environment, 2., to detect any adverse effects of the GMO on human health and the environment not anticipated in the ERA. The monitoring strategy distinguishes between a specific and a general monitoring.

Specific monitoring
Such monitoring includes all potentially unwanted effects that are identified in the environmental risk assessment. For example, it may be necessary to monitor potential environmental consequences of pollen transmission from GM plants and the dispersal and survival of the plants.

The notes also mention that it may be considered to include the “possibility of transfer of genetic material to sexually compatible organic and conventional crops” (quotation from the notes) if this is likely to pose a threat to human health or the environment.

General monitoring
The objective is to observe and record any indirect, delayed and/or cumulative, unwanted effects that are not foreseen in the risk assessment. This could be a part of the already existing, routine monitoring of agricultural crops, which is carried out as part of the calculation of the use of manure and in connection with the control of pests, diseases and weeds.

It appears from the guidelines that the member states, in accordance with the treaty, are entitled to lay down further measures with regard to monitoring and control with marketed GMOs by national authorities.

Monitoring the effect of control measures as steps in a phased introduction of GM crops
The effect of the control measures that this report proposes in order to ensure the possibilities of co-existence in Denmark should be monitored so that it is possible to adjust the control measures according to need. The monitoring should take place on selected representative localities and should include all grown GM crops.

It would seem most appropriate to monitor the effect of the most important control measures mentioned in the report (see chapter 9, Table 9.1). Those include:

- Inspection of seed and harvested crops.
- Separation distances, buffer zones and field size.
- Cropping intervals.
- Control of volunteers.
- Cleaning of sowing and harvesting equipment, transport material and stores.

The monitoring of the effect of the control measures could take place in separate research projects.

Inspection of seed and harvested crops
It is to be assumed that the seed companies themselves will do a lot to ensure that they supply conventional and organic farmers with seed with the lowest possible GM content. In order to check that this is the case, samples should be taken and analyses made of the conventional and organic seed that is supplied to a representative number of farmers. This inspection should be carried out over a number of years to follow the temporal development in the GMO content. In addition, by analysing samples of the harvested crops, originating from the analysed seed lots, it will be possible to investigate whether there is any multiplication of GM seed taking place during crop production.

Separation distances, buffer zones and field size
An evaluation of whether the recommended separation distances are sufficient may be carried out by studying the pollen dispersal from fields with GM crops into a representative number of conventional and organic fields with the same crop. If the pollen dispersal for a given crop turns out to be larger than expected, it may be due to too short separation distances. If, on the other hand, the pollen dispersal turns out to be smaller than expected, it will be possible to reduce the distance.

There is a need for more knowledge about the effect of buffer zones on the reduction of pollen dispersal. The effect could be investigated by comparing the GM content, e.g., in conventional oil seed rape fields (of the same size and shape) with and without barrier rows, and in different distances from fields with GM oil seed rape. Further, the effect of changing the size and shape of non-GM fields on the GM content in the harvested products from these fields should be investigated.

Cropping intervals
The effect of the recommended cropping intervals can be evaluated by studying the presence of GM volunteers in the years following the cultivation of a GM crop in a given field. This should include a representative number of fields for each GM crop. Depending on the result of the studies, the cropping intervals should be adjusted, either increased or decreased.

Control of volunteers
In practice, the control of GM volunteers will be left with the individual farmer as a part of good farming practice. The effect can be studied by comparing the presence of GM volunteers in fields in which control (either mechanical or by spraying) was carried out with the presence in fields in which control was experimentally omitted.

Further, the presence of GM volunteers in field boundaries, along between-field roads and in the area appearing as a result of dropping seed after harvest and during transport of the GM crops should be monitored.

Cleaning of sowing and harvesting equipment, transport material and stores
It is a requirement for effectively avoiding the dispersal of GM seed that sowing and harvesting equipment, transport material and stores are adequately cleaned.

An indication of the effect of cleaning may be obtained by studying – for different crops – how many seeds are left in the sowing and harvesting equipment before and after cleaning.

Further, a random check should be carried out of whether sowing and harvesting equipment, transport material and stores handling GM seed and crops are sufficiently cleaned.

Inspection of compliance with co-existence regulations
Apart from the monitoring of the effects of control measures outlined above, there will be a need to establish a system to supervise the compliance with regulations concerning the co-existence of genetically modified, conventional and organic crops. These regulations are to be developed.

The regulations on co-existence are expected to be based on a selection of the recommended control measures for ensuring co-existence.

The inspection will serve to ensure compliance with the regulations on co-existence. The monitoring serves to evaluate the effect of the recommended control measures and can be the basis for possible revisions of the regulations.

7.2 GM analyses

Sampling and testing for the presence of GM material may be carried out at several points "from farm to fork". For instance, samples can be taken of the seed before sowing, of the plants in the field, of the crop products after harvest and at various points during further processing. Further, samples of feed and manure can be tested.

A decision on how to take samples and test for GM content will be a balance between which analysis will be most relevant, compared to the costs of these analyses as most analyses are still very costly.

Today, the GM content in seed and feed for use in organic farming is already under inspection. In addition, the GM content of imported seed from countries outside the EU is inspected in Denmark.

Sampling
For all sampling methods the challenge is to take a sample that is representative of the original lot. Thus, the results of analysis can be totally dependent on the original sampling and subsequent sub-sampling being representative of the original lot. There is also a relation between the size of the sample and the threshold value to be complied with. The lower the threshold value, the larger the sample has to be.

Recommendations for sampling methods exist for several of the testing points mentioned above:

For the seed testing, one may use the regulations on sampling from ISTA (International Seed Testing Association). A working group under the EU’s Standing Committee on Seeds and Plant Propagation Material recommends that these regulations should be used for checking conventional seed for its GM content. Furthermore, the group recommends a sample size of 3,000 seeds to detect threshold values of 0.3-0.7 %.

In the co-existence report from JRC/IPTS (2002), which only includes oilseed rape, maize and potatoes, it is assumed that GM supervision of oilseed rape and maize takes place after harvest by sampling 10,000 seeds from each field for testing. As regards potatoes, it is recommended to take 10,000 leaf samples from the plants in the field. These sample sizes are to quantify the GM content at a level of 0.1 %.

In addition, there is in the EU a network of authorities for testing of GMOs. They have produced a set of standard procedures for the sampling of leaves and seeds for GM analysis. The procedures include identifying the presence of a GM characteristic in GM plants, admixtures of other GM characteristics or a non-GM variety in a GM crop and admixtures of GM seeds in conventional seeds.

As regards animal feeds there is an EU directive that states methods for sampling different types of feedstuffs and for the official testing of feedstuffs.

Sampling of seed lots costs 246 DKK/hour (Danish Plant Directorate prices 2002). The minimum charge is for 2.5 hours of sampling (615 DKK).

Analyses
GM analyses can be divided into 3 types.

- Detection, which tests <u>whether</u> the material contains GMOs.
- Identification of which GM materials are present.
- Quantification.

The current GMO analytical methods can roughly be divided into protein-based and DNA-based methods.

The protein-based methods are the fastest, cheapest and the most simple to perform. The methods are based on the development of antibodies that are specific against new proteins that are produced in the GM plants. The currently commercially available methods for analysis for GM plants have been developed for B.t. toxins, which result in insect resistance, and for herbicide tolerance. As some of the proteins are common in different GM plants, the methods can only be used for detection of the GM characteristic but not for identification of the individual GMOs.

The most sensitive protein-based method is the so-called ELISA method (Enzyme-Linked Immuno Sorbent Assay) which is a laboratory-based method. The method is suitable for both detection and quantification, but since the protein content may vary considerably, the quantitative determination is not reliable.

The lateral flow strip test is an analysis that can be carried out in just 10-20 minutes. The method does not require a laboratory. Tests can be carried out "in the field", for example on seed lots. The test can only be used for detection (but not the quantification) of the mentioned GM types and is a useful provisional screen for GM content.

The most often used DNA-based methods are the so-called PCR (Polymerase Chain Reaction) methods, which can be used for both qualitative (detection and identification) as well as quantitative analyses.

The PCR tests must be carried out in a laboratory, and require more time and are more expensive than the protein-based methods. On the other hand, they are far more sensitive and specific than protein-based methods. PCR analyses are considered to be 10 and 100 times more sensitive, respectively, than ELISA and lateral flow strip tests. This method is used when one has to determine unambiguously which GM genes may be present in a given product.

With a PCR test the presence of the inserted gene itself is studied. If one examines the transition between the inserted gene and the plant's own DNA, the individual GM plant ("transformation event") can unambiguously be identified.

In the PCR methods, the logical sequence is first to carry out a qualitative analysis to detect the GM genes. This is followed by quantification of GM content if the first analysis is positive. The limit of reliable quantification of GM content is considered to be 0.1 %.

A comparison of the methods mentioned above is shown in Table. 7.1.

Table 7.1. Duration and approx. prices of selected GM tests.

Method	Duration	Price
ELISA	3-5 days[1)]	750 DKK
Lateral flow strip test	10-20 min.	30 DKK
PCR detection (screening)	3-5 days[1)]	1,400 DKK
PCR quantification	3-5 days[1)]	1,100 DKK[2)]

[1)]: Execution time (working days) for test carried out by a commercial laboratory.

[2)]: Additional charge after previous detection. Price stated for maize.

The prices stated are average prices of tests that are carried out by commercial laboratories. The prices are taken partly from JRC/IPTS (2002), partly from price lists provided by two private laboratories.

According to JRC/IPTS (2002), it is assumed that the price of a test of the GM content at field level (quantitative PCR) may drop to 1,300 DKK per test (combined price of detection and quantification). This assumption is based on the expected increase in demand and on requesting one GM test per field harvested.

Technical limits of detection

In the DNA-based GMO testing methods (the PCR methods), there are limits of detection and quantification of GMOs, respectively. The detection limit is the smallest amount of GM DNA, which is measurable. The quantification limit is the smallest amount of GM DNA, which is necessary for measuring the actual content of GM DNA.

The theoretical limit for detection of GMOs by the PCR method is often stated as 0.01 % or less. In practice, the average detection limit will often be near 0.1 % because of sampling and measuring uncertainty.

The EU Scientific Committee on Plants has also in its statement of 7 March 2001 on the adventitious presence of GM seed in conventional seed, declared that the technical limit for detection is 0.1 % for routine tests.

In addition, some plant species (*e.g.* wheat) have a large genome (large amount of chromosomal DNA), that sets a limit on the minimum detectable quantity of GM DNA, because there are limits to the amount of DNA that can be present in the PCR reaction.

The relationship between the size of the genome and the detection and quantification limits are shown in Table 7.2. The figures are stated for PCR tests in which 100 ng of DNA are used in the PCR reaction on the assumption that there must be 10 GM DNA copies available for detection and 100 GM-DNA copies for quantification. The stated values apply under optimum analytical conditions and will often be higher due to the uncertainty factors mentioned above.

Table 7.2. Practical limits of detection and quantification of GM-DNA in different plant species.

Plant	Size of genome (1 C value)	Detection limit	Quantification limit
Oilseed rape	1.15 pg	0.01 %	0.12 %
Maize	2.73 pg	0.03 %	0.27 %
Soya	1.14 pg	0.01 %	0.11 %
Wheat	17.33 pg	0.17 %	1.73 %

The relationships mentioned apply to tests of the GM content in seed, which are relatively simple to carry out. In tests of admixtures the detection and quantification limits are increased because the measurable DNA is diluted. In tests of processed material it must be taken into account that the nature of DNA might change during processing, which increase the uncertainty, and hence the detection and quantification limits are proportionally increased.

This also applies to quantification of GM content as there is considerable uncertainty which makes it difficult to make an accurate quantification of very small amounts of GM DNA. As a consequence of this, it may be difficult to enforce very low threshold values.

The limitations of the methods

As mentioned in the section on sampling, it is crucial for the reliability of the test results that the sample that is to be tested for GM content is representative. The problem is smaller for ground material such as animal feed which is relatively homogeneous. By contrast, it is difficult to take a representative sample for a possible adventitious presence of GM seed in a lot of conventional seed which is not homogeneous. An EU project was recently initiated under the management of the EU's Joint Research Centre to examine these problems.

It applies to both protein-based and the DNA-based analytical methods that they are only able to detect a limited quantity of GM plants at a time. In both types of methods, it is initially possible to screen for proteins or pieces of DNA that are common to a number of the GM plants grown today. For example, with the PCR detection method it is possible to screen for pieces of DNA that occur in most of the GM plants that have been marketed so far.

However, GM plants that do not contain any of those specific pieces of DNA are already on the market. In addition, it must be expected that there will be more GM plants without shared pieces of DNA in the future.

In addition, in some cases there may be parts of the plant that cannot be tested with the cheaper protein-based methods (ELISA and lateral flow strip test). For example, if the inserted gene is expressed only in the vegetative parts of the plants, it will only be possible to test the seeds of that plant line with the more expensive PCR methods.

For identifying which GM plant is present in a sample, it is only possible to test a single or very few GM plants at a time with the PCR analysis. This makes the test much more expensive as it has to be repeated for each GM plant tested for.

As mentioned below it will, however, be possible to test a number of plants at a time with the "micro-array" method.

In order to identify the individual GM plants, it is necessary to have access to information about the specific DNA sequences that make up the transition between the plant's own DNA and the inserted DNA. According to the new release directive, the companies that apply for approval for marketing of new GM plants must submit information for the use of identification of the specific construct in their application.

By contrast, it will not be immediately possible to identify GM plants that are grown outside the EU but are not approved for marketing here. The possibilities of identifying those GM plants depend among other things on the readiness, if any, of the companies to hand over the necessary DNA sequences.

Alternative methods
A number of alternative methods of GM testing exist, such as herbicide bioassays. These tests are suitable for screening for the presence of herbicide tolerant GM crops by letting seed germinate on a herbicide-containing medium. Such tests are relatively cheap.

The relatively recently developed "micro-array" technique is suitable for screening and identifying many GM plants in a single test. The test is performed on a small glass plate on which a specific piece of DNA from each GM plant that is to be analysed is fixed. In the analysis, DNA from the inserted genes in the GM plants that may be present in the tested sample is fixed to the corresponding DNA on the glass plate. The analysed DNA is labelled beforehand so that it can subsequently be visually detected on the glass plate.

In this way, it will be possible to test for the presence of all GM plants that are approved in the EU at the same time. Depending on getting access to specific DNA sequences from the GM plants that, *e.g.,* is approved in the USA but not in the EU, it will be possible to include these in the tests as well.

Currently, micro-arrays (also called "biochips") are marketed for such tests by a few companies. In addition, there is an EU project with a view to developing these methods for testing the GMO content in foods (www.gmochips.org).

It is not yet possible to carry out reliable quantitative analyses using micro-arrays. At present the method can be used for the initial detection and identification of GM plants, after which the quantity should be determined by quantitative PCR.

Test for the presence of GM material in conventional seeds
After the adventitious presence of GM oilseed rape seeds was found in conventional oilseed rape varieties in several EU countries in 2002 (including Denmark), the EU Standing Committee on Seeds and Propagating Material agreed on an action plan for the testing of conventional seed lots. Initially, the inspection was of imported seed lots from countries outside the EU. The species were soybean, maize, oilseed rape, beet, potato, cotton, tomato and chicory, which are allowed for marketing in the countries that currently grow GM crops.

Import of seed for sale from countries outside the EU must be reported to the Plant Directorate. In addition, the Plant Directorate each month receives information about such imports from the Danish Customs and Tax Authorities. If the import was from countries in which GM crops of the species in question are produced, a decision is then made with the

Danish Forest and Nature Agency whether a GM test of the seed lot in question should be carried out.

Until now, it was only necessary to test a single lot of maize that had been imported from Canada. The sample turned out to be GMO free.

Testing for the presence of GM material in organic feed

The Danish Plant Directorate tests samples of organic feed and seed for their GM content. Concerning feed, samples for inspection are taken from companies producing organic feed. The samples are analysed for their GM soybean and maize content. In 2002, GM soybean material was found in 25 % of the tested feed samples.

The results of the tests for GM content in organic feed samples in 2001 and for the period of January-July 2002 appear in Table 7.3.

Table 7.3. Results of the tests for GM content in organic feed samples in Denmark, 2001 - 2002.

Sampling period	Number of samples	Samples free of GMO	Samples below 0.1 % or with traces*	Samples containing 0.1 - 1 % GMO in ingredient	Samples containing more than 1 % GMO in ingredient
Jan-May 2001	48	58 %	27 %	0 %	15 %
June-Dec 2001	88	36 %	15 %	3 %	46 %
Jan-April 2002	59	75 %	2 %	17 %	7 %
May-July 2002	73	75 %	3 %	21 %	1 %

* Category used when GMO is found in dust, *i.e.* in an ingredient that was not declared and must not be found in the mixture.

Furthermore, a few samples of organic maize, oilseed rape and beet seeds were tested at seed selling companies. No GM material was found in those samples.

The results from the period January to July 2002 showed a markedly smaller presence of GM material in the samples taken from organic feed compared with 2001. In 75 % of the cases, the feed samples were free of GM material. In the cases where GM material was detected, the majority of the samples were in the interval of 0.1-1 %. In 2001, only 44 % of the samples had no detectable GM material.

8. Dispersal routes

8.1 Dispersal routes for GM crops

There is no difference in the manner of dispersal between a conventionally bred variety and a genetically modified variety as regards the vast majority of characteristics. Dispersal routes will depend on the plant species in question. The dispersal routes of GM genes are described below, but it is important to stress that the dispersal does not deviate from the manners in which conventionally bred plants exchange genes.

The main dispersal organs in the vast majority of wild and cultivated species are pollen and seeds. Some plant species also have vegetative propagation and dispersal by shoots, stolons, rhizomes or tubers. In Figure 8.1, routes of both biological dispersal and mechanical dispersal in seed, feed, straw and organic manure and via agricultural and other machinery are shown.

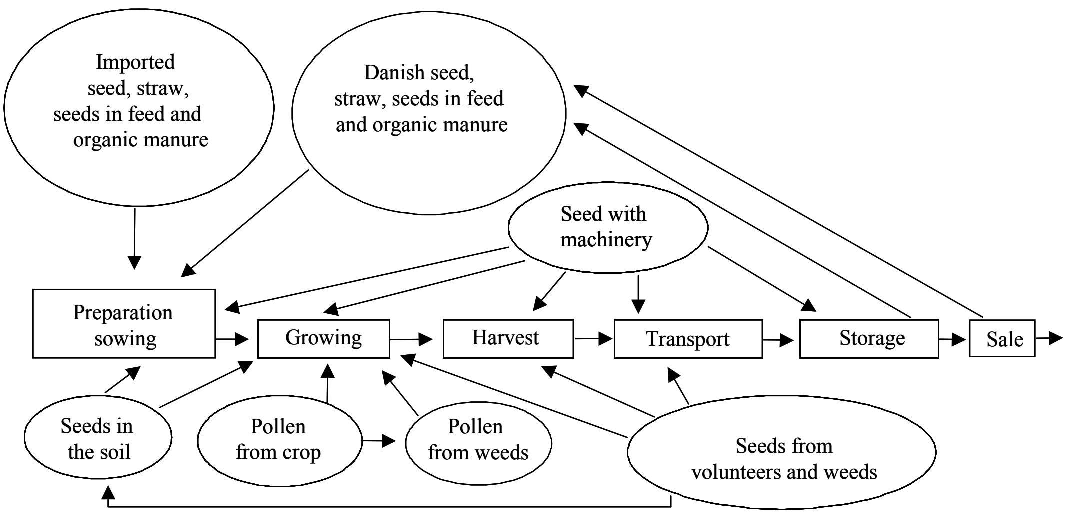

Figure 8.1. Dispersal routes for possible admixture of GM crops at different stages in crop production. Man-made dispersal routes are at the top; biological dispersal routes are below.

Adventitious dispersal of GM genes over time and the establishment of plants with GM characteristics in the field may occur via:

- Pollen dispersal and hybridisation, between plants of the same species in other fields and locations (including wild/feral populations).

- Hybridisation with wild or weedy related species.

- Seed dispersal through time (*e.g.* carry over into subsequent crops) and space to other locations through transport and handling, in seed, feed, manure, straw etc.

Seed carry over results in volunteers that will directly contaminate subsequent crops and also pollinate them to contaminate seed.

8.2 Cross pollination

The extent of pollen dispersal from GM crops depends on physical pollination conditions and the biological interaction between the donor and recipient non-GM crop.

The following conditions influence the level of GM introduction in the seed from cross-pollination. (Kjellsson *et al.*, 1997):

- The pollination system of the plants, specifically the degree of cross-pollination compared with self-pollination. The plant species can be grouped according to pollination system as either cross-pollinators or self-pollinators. However, there are only a few species that are solely cross-pollinated or self-pollinated. Species with a high degree of self-pollination have a reduced probability of GM characteristic being crossed into the plant.

- The pollination vectors of the plant, whether pollen dispersal occurs by wind, by insects or both (Proctor *et al.*, 1996).

- Species dispersed by wind usually have a large pollen production. The dispersal may occur over large distances, but whether the pollen lands on a stigma and pollinates depends on pollen density and terminal velocity. Maize and most grasses are dispersed by wind while cereals are dispersed by wind or are self-pollinating.

- Within a given distance from the pollen source, there will normally be considerable more gene dispersal as a result of pollen dispersal by insects compared to pollen dispersal by wind. This is due to the fact that the pollinating insects transmit the pollen to flowers that are ready for pollination whereas it is a more random event where the pollen dispersed by wind will land. Honey bees usually collect the major part of their food less than 1 km from their hive but may – if necessary – forage further away, at least 3 km from the beehive (Waddington, 1983).

- The most important pollinating insects in Denmark are (in decreasing importance): honey bees, bumblebees, solitary bees and to a lesser extent flies. The presence of bumblebees is among other things dependent on the presence of suitable breeding habitats near the field (undisturbed partly covered land, *e.g.* permanent pasture).

- The distance from the source of GM dispersal and the sizes of the source and of the receptor field are of great importance to the extent of outcrossing. In many species pollinated by wind, such as maize and beet, pollen dispersal will decrease exponentially with the distance (Eastham & Sweet, 2002). However, factors such as wind speed and turbulence are also of great importance, so the dispersal pattern can become irregular (Giddings *et al*., 1997 a and b). The current separation distances in seed production of different crops are based on practical experience of crossing.

Special factors regarding the location and the size of the fields also have an effect on the probability of GM dispersal. The effect of GM outcrossing will thus for many crops be relatively smaller for a large field area of the receptor crop than for a small field area due to dilution of pollen in the receiver crop. This is because large fields will generate large sources of their own pollen, which will compete with the influx of alien pollen. This effect is particularly demonstrated by the decline in outcrossing as one moves towards the centre of the field. Conversely large GM fields (dispersal sources) located near small conventional or organic farms (receptor areas) will usually result in higher levels of outcrossing across the field and greater levels of adventitious presence.

For crops that are pollinated by honeybees or bumblebees, the amount of GM pollen carried by pollinators from outside and deposited on flowers will decrease for each subsequent flower visited (Cresswell *et al*., 2002; Harder *et al*., 2001). Consequently, the degree of hybridisation with the outside GM crop is expected to decrease from the border to the centre of the field and the level of self pollination from within the crop itself will increase.

Hybridisation with wild relatives

GM characteristics can be dispersed via crosses (hybridisation) to related wild and weed species or fields and then subsequently to other crops. The probability of hybridisation depends on the compatibility of the two species and their proximity. The probability is highest with compatible species and hybrids in the field itself (such as between GM oilseed rape and wild turnip growing as a weed in the crop) or through gene transfer to plants in adjoining areas (*e.g*. between clover and grasses in fields and field margin populations). However, many crops have no wild relatives in Denmark and therefore cannot form interspecific hybrids. Several cultivated plants can, however, “spread” to field boundaries, verges and natural areas and these feral populations can function as local sources of hybridisation and possible seed dispersal.

Generally, the frequency of hybridisation depends on:

- Overlap in the distribution and the physical distance between the GM plants, volunteers of the same species and related species, including weeds.

- Overlap in the flowering time of the GM plants, volunteers of the same species and related species, including weeds.

- The reproduction system. Generally, hybrids are formed more easily for species with cross-compatibility than for species with high self-compatibility.

- Environmental factors at different localities that have an influence on plant density and flowering and consequently on the risk of gene transfer.

Furthermore, in GM crops the development of bolters in beets and flowering plants in vegetables such as carrot can result in hybridisation between GM and non-GM crops or wild relatives flowering synchronously and – depending on the conditions- perhaps be dispersed in the outcross seeds.

8.3 Seed dispersal and vegetative dispersal

For most cultivated crops, seed ripening and dehiscence has been adapted by plant breeding to suit harvesting methods and so that seeds ripen homogeneously to maximise yield and minimise losses. A certain degree of seed loss in the field both before and during harvest is, however, inevitable. At harvesting, small seeds are more likely to be lost as these could be blown out of the harvester or escape through sieves and thus may also be dispersed on the field with straw and other plant residues.

In most cultivated plant species the seeds will be dispersed close to the plants. Species with very light seeds have, however, a strong possibility of seed dispersal by wind to arrive outside the cultivated area. A few species, including carrot, some grasses and barley, may be dispersed by seeds attaching to passing animals or humans. Birds or possibly mammals may disperse seeds such as oilseed rape and cereals outside the field and across large distances.

In some cultivated plant species, the dispersal may also take place vegetatively via stolons (shoots) (*e.g.* white clover, fescue and meadow grass) or tubers (*e.g.* potatoes). Vegetative parts of plants may constitute a particular risk of dispersal after harvesting, handling and soil treatment.

Volunteers
Seeds from conventional as well as GM crops, may survive for several years in the soil (Table 8.1), depending on the current crop, in the so-called seed bank.

Table 8.1. Seed survival in the soil of some important crop plants*.

Type of seed bank, survival interval in number of years	Plant species
Temporary survival, normally < 1 year	Oats (*Avena sativa*), wheat (*Triticum aestivum*), maize (*Zea mays*), rye (*Secale cereale*), onion (*Allium cepa*)
Short-term seed bank, 1- 4 years	Barley (*Hordeum vulgare*), perennial rye grass (*Lolium perenne*)
Short- long-term seed bank, 1- >10 years	Italian rye grass (*Lolium multiflorum*), lucerne (*Medicago sativa*), parsnip (*Pastinaca sativa*), carrot (*Daucus carota*)
Long-term seed bank, 5 - > 20 years	Oilseed rape (*Brassica napus*), sugar beet, fodder beet (*Beta vulgaris*), hop medic (*Medicago lupulina*), red clover (*Trifolium pratense*), white clover (*T. repens*), celeriac (*Apium graveolens*), potato (true seed) (*Solanum tuberosum*)

* Information on the capacity of surviving temporarily or forming a short-term or long-term seed bank is based on information in Thompson *et al.* (1997) and for potato in Lawson (1983). The stated survival intervals represent averages assuming natural deposition in undisturbed soil. The seed survival will be longer if the seeds are ploughed in deeply and shorter under intensive soil management.

Generally, small seeds can survive longer in the soil than large seeds, but there is much difference from plant species to plant species, and the variety also has an influence. In addition, the following factors are of great importance to the appearance of unwanted plants in the field:

- The number of new recruits added to the seed bank. Usually, there will a high mortality of seeds that may have shed or been wasted before and during harvest. The number of new recruits is thus reduced, mostly by letting them remain on the soil surface as long as possible. Many seeds will germinate during the autumn, and will not survive winter temperatures or will be eaten by birds and other animals or be destroyed as a result of fungal attacks.

- Soil treatment and crop rotation. Deep ploughing will bury seeds, inducing dormancy so that they will normally survive longer. A breaking dormancy and germination from the seed bank occurs when the seed is brought to the surface again by cultivation.

- The climatic conditions in the current year and the soil conditions such as soil temperature and moisture in the field have an influence on dormancy and survival.

Studies of Danish arable soils showed that the seed bank does not contain large quantities of seed from cultivated crops apart from oilseed rape and barley (Jensen & Kjellsson, 1995).

Multiplication in the crop rotation
Cultivated plants may occur as weeds in subsequent crops through germination from the soil seed bank. Grass and clover volunteers for example can establish in a cereal crop (*e.g.* winter wheat) in which they may develop viable seeds. If those volunteers ripen before the crop, the seeds will be shed and may enter the soil seed bank after cultivation. Winter oilseed rape volunteers that germinate in a cereal crop in the autumn (for example winter wheat) and spring oilseed rape volunteers that germinate in a spring-sown crop (for example spring barley) can develop flowers and set seeds. These will shed to the ground at or before harvest and can enter the seed bank and replenish it. However, there are effective herbicides for the control of oilseed rape in cereal crops that are regularly used. Consequently, volunteer oilseed rape is not a common weed in established conventional cereal crops.

In most cases volunteer plants can be controlled (either chemically or mechanically), but there are crop combinations and situations in which such control cannot be completely effective. Volunteers of the same species as the current crop are very difficult to control (except with herbicide tolerant systems). If the variety grown previously was a GM crop, volunteers from that crop will be a source of GM admixture and dispersal in the current crop.

8.4 Dispersal by farming machinery and during handling and transport

Seeds from GM plants may be dispersed by machinery. It is estimated, however, that soil treating equipment can be cleaned so that seed transfer from one field to another is avoided whereas sufficient cleaning of harvest machinery and balers is very difficult.

Seed dispersal may occur during transport from the field to the drying plant/store on the farm and from farm to the processing plant. During transport using an open truck, the seed dispersal can be extensive. Furthermore, seeds can also be dispersed by handling and transport of straw.

Dispersal of GM seeds during storage and drying can be avoided by a thorough cleaning of the storage and drying facilities between two different lots if they belong to different categories, for example conventional lots and GM lots.

The possibilities for the cleaning of different drying plants would be of interest to assess as well as the possibilities of the production planning (see also chapter 11.4). There will be equivalent problems when GM crops are used for feed. During processing, the dispersal of GM material can be reduced by carefully cleaning the processing equipment between different lots of feed materials. However, it may be impossible to clean the plant completely. The experience of the Plant Directory based on GM analyses of organic products show that normally it is difficult to ensure complete freedom of GM material if the same plant is used for both GM- and non-GM crops. In Denmark there were several cases of finding GM material in soybean, in feed mixes meant for organic production. Despite the fact that the purchased soybean was supposed to be GM free, GM material was found in about 50 % of the 136 samples analysed in 2001 and 25 % of the 132 samples taken in 2002. By 2002, several of the firms had established separate production plants for GM, non-GM and organic feeds.

Certain GM products, such as soybean and maize, are likely to cause GMO admixture of the organic and conventional feed during storage and processing at a feed plant which is used for both GM and non-GM products.

8.5 Seed and other products with GM material

The admixture of GM material occurring in products such as seed, feed and manure means that GM material would be introduced in both organic and conventional crop rotations under the current production conditions. Admixtures may occur as adventitious and unidentified presence at or below the permitted threshold value. Since it will not be possible to avoid the admixture of GM material testing needs to be conducted at critical points in the production system.

Seed

Since a GM content below a given threshold value is permitted in seed lots, GM crops will appear in both conventional and organic crops rotations through the use of certified, conventional seed. Some "GMO-free " organic seed will be produced but the supply of organic seed in some crops is insufficient to cover the demand for varieties worth growing in Denmark. This may have serious consequences for organic farming, especially in species where seeds may persist and spread on organic farms. The extent of dispersal of GM crops through seed depend on:

- GM content.
- Dormancy and viability characteristics of the species/variety.
- Growing conditions during seed production.
- Soil conditions, temperature, moistures *etc.*
- Safeguards in connection with certification of the seed.
- Seed handling and distribution systems.

From the year 2004, all seed for use in organic farming must be produced organically. Due to the lack of a sufficient supply of organic seed for all crops, this regulation is temporarily suspended, and until the end of 2003 the use of conventionally produced, untreated seed is permitted.

For spring wheat, oats, field peas, lupin, maize, red and white clover, lucerne and certain grass species, the available seed in the spring of 2001 was less than the demand (Boelt & Bertelsen, 2002). For important vegetable species such as carrot and onion, there was no supply of organic seed from varieties considered worth growing in Denmark. However, seed of 5 varieties of leek was sufficiently available.

In 2000, the presence of seeds of GM oilseed rape was detected in conventional seed from several varieties of oilseed rape in several European countries (including Denmark). This contamination probably came from imported seed lots from Canada. In the light of that, the EU introduced an action plan for the inspection of seed lots from countries outside the EU, including seed of soybean, maize, oilseed rape, beet, cotton and tomato.

Seed production of certain crops is concentrated in only a few localities. For example, seed production of beets take place in an area from South-East France to Northern Italy, and for certain grass and clover species, such as smooth-stalked meadow grass *(Poa pratensis)* and white clover, about 80 % of the EU seed production takes place in Eastern Denmark. Any introduction of GM crops into these areas could have serious consequences for seed production.

Feed

Monogastric animals, such as pigs and chickens, are mostly fed on feed mixes that consist of grain and one or more protein products. Grain has a low content of essential amino acids, which reduces food utilisation in the animals. Soybean is an often-used protein crop, whose amino acid composition supplements grain well in the feeding of monogastric animals.

Concurrently with an increase in the distribution of GM soybean, the admixture of GM crops in feed is expected to increase. The share of soybean in the various feed mixes for pigs vary between 2 and 20 %.

Oilseed rape and maize can also be used in the feeding of pigs and chickens. The use of these crops as well the distribution of their GM varieties is expected to increase in the future. However, most feed components are used in a processed form, ground, pressed or otherwise processed, which increases the food utilisation of animals and also destroys the germination capacity of the seed. Thus GM dispersal is also prevented.

Conventional feed materials can be used to a limited extent in organic production and this will be permitted until 2005. However, in future, a precondition is likely to be that such conventional vegetable products are free of GM material. Otherwise, the only solution would be to introduce a requirement of 100 % organic feeding of organically kept animals. However, many producers, such as a large part of milk producers currently already use 100 % organic feed.

Animal manure
When whole seeds are used as feed, they can to a limited extent survive the passage through the alimentary canal of the animal and persist in animal manure. This form of dispersal is, however, expected to be very limited.

GM seed can be dispersed in hay and straw, partly from crib waste and partly with the use of deep litter. Hay and Straw are commercial products and through exchange between farmers may also be a potential source of dispersal.

Dispersal to other products
When GM varieties, especially oilseed rape or clover are grown, it is probable that honey from producers in the area would contain pollen or nectar from GM crops.

9. Measures for managing crop purity

Measures for reducing the dispersal of GM genes are described below, but it is important to stress that these measures form the basis of current seed certification regulations.

Experience shows that the growing of a normal, reproductive crop in an area can result in dispersal to related crops in the area. The extent of the dispersal may, be determined by different management measures.

A number of different measures can be taken to limit pollen and seed dispersal (Table 9.1). Seed testing is important to monitor adventitious presence – especially when seed is multiplied in areas with an extensive GM production of the given crop. Other monitoring of possible sources of GM admixture, in both cultivated and uncultivated areas, is also a valuable tool for determining the measures necessary to restrict adventitious gene dispersal.

Table 9.1. Management measures for reducing the dispersal and introduction of GM pollen and seeds and their general effectiveness.

Management measure	Pollen dispersal	Seed dispersal
Seed testing	-	XXX
Isolation	XXX	-
Field size	XXX	-
Buffer zones	XX	-
Cropping interval	X	XXX
Crop choice in the crop rotation	XX	XX
Control of volunteers	XX	XXX
Beehives in the field	X	-
Cleaning of sowing equipment	-	XXX
Cleaning of combine harvester *etc.*	-	XXX
Cleaning of transport material	-	XXX
Cleaning of store room	-	XXX

XXX= highly effective; XX=medium effectiveness; X =low effectiveness.

9.1 Reduction of pollen dispersal

The following measures will reduce the dispersal of GM pollen to organic and conventional non-GM fields.

Isolation and field size
The separation distance between fields with GM crops and non-GM crops belonging to the same species or to species with which the GM crop can cross-pollinate is the most important factor for reducing the rate of GM pollen transfer to other fields. Separation distances are already used in the production of certified seed.

The required distance will depend on:

- The dispersal and reproduction characteristics of the individual plant species (*e.g.* pollen size, pollen vector, out-crossing ability *etc.*).
- The threshold value for GM content in non-GM crops.
- Growing, topographical and climatic conditions.
- Size of pollen source and receptor crop.

Recommendations on isolation distances can be based on existing experience on the production of certified seed, and use similar guidelines for calculations of scenarios and modelling.

In recent years numerous studies, mostly on oilseed rape and maize, have been published concerning out-crossing between GM plants and non-GM plants at different distances. In these studies, the inserted gene was used as a genetic marker. Results from these investigations can, combined with the existing seed regulations for separation distances, be used to establish regulations on isolation distances between GM fields and non-GM fields of the same crop.

Investigations of cross-pollination via GM pollen have so far mostly dealt with measurements of cross-pollination frequencies in non-GM crops measured at varying distances into the GM field while the total crosspollination percentage of the field only rarely has been studied. Depending on the size of the non-GM field, and the width of the field facing the GM pollen source, it should be possible to calculate isolation distances required to reduce the field-scale cross-pollination percentage below the threshold value.

Buffer zones
Buffer zones may be used for the protection of organic and conventional non-GM crops against GM pollination. The buffer zone may consist of the same species or other flowering plants (crops with insect pollination). In seed production practice, the buffer zone must consist of plants of the seed crop, which do not contribute to the harvested sample or of another species.

In the case of partly self-pollinating crops, the buffer zone will also reduce the pollination by GM pollen dispersed by wind. The width of the buffer zone will be determined after considering the crop's ability to outcross. The buffer zone width will also depend on the distance to and size of the source of GM pollen. Hence the width of the buffer zone will be determined by studies of pollen dispersal, supplemented with results from models and calculations of possible scenarios. However, for some crops there is little practical experience to inform this process.

Biological confinement in the form of a marginal zone consisting of a non-GM variety around a GM crop is used as standard procedure in many experimental plantings with GM crops (*e.g.* oilseed rape) to reduce pollen dispersal from crops.

Physical buffer zones in the form of hedgerows or belts of high vegetation around the field have also been used for reducing the amount of pollen dispersed by wind. However, in practice, this has not been an effective way of preventing pollen dispersal by wind.

Procedures for bee pollination

The location of honeybee colonies in relation to fields of GM and organic/conventional crops which are insect pollinated will have an effect on the dispersal patterns of GM pollen.

Pollen dispersal by bees

Pollinating insects will forage over considerable areas, encompassing several fields, depending on available sources of pollen and nectar. It is therefore important that the number of honeybee colonies deployed is consistent with the size of the food sources and does not encourage ranging over adjacent farms growing GM crops. However, climatic factors, such as low temperature, may cause a temporary shortage of nectar. In such cases the bees will search over a larger area for food, and may thereby acquire and transfer GM pollen. Bees carry pollen from many flowers, but usually the cross-pollinating potential is largest from the flower last visited.

In order to restrict pollen dispersal between fields by bees a marginal belt of other attractive bee plants can be sown around the GM crop. This will provide extra food sources so that pollen carry-over from the GM crop is reduced. The procedure has been much used in field release trials with GM crops, but the effect of this method is not well documented.

GM free areas

If the growing of GM crops is avoided in one or more selected regions of the country, the probability of dispersal of GM pollen in these regions will be drastically reduced. The probability of GM admixture in seed will, however, still exist and require relevant preventive measures.

9.2 Cultivation techniques to reduce pollen and seed dispersal

Roguing
In crops, such as beet and carrots, where the vegetative part of the plant is harvested, but where flowering plants may also occur, GM dispersal via pollen and seed can be prevented by removal (roguing) of these reproductive plants. In grass fields, the flowering and seeding heads that grazing animals do not eat should be cut to reduce pollen and seed dispersal.

Weed and volunteer control
GM volunteers should be controlled to limit both seed and pollen dispersal in the crop rotations. For example, in subsequent crops of the rotation herbicide tolerant volunteers should be controlled by using alternative approved and effective herbicides. Weeds and volunteers can also be controlled mechanically. The more effective the volunteer control methods, the less admixture will occur in subsequent crops. Careful planning of crop rotations can be used to control numbers of volunteers in the subsequent crops.

Row cropping can be used to easily identify volunteers from previous crops. These volunteers can be removed by weed control (chemically or mechanical) in both conventional and organic crop rotations. This technique will not detect volunteers in crop rows but can be used to reduce them to a considerable extent.

9.3 Reduction of seed dispersal

Separation at harvest
Where GM and a similar non-GM crop are found near to each other the removal and destruction of the buffer zone (of te non-GM field) at harvest will reduce the adventitious presence of GM material in the harvested sample. Similarly, the effect of cross-pollination from the GM crop and any hybridised volunteers can also be reduced.

Choice of crop and crop rotation to restrict volunteers in the soil
The crop rotations on Danish farms are generally very complex, which provides an opportunity to develop crop rotations that will reduce the propagation of GM crop volunteers and hybrids. It is important to combine a sequence of crops that allow efficient control of GM volunteers in the years immediately after the cultivation of the GM crop.

Soil treatment
Cultivation techniques are very important for the survival of volunteers (Jensen, 2002). Seed viability will be highest if seeds are incorporated into the soil immediately after harvest and buried. The lowest viability occurs when the seeds are left on the soil surface after harvest because a large proportion of potential volunteers will germinate during the autumn. These can be controlled chemically, by ploughing or mechanical weed control. Growing winter

barley and winter wheat immediately after GM oilseed rape may mean early soil cultivations and thus the incorporation of GM volunteer seed into the soil where they may retain their germination capacity for a relatively long time. The current interest in no or reduced soil tillage could restrict the number of seeds that are added to the soil seed bank.

Cropping intervals of several years between a GM crop, and a non-GM crop of the same species will reduce or minimise GM volunteers occurring in the subsequent related crop and deplete the soil seed bank.

Organic conversion
The conversion period for land from conventional to organic production is 24 months. However, volunteers from a large number of cultivated plants can persist for more than 2 years in the soil seed bank. It will be very important if GM crops are grown in land likely to be converted to organic. To be able to check whether GM crops were grown before conversion, it will be a precondition that all areas on which GM crops are grown are registered, including field number (geographic coordinates), crop species and crop variety/hybrid.

Monitoring of GM volunteers and GM hybrids on areas being converted to organic production will assist in the reduction of the GM presence. Additionally, an extension of the conversion period could be required on areas in which GM crops or conventional crops that may be GM contaminated were grown prior to conversion.

Use of machinery
Seeds can be dispersed by agricultural machinery between fields and between farms. Dispersal can be avoided if the machinery is cleaned thoroughly before they are moved from one field to another. By taking the necessary care it is possible to clean soil treatment equipment so that the transfer of seeds and plant residue is avoided. This is an element of good farming practice. It is far more problematic and time consuming to clean combine harvesters and balers. It would be useful to have guidelines on managing machinery shared by farmers and the use of machine pools at harvest in order to restrict the transfer of seeds.

9.4 Use of seed, feed and manure containing GM

Seed
Conventionally produced oilseed rape, maize, lucerne and vegetable seed is regarded as a potential source of GM material in both conventional and organic farming.

For GM oilseed rape and GM maize, quite significant production of genetically modified plant material has been established outside the EU. It must therefore be envisaged that the probability of adventitious GM presence in seed will increase.

The production of oilseed rape and other Brassica seed in areas with GM production of these crops presents a greater likelihood of adventitious GM presence, mostly due to the strong attraction of these crops to pollinators, and thus a greater chance of cross-pollination and the long survival time of seed in the soil.

If conventional seed is used in organic farming, it will be necessary – through testing – to ensure “GMO free” seed lots.

There is a great need to ensure access to seed with a low or no GM content. The access to organic “GM free” seed is a precondition of maintaining GM free organic farming. After 2004 it is assumed, that all seed for use in organic farming must be organically produced. It is very important that organic seed-growing opportunities are maintained in Denmark. However, it must be stressed, that for certain crop species the Danish demand for both conventional and organic seed might be too small to maintain production.

Manure

Considerable amount of non-organic manure is imported onto organic farms, and similarly, animal manure is transferred between conventional farms, especially from pig farms to crop farms. The non-organic manure products may be in the form of farmyard manure, but the use of town waste compost is expected to increase in the future. GM seeds can be present in animal manure from farms where feed or litter contains GM material. Control measures against GM dispersal from these farms will have to be established. During appropriate storage, the temperature can become so high that seeds from any (GM) plant lose their germinating capacity. Similarly, dispersal of GM seeds in town waste compost can be avoided if the waste goes through a process during which high temperature destroys their germinating capacity.

Feed

The majority of Danish pig farms use imported protein feed. In organic farming up to 20 % non-organic feed, which mainly consists of soybean, oilseed rape and maize, may be used until 2005. Today most of the non-organic constituents have no GM varieties and this ensures “GM free” feed.

In order to prevent the introduction of GM crops into farms in purchased feed, processing methods would be introduced that destroy the germinating capacity of the seed. This treatment could be either grinding or heat treatment.

Developing production of alternative organic or conventional ("GM free") protein crops and optimising feed mixes in which they are included could be a useful strategy to avoid the import of GM protein products.

Transport and use of straw from GM crops (such as cereals and grass seed) can also contribute to the dispersal of GM-seeds, along the transport network, as well as from farm to farm.

9.5 Monitoring

Suspected GM dispersal routes such as GM seed shedding in fields and their surroundings, including field edges, roads and permanent grasslands should be monitored. The results may indicate the scale of dispersal of GM crop products and hybridisation with weeds and the need to take specific measures against these routes of dispersal. Simple, broad-spectrum methods for testing GM crops and weeds in the field (immunological methods) can be used, when there are little need for more costly and precise methods such as PCR analysis (see chapter 7.2). The results of monitoring can serve as an early warning of possible problems so that relevant precautions can be initiated quickly (Kjellsson *et al.*, 2002).

The monitoring of GM volunteers may be conducted by farmers, whereas the more advanced monitoring tasks, such as long-term effects and genetic analyses, requires a specialist research effort.

During the phased introduction of GM varieties, it will be important to monitor the GM content in seeds in order to follow the temporal development of GM content. The results of such monitoring can be used for evaluating the results of current initiatives and management measures.

9.6 Training for production of GM crops

It is apparent that there are a large number of possible measures for managing GM dispersal. Many of these measures assume particular care in the organisation and planning of crop production.

In connection with the debate on the subject the Agricultural Council of Denmark published the following “code for GMO production”:

1. Only genetically modified crops are sown for which there is an approved use.

2. Names of varieties and their GM status should be stated in the growing record of all crops, when genetically modified crops are grown on a farm.

3. If a farmer wishes to be able to supply non-genetically modified crops, there must be a clear physical separation between the non-genetically modified crops and neighbouring crops, not just in the field but also during storage and shipping.

4. When selling crops produced using genetically modified seed, the seller must inform the buyer of this.

5. When a farmer considers growing genetically modified crops, he must contact neighbours, *e.g.* ecologists or farmers with particular special crops, to discuss and take into account possible problems of pollen dispersal, well in advance.

6. Machinery and equipment that are used in genetically modified crops and that can accidentally transport seeds, must be cleaned before they are used in other areas.

7. Volunteers after genetically modified crops must be controlled in the subsequent crops.

8. Genetically modified crops are to be treated in the way that is most careful with regard to the fauna.

   (The Agricultural Council of Denmark, 2000).

A further initiative to manage the dispersal of GM materials would be the introduction of a requirement for training prior to permitting GM production by a farmer. A similar measure exists regarding the use of pesticides (spraying certificate).

Farmers, also need information on the growing of both GM and non-GM crops on their property. This means that different management procedures and different regulations are required for the different types of farms, again depending on the crop in question and on the crop rotation in which the crop is grown. GM and non-GM growing of the same crop on the same farm would significantly increase the likelihood of contamination. It will be unrealistic to have GM, conventional or organic growing of the same crop on one property without a great probability of admixture.

10. Review of crops

10.1 Background for the sections on crops

In relation to this evaluation, the Working Group chose to give the highest priority to the crops which are currently genetically modified or likely to be within the next few years and are significant in Denmark.

The sections are divided according to crop types or closely related crops that are expected to behave in a rather similar way and will require similar management.

For each crop type the Group gives a short description of:

- ***Background***. Reproductive biology, *etc.*

- ***Crop area*** in Denmark, including the extent of organic and conventional growing and the importance of the crop (DIAS, 2003).

- ***Growing practices***

- ***Experiences from GM growing***. Cultivation, experimental releases, and plant characteristics.

- ***Dispersal sources*** that the Group was able to identify *cf.* chapter 8.

- ***Measures for managing crop purity.*** Possible control measures that are expected to reduce and possibly eliminate the dispersal of GM material and with that adventitious GM presence (*cf.* chapter 9). In advance, the Group has assumed that "good farming practice" is followed, *cf.* chapter 4.4.

- ***Adventitious presence*** and the possibility of applying with existing and assumed threshold values are evaluated both in conventional crops and in organic crops, in seed growing and in production at the primary producer until the 1st stage of distribution.

- ***Need for further knowledge***

- ***Conclusion***

When the Group suggests measures to minimise the adventitious presence of GM material in conventional or organic crops, the starting points were:

- Current Danish regulations on cultivation of certified seed.
- Foreign and Danish reports, scientific papers, model analyses and case studies.

Basic control measures (close to regulations of certified seed) and extended control measures (approximate regulation on basic or pre-basic seed) are used. In addition, more rigorous measures are used to separate crops.

In the evaluation of the extent of adventitious GM presence, the Group took its starting point in the following three scenarios for each crop:

The 0 % scenario:

- GM crops of the type in question are not grown in Denmark. However, there will also in this scenario be a possibility of adventitious presence if seed is imported from areas with GM cultivation or via pollen dispersal across the border area.

The 10 % scenario:

- A situation with a moderate distribution over the relevant cropping area, where 10 % of the crop is grown with GM varieties.

The 50 % scenario:

- A situation with an extensive growing of a GM crop, similar to the development in countries such as Canada, where the distribution of GM oilseed rape now exceeds 50 % of the oilseed rape areas.

However, within the given time frame, the Group was not able to analyse at depth the importance of the extent of the distribution for each crop. Therefore, a division into the 10 % and 50 % scenarios is only made for a few crops. As a principal rule, the two scenarios are treated together.

In the Group's evaluations for conventional production, the starting point was the suggested threshold values for adventitious GM presence in conventional seed of 0.3-0.7 %, depending on species, *cf.* chapter 6.4. The possibility of co-existence for conventional production is evaluated based on the established threshold value on labelling of GM material in foods and feed of 0.9 %.

For organic production, it is assumed that "GM free seed" is used. Further, it is assumed that adventitious presence must be kept below the current limit of detection (~0.1 %), as there has been no decision on a specific threshold value for organic farming.

10.2 Oilseed rape

Background

In Denmark, two types of oilseed rape *(Brassica napus)* are grown: winter oilseed rape (autumn-sown oilseed rape) and spring oilseed rape (spring-sown oilseed rape). The crop is mainly used for foods and feed and to a small extent for energy purposes.

Oilseed rape plants are both self- and cross-pollinated. The pollen dispersal takes place via wind or insects.

Some oilseed rape plants are pollen sterile, and can therefore only be cross-pollinated. This is used in the breeding of hybrid varieties. Hybrid seed is produced by growing a mixture of pollen sterile and pollen fertile plants in the proportion of 80:20. For the production (multiplication) of other seed types (self-fertile varieties), only pollen fertile plants are grown.

The area of hybrid seed production is less than 5 % of the total Danish oilseed rape seed production area.

In production crops of hybrid varieties a certain proportion of the plants may be pollen sterile due to incomplete restoration of the pollen production. This proportion is expected to be so low that the hybrid production crop will resemble that of a self-fertile variety with respect to pollen production and cross-pollination. This will be assumed in the evaluation.

Crop area, Denmark, harvest 2002

Conventionally grown winter oilseed rape (production):	75.000 ha
Conventionally grown spring oilseed rape (production):	6.000 ha
Conventionally grown oilseed rape (seed):	600 ha [1)]
Conventionally grown oilseed rape in total:	81.600 ha
Organically grown winter oilseed rape (production):	800 ha
Organically grown spring oilseed rape (production):	80 ha
Organically grown oilseed rape (seed):	10 ha
Organically grown oilseed rape in total:	890 ha
Oil seed rape in total:	83.000 ha

1) This approximate figure is made up of 478 ha winter oilseed rape and 84 ha spring oilseed rape. Seed production of hybrid varieties of winter oilseed rape and spring oilseed rape is about 5 % (less than 30 ha) and 0 % respectively of the respective areas.

Formerly, some oilseed rape crops were also grown which were a mixture of pollen sterile (80%) and pollen fertile (20%) varieties (varietal associations). Varietal associations are not grown in Denmark at present and are not included in the evaluation.

In 2002 oilseed rape occupied approximately 3 % of the total cultivated area in Denmark. The crop was grown in most of Denmark. The highest concentration was found in the eastern part of Jutland with up to 9 % of the area, on Funen and North Zealand. Only in two urban municipalities in North Zealand with a very small acreage a concentration of up to 19 % was found (Figure 10.1). In 2002, winter oilseed rape fields had an average size of 5.7 ha (maximum 55 ha). Spring oilseed rape fields had an average size of 3.7 ha (maximum 30 ha).

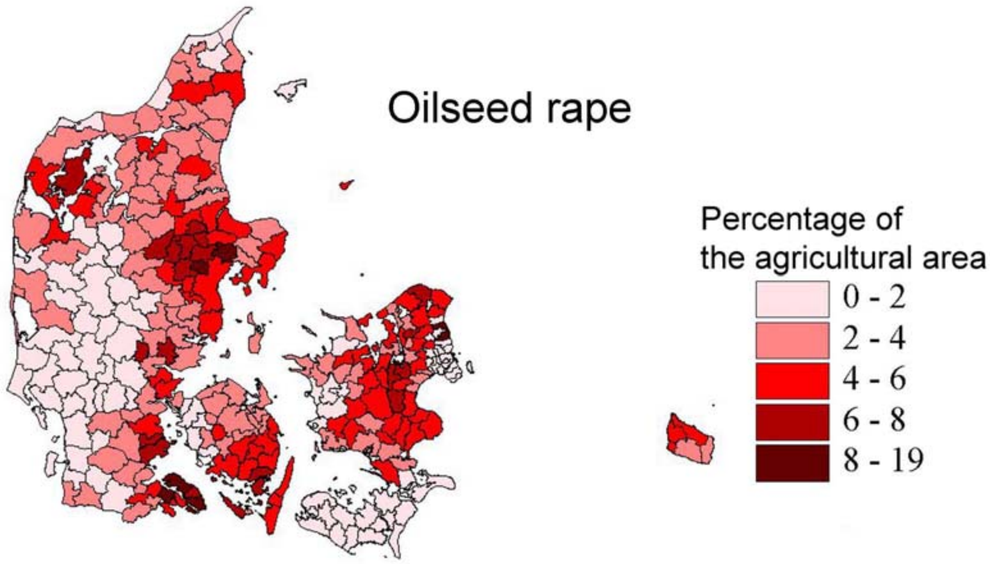

Figure 10.1. The distribution of oilseed rape in Denmark, 2002 (Dalgaard & Kristensen, 2003).

The total oilseed rape area is expected to increase considerably in the years to come. Applications were made for financial support for 103,000 ha of winter oilseed rape and for 4,300 ha of spring oilseed rape for harvesting in 2003. Due to disease problems and crop rotation constraints, the total oilseed rape area is expected, however, not to exceed approx. 250,000 ha, about 10 % of the cultivated area. The share of spring oilseed rape is decreasing, and this trend will presumably continue because the economic margin is considerably smaller for spring oilseed rape than for winter oilseed rape.

Organic fields make up about 1 % of the total oilseed rape area. The area is expected to increase further if problems with cabbage stem flea beetles and other pests can be solved. It is estimated that about 700 ha of organic winter oilseed rape were sown in the autumn of 2002, about 90 % of this in Jutland. The organic oilseed rape producers also mainly grow winter oilseed rape because of problems with cruciferous weed species, especially charlock (*Sinapis* *arvensis*), in spring oilseed rape. Furthermore, volunteer spring oilseed rape plants may cause problems being weeds in subsequent crops. In organic farming, the economic margin of winter oilseed rape is also larger.

Growing practice

Generally, winter oilseed rape forms part of a commercial crop rotation of minimum 4 years in arable and mixed (especially pig) farms. The most common type of crop rotation is assumed to be winter oilseed rape-winter wheat-spring barley-pea-winter wheat-winter barley. Spring oilseed rape is often grown where winter oilseed rape died due to winter damage.

Organic crop rotations with winter oilseed rape will typically be at least 5 years and include grass for seed production, where the grass is undersown in spring barley.

Conventional seed is primarily produced in Denmark, but importation can be up to 50 % of the market in certain years. The extent of farm-saved seed is not known, but presumably it is less than 10 % of the cropped area. Organic and conventional farms use farm-saved seed almost equally.

The set of regulations for seed production (certification) is stated in Table 6.1. It should be noted that there are different regulations for separation distances and cropping intervals according to whether varieties are self-fertile or hybrid varieties. There are more rigorous regulations for cropping intervals for varieties with different erucic acid and/or glucosinolates content.

Relatives of oilseed rape

Oilseed rape has several wild relatives in Danish cultivated areas with which it can cross (Chevre *et al*., 2003; Mikkelsen & Jørgensen, 1997). Oilseed rape crosses easily with wild turnip (*Brassica rapa* ssp. *campestris*) and brown mustard *(B. juncea*) and in rare cases with wild radish (*Raphanus raphanistrum*) and charlock.

Oilseed rape also has a number of related crops with which it can cross spontaneously.These include swede (*Brassica napus* var. *napobrassica*), turnip (*Brassica rapa* sp. *rapifera*), stubble turnip (*Brassica rapa* ssp. *oleifera*) and brown mustard. The area grown with those crops is much less than 0.1 % of the total Danish crop rotational area.

Presence of oilseed rape and wild turnip as weeds

The presence of wild turnip and oilseed rape in unsprayed areas of conventionally grown Danish fields was studied in the period from 1987 to 1989 (Andreasen, 1990). Similar studies of the weed flora were performed again, and interim results from 2001 and 2002 are shown in Table 10.1 (Andreasen & Streibig, 2002). This project will continue for another two years, so the results are only preliminary. The variation between the fields can be very large, and a large incidence in a single field can therefore have a large influence on the average. The table shows that wild turnip rarely occurs in the studied fields, and where it is present, it is at a low frequency. The frequency of wild turnip has, however, not been calculated for oilseed rape fields. In other studies, wild turnip has been observed to be more frequent in such fields (Hansen *et al.*, 2001). It is also apparent that oilseed rape is a very common weed in arable fields.

Table 10.1. Wild turnip and oilseed rape frequency in areas of crop rotational fields receiving no herbicide, and the proportion of studied fields in which those species occur.

Crop (number of fields studied 2001-02)	Wild turnip *Brassica rapa*		Oilseed rape *Brassica napus*	
	Frequency[1)] (%)	Incidence (% of fields)	Frequency[1)] (%)	Incidence (% of fields)
Spring barley (31)	0.0	0.0	7.6	61.3
Sugar beet (32)	0.0	0.0	1.1	25.0
Fodder sugar beet (28)	0.0	0.0	2.3	28.6
Maize (23)	3.0	4.3	5.2	34.8
Pea (27)	0.5	5.0	12.5	65.0
Spring oilseed rape (30)	-[2]	-[2]	100	100
Winter oilseed rape (15)	-[2]	-[2]	100	100
Winter wheat (18)	0.0	5.5	0.3	22.2
Winter barley (10)	0.0	0.0	7.5	70.0
Winter rye (10)	0.0	0.0	0.0	10.0
2nd year grass clover (31)	0.0	0.0	0.0	6.5

1) The frequency indicates the probability of finding the species in a sample area of 0.1 m^2

2) At the stage observed, it was not possible to distinguish between oilseed rape and wild turnip; therefore the value is unknown.

Experience with GM oilseed rape

At present, GM oilseed rape is not grown commercially in the EU, but lines with a system providing male sterility/restoration of fertility (the basis of hybrid varieties) with herbicide tolerance have been approved for seed production. Further, one GM variety has been approved for import for processing purposes. In addition, a small number of applications for approval of varieties with pollen sterility and/or herbicide tolerance are under consideration (see Annex 1 Tables 1 and 2).

There have been 364 experimental releases of oilseed rape in 10 EU countries, 4 of these trials were situated in Denmark.

In 1999, seed lots of the variety Hyola 401 with adventitious presence of GM seeds were grown in several places in the EU. The supplier subsequently reported that the seed might have up to 1 % GM content (Danish Plant Directorate, 2000).

As mentioned in chapter 4, there are large areas of GM oilseed rape in the USA and Canada. In Canada, GM oilseed rape constitutes more than 50 % of the total oilseed rape area. It is mostly herbicide tolerant GM oilseed rape, but GM oilseed rape with an increased content of the fatty acid lauric acid is also grown in these countries.

Dispersal sources

Pollen dispersal, including hybridisation

Oilseed rape plants are both self- and cross-pollinated via wind and insects by pollen from other plants. The proportion of the flowers that self-pollinate depends on the variety, climate and other conditions for pollen dispersal. Often more than half of the flowers will be self-pollinated. For example, for the variety Topas, the share of seeds resulting from self-pollination varied from 53 to 88 % under different growing conditions in Scandinavia (Becker *et al*., 1992). In crops with a certain percentage of pollen sterile plants, it is often observed that there is a higher frequency of cross-pollination from other fields than in fully self-fertile crops (Simpson *et al*., 1999).

In section 8.2 many factors are discussed that are of importance to pollen dispersal in oilseed rape. For pollen dispersal to result in characteristics being transmitted to seeds (gene flow/gene dispersal) cross-fertilisation of seed embryos has to occur and the subsequent seeds have to be viable. A prerequisite for cross-pollination between varieties is that they flower at the same time. In Denmark the flowering period does not differ much from variety to variety. For winter oilseed rape germinating in the autumn, the flowering period is approx. 1 May to 5 June, whereas it is approx. 10 June to 25 June in spring oilseed rape. Thus crossing between spring and winter oilseed rape is rare. It can occur if the winter oilseed rape is severely damaged by winter weather or pest attack, retarding crop growth and therefore flowering later than normal.

Cross-pollination with foreign pollen mainly occurs between oilseed rape crops but can also occur with pollen from oilseed rape volunteers in fields, along roads, at the edges of ditches, at building sites, *etc*. as well as with weeds that are related to oilseed rape (especially feral oilseed rape and the species wild turnip) growing in similar places. However, permanent (self-maintained) populations of feral oilseed rape are rare in Denmark The frequency of crossing between oilseed rape and related species will depend on environmental factors and on the characteristics of both the oilseed rape variety and the wild species (Pertl *et al*., 2002; Hauser *et al*., 1998, 2003). Growing of GM oilseed rape may transmit GM characteristics to those plant species, so that they in turn can be a source of GM characters for related non-GM crops, weeds and wild species.

In organic fields where weed control is rarely as effective as the chemical weed control in conventional fields, there are a number of problems with related weeds. This is due to the fact that seeds of the weedy species can survive in the soil for many years due to seed dormancy and cause gene dispersal if oilseed rape is grown in the same field later. A study of a large wild turnip population in an organic field showed that 44 % of the wild turnip had oilseed rape genes as a result of crossing with oilseed rape (Hansen *et al*., 2003). A UK study of naturally occurring wild turnip in GM oilseed rape also showed a high incidence of hybridisation between these species. (Norris *et al*., 2003).

Oilseed rape flowers are very attractive to pollinating insects as they offer large amounts of nectar and pollen. The importance of insect pollination vs. wind pollination is not known. It is assumed insect pollination occurs more often in spring oilseed rape due to its flowering period.

The distance that insects can disperse pollen depends on the forage radius of the insects. Most solitary bees seek their food within a radius of a few hundred meters. In Denmark, bumblebees usually fly within a radius of 2 km from their nest, whereas honeybees may seek their feed within at least 5 km from the beehive.

The extent of pollen dispersal by insects is not known. A source of pollen dispersal across large distances is the moving of beehives between winter and spring oilseed rape fields.

A large number of experiments have been carried out to measure pollen dispersal and gene dispersal in oilseed rape. Examples of the gene flow due to pollen dispersal between oilseed rape plots or fields and oilseed rape recipient trap plants, plots or fields at different distances from the source of dispersal are shown in Table 10.2. The recipient plants were either self-fertile (pollen fertile) or pollen sterile. As appears from these examples, experiments can be designed very differently. Both within and between experiments a very high degree of variation in frequencies of cross-pollination has been observed, but the levels of gene flow are most often comparable. The large variation could have been caused by:

- Different sizes of pollen donor plots and recipient plots.
- Different sampling and testing methods.
- The nature, fertility and purity of the donor and recipient varieties.
- Gene dispersal from volunteers in the recipient field.
- Differing proportions of insect and wind pollination.
- Different environmental conditions.

Prediction of frequencies of adventitious presence based on few experiments, such as calculated by Ingram (2000), are, therefore, very uncertain.

Table 10.2. Examples of gene flow between separate plots/fields of oilseed rape as a function of the distances from the pollen source.

Description of experiment, source and recipient.	Dispersed characteristic	Recipient plant's distance from the source	Frequency of the characteristic in seeds of the recipient[1)]	Reference
30x60 m source plot surrounded by oilseed rape buffer zone of 30 m		0-30 m	0.02-0.69 %	Staniland *et al.* (2000)
Smaller plots	Transgene herbicide tolerance gene	200-400 m	0.0038-0.016 %	Scheffler *et al.* (1995)
Smaller circular GM plots in larger circular non-GM plots	GM glufosinate tolerance	1-70 m	0-1.6 %	Scheffler *et al.* (1993)
0,8 ha source and recipient plots of herbicide tolerant winter oilseed rape in a 10 ha field	Glufosinate tolerance	Approx. 26 m Approx. 50 m	• approx. 0.2 % (self-fertile) • approx. 8 % (compound variety) • approx. 0.1 % (self-fertile) • approx. 7 % (compound variety)	Simpson (unpubl.) in Eastham and Sweet (2002)
Pollen sterile trap plants in area with oilseed rape		1-4,000 m	Observation of pollinating at a distance of up to 4000 m	Thompson *et al.* (1999)
Trap plants of different types of oilseed rape in 4 wind directions from source of approx. 9 ha	GM herbicide tolerance	100 m 400 m	• 7-21 % (pollen sterile) • 0-0.12 % (self-fertile) • 0-12 % (pollen sterile) • 0-0.06 % (self-fertile)	Simpson *et al.* (1999) and Eastham & Sweet (2002)
Oilseed rape field of the size 25-100 ha (2 % of the total oilseed rape area in the region)	Herbicide tolerance gene from non-GMO herbicide-resistant oilseed rape – one variety	0-5,000 m (63 recipient fields of different varieties)	• Max. 0.197 % (approx. 1500 m) • Varies from approx. 0 to approx. 0.06 % depending on variety • Observation of gene dispersal up to 3,000 m	Rieger *et al.* (2002)

1) Where nothing else is mentioned, the plants are self-fertile. A compound variety (variety association) consist of both pollen fertile and pollen sterile plants.

Published frequencies from 11 studies of cross-pollination in self-fertile varieties in England, France, Australia, Canada, the USA, Denmark and Sweden have been collated by Damgaard and Kjellsson (2003, pers. comm.). Data on proportion of foreign pollination was used in a model to predict probabilities of adventitious GM-presence in seeds harvested from fields of different width, at different distance from a GM field and with different separately harvested buffer zones. The data were assumed to constitute a random sample of pollen dispersal events with respect to different field sizes and locations, different environments and different varieties.

The model analysis shows that an increased distance between a GM and a non-GM oilseed rape field reduces the number of GM seeds in the harvested seeds and most in small (narrow) fields (Figure 10.2). The effect of doubling the width of the field is generally larger than the effect of doubling the distance to the GM field. In the analysis the effect of not harvesting a zone of 1-5 m along the side of the non-GM field towards the GM field is also evaluated. A reduction is achieved in the GM content in the remaining crop of up to a third according to the model.

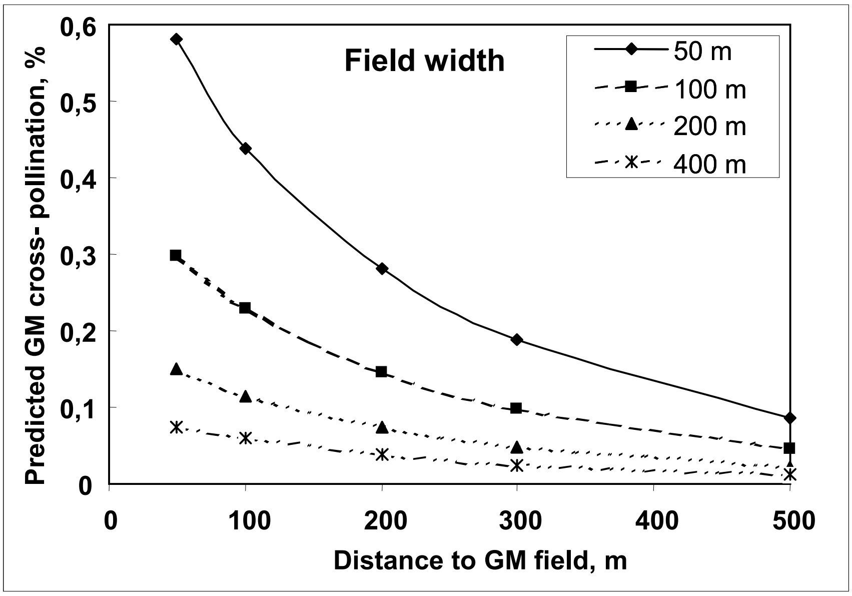

Figure 10.2. Model predictions for the percentage of GM-containing oilseed rape seeds harvested in non-GM fields of different width as a function of distance to a GM field. (The results are shown as 95 percentiles, i.e., in 5 % of fields, the average GM-content is expected to be higher than the shown value). Source: Damgaard & Kjellsson, unpublished.

The model predicts that the average GM content as a result of pollen dispersal can be kept below 0.3 % at a separation distance of 200 m in 95 % of fields.

Seed dispersal

Seed dispersal via seed bank (within field)

Seeds are an important source of adventitious dispersal. When seeds are dispersed, new pollen- and seed-producing plants can grow in new locations and in subsequent seasons, providing both spatial and temporal gene flow.

Oilseed rape sheds seeds easily especially at harvest. The proportion of seeds lost depends on the variety and local conditions. This usually amounts to 5-10 % of the produced seeds, but a loss of up to 50 % has been observed. The resulting volunteers are a contaminant themselves in subsequent oilseed rape crops and also a source of pollen for dispersal to subsequent crops and other crops.

The seed banks in many Danish cultivated areas contain oilseed rape, which can be seen from the great frequency with which oilseed rape is found in all crops (Table 10.1). Oilseed rape seeds can survive in the seed bank for many years (Table 8.1). Studies in Scotland and England (G. Squire, pers. comm.) has shown that viable oilseed rape seeds can be found in the soil for 10 to 12 years after growing both spring and winter oilseed rape. On average, the seed pool was about 100 seeds/m^2. The preliminary results in Table 10.1 indicate the same situation in Denmark.

Crop rotation and soil tillage are important aspects of land management determining the composition and size of the soil bank. In Denmark, winter wheat is often grown after winter oilseed rape, and the wheat is sometimes sown without ploughing beforehand. However, if the oilseed rape stubble, is ploughed or harrowed just after the oilseed rape has been harvested, shed seeds are incorporated into the soil and become dormant preserving their germinating capacity for a long time.

To avoid the incorporation of oilseed rape seeds into the soil, it is important that there is no soil inversion immediately after harvest. Seeds of oilseed rape have no or very little dormancy at harvest and will germinate on the soil surface after harvest under humid conditions. These germinated seedlings can be controlled by a later soil tillage and/or herbicide treatment.

Winter oilseed rape volunteers are usually not a problem in spring-sown crops as the volunteers rarely flower or produce seeds. An exception can be winter oilseed rape plants in spring oilseed rape fields when winter-damaged winter oilseed rape fields are re-sown with spring oilseed rape in the spring. Spring oilseed rape volunteers can be a serious problem in other spring-sown crops.

The long persistence of seeds in the soil can locally contribute to hybrids between oilseed rape and related species, which in turn can persist for long periods and act as a gene reservoir for oilseed rape characteristics.

Weed control of oilseed rape volunteers through herbicides and mechanical methods is very effective.

Seed dispersal between fields
Natural dispersal of oilseed rape seeds, by wind or animals, has been only briefly studied (Colbach *et al.*, 2001b). However, it is expected to be small compared to pollen dispersal.

Combine harvesters, windrowers and balers are a very important means by which seeds can be dispersed from field to field. To avoid that dispersal, it is important to clean the machines. As oilseed rape seeds are small (1 kg of oilseed rape corresponds to approx. 200,000 seeds), it may be difficult to carry out a complete cleaning of combine harvesters.

Seed dispersal after harvest in connection with transport and storage
As oilseed rape seeds are small and round, they are easily lost during transport between fields and storage facilities. The extent of this dispersal has not been studied closely, but it is assumed that it can be considerable. At storage, seed lots with and without GM content can be mixed by mistake, insufficient cleaning, *etc.*

Seed dispersal with seed lots
The content of GM seeds in seed lots is very important for the introduction of GM material into crops and fields and for determining the GM content in the harvested crop. Where farm-saved seed is used, hybrid seeds from volunteers and weeds, *e.g.* between oilseed rape and wild turnip, can be an extra source of GM content in the harvested seed crop.

Even without growing GM oilseed rape in the EU, GM material can be dispersed via admixtures in seed introduced from other countries, such as seen with the Hyola 401 variety.

Measures for managing crop purity
Measures are required so that:

- It is possible to grow non-GM oilseed rape in fields where GM oilseed rape has been previously grown.
  - It is estimated that <u>volunteers</u> are the greatest problem.
  - Appropriate measures are: adjusting the soil management and herbicide programmes to make volunteer control more effective and extending or adjusting the crop rotation (regulations on cropping intervals).

- It is possible in the same year to grow non-GM oilseed rape and GM oilseed rape in the same area.
  - It is estimated that <u>pollen dispersal</u> is the greatest problem for obtaining this – especially for non-GM fields containing seed production crops of hybrid varieties.
  - Appropriate measures are: increased separation distances (isolation distance), separately harvesting the field border in the non-GM field and increased field size of non-GM crop (squared fields).

- It is possible that non-GM fields can remain below GM thresholds in an area with GM fields for the foreseeable future.
  - It is estimated that <u>pollen dispersal,</u> <u>seed dispersal</u> and <u>handling</u> can be problems for obtaining this.

- Appropriate measures are: those mentioned above plus removal of all oilseed rape volunteers and related weeds every year in all fields in the area on both GM and non-GM farms, including non-cultivated areas and ensuring that machinery is completely cleaned and that transport takes place in seed-tight containers.

Further, the degree of adventitious presence will be reduced if certified seed with a low GM-content is used.

In order to keep the adventitious presence in the harvested seeds below the threshold values, a combination of these control measures is required. The actual requirements on the extent of the control measures depend on the threshold values to be achieved and an evaluation of the particular management issues on each farm. Available knowledge and experience of gene flow under different conditions is evaluated below.

Adventitious presence
Due to the many factors that have an influence on the GM content in certified seed and in the oilseed rape crop (see the section on dispersal and chapter 8), estimated frequencies of adventitious presence are subject to a very high degree of uncertainty. Experimental knowledge most often derives from pollen dispersal experiments, studies of the seed bank and a few studies of certified seed. The extent of dispersal via handling is unknown and will often relate to the level of management and the availability of appropriate equipment.

Experience from seed certification
The most extensive knowledge of Danish varietal purity is found in the many years' experience of certification of seed, which put high requirements on the permitted presence of other varieties in the certified seed. Varietal purity is in oilseed rape tested on morphological characteristics of the growing crop. Regulation for different isolation distances and cropping intervals have been given to obtain the different requirements (see Table 6.1):

- For seed of self-fertile varieties:
  - Adventitious presence of <0.1 % based on morphological characteristics. This can be achieved with an isolation distance of 200 m and a cropping interval of 6 years.
  - Adventitious presence of <0.3 % based on morphological characteristics. This can be achieved with an isolation distance of 100 m and a cropping interval of 6 years.

- For seed of hybrid varieties:
  - Adventitious presence of <10 %. This can be achieved with an isolation distance of 300 m and a cropping interval of 6 years.

As regards seed production of varieties with different content of erucic acid or glucosinolates, the requirement on cropping interval to obtain the specific proportion of adventitious presence is 8 years, because of more precise detection methods for adventitious presence based on these quality traits. However, for a number of years only varieties with a low content of both erucic acid and glucosinolates (so-called double-low varieties) have been grown commercially in Denmark so this regulation has not been applied recently.

Varietal purity is assessed by morphological characteristics and not by genetic analyses. The heterogeneity in seed lots based on DNA variation is not known but is assumed to be larger (see chapter 6). Purity of non-GM seed and crops are defined at the genetic level. Therefore, to obtain adventitious presence below the thresholds, the requirement on the cropping interval should be at least 8 years.

The cropping distances mentioned above are in accordance with the EU directives on seed for the certification of conventional seed. However, it is possible to establish more rigorous national regulations. The separation distances in the UK for self-fertile varieties to achieve an adventitious presence of <0.3 % and 0.1% are 200 and 400 m, respectively.

As regards separation distances in connection with co-existence with GM herbicide-tolerant crops, the UK preliminary requirements, based on SCIMAC (Supply Chain Initiative on Modified Agricultural Crops) guidelines, are separation distances of 200 m for conventional seed production and organic oilseed rape products, as well as 50 m for conventional (non-varietal association) crops.

In a Canadian report on certified seed, the effectiveness of the separation distance of 100 m was evaluated for providing the threshold value for purity (<0.25 %) for certified seed of self-fertile varieties (Downey & Beckie, 2002). Fifty-four samples from certified seed lots of 14 herbicide-sensitive varieties were assessed for the presence of two herbicide tolerance genes. In several cases a contamination above the permitted of 0.25 % and up to 1.02 % was found. It was stated that the contamination was due to either too high adventitious presence in the basic seed used or adventitious admixture in connection with handling during seed production. It was concluded that under Canadian growing conditions the separation distance was satisfactory but that pre-basic and basic seed in the future should be tested for the specific genes to ensure the purity of certified seed. An implication of this would be that the separation distance for pre-basic and basic seed may be too low.

Foreign evaluations of co-existence

In different international reports several evaluations have been performed of the adventitious presence of GM seeds in various production systems (see Table 10.3).

Table 10.3. Estimates of adventitious presence of GM seeds (%) until the first stage of distribution for different scenarios and based on different reports.

<table>
<tr><th rowspan="3">Process</th><th rowspan="2">Estimate[1] from SCP</th><th colspan="2">Simulation[2] (year 13) from JRC</th><th colspan="2">Simulation[2] (average of 2nd rotation year 4-6) from JRC</th></tr>
<tr><th>10 % GM oilseed rape in the region</th><th>50 % GM oilseed rape in the region</th><th>10 % GM oilseed rape in the region</th><th>50 % GM oilseed rape in the region</th></tr>
<tr><th>Production of self-fertile variety</th><th colspan="2">Seed production of hybrid variety.
Basic seed with no GM content
300 m isolation
6 years' crop rotation
10-12 % oilseed rape in region
6 ha fields</th><th colspan="2">Production of self-fertile variety and farm-saved seed.
No isolation
3 (conv.) or 6 (org.) years' crop rotation
20 % oilseed rape in region
10-12 ha fields</th></tr>
<tr><td>Adventitious presence in seed</td><td>0.3</td><td colspan="2">0</td><td colspan="2">Varies according to harvest lot, included in the calculations</td></tr>
<tr><td>Adventitious presence in volunteers/seed bank in field</td><td>0.2</td><td rowspan="2">From <0.01 to 0.57
except[3]</td><td rowspan="2">From <0.01 to 0.71
except[4]</td><td rowspan="2">From 0.0004 to 0.21</td><td rowspan="2">From 0.006 to 1.34
except[5]</td></tr>
<tr><td>Cross-pollination from other field etc.</td><td>0.2</td></tr>
<tr><td>Soil inversion</td><td>0</td><td colspan="2" rowspan="6">Estimate:
0.01 (organic)
0.02 (conventional)</td><td colspan="2" rowspan="6">Estimate:
0.09 (organic)
0.5 (conventional, use of shared machinery)</td></tr>
<tr><td>Sowing</td><td>0</td></tr>
<tr><td>Harvest</td><td>0.01</td></tr>
<tr><td>Transport (field to farm)</td><td>0.05</td></tr>
<tr><td>Storage/drying</td><td>0.05</td></tr>
<tr><td>Transport (from farm)</td><td>0</td></tr>
<tr><td>In total (sum)</td><td>0.81</td><td>From <0.01 to 0.59 except[3]</td><td>From <0.01 to 0.73 except[4]</td><td>From 0.09 to 0.71</td><td>From <0.09 to 1.84 except[5]</td></tr>
</table>

[1] Based on SCP/GMO-SEED-CONT 13 March 2001. These calculations assume good farming practice, including reasonable attempts at isolating the crop and at separating products.
[2] Based on JRC/IPTS report (Bock *et al*., 2002). Approx. 20 different scenarios for both conventional and organic cropping systems are simulated. The trait is herbicide tolerance determined by a dominant gene. The GM variety is homozygous. The model seems to underestimate the adventitious presence compared to French observations.
[3] **except** in a scenario with attempted control of volunteers by the selective herbicide (then 4.4 %-5.4 %).
[4] **except** in a scenario with attempted control of volunteers by the selective herbicide (then 4.9 %- 6.0 %).
[5] **except** in a scenario with attempted control of volunteers by the selective herbicide (then up to 2.5 %).

In the SCP report (Scientific Committee on Plants, 2001) the values are given for production crops of self-fertile varieties using certified seed (0.3% GM-content) estimated based on expert assessments. From this report, it can be concluded that it is possible to achieve crop production below a 1 % threshold of non-GM purity using certified seed, good farming practice, a suitable isolation distance, and the segregation of crops.

In the JRC/IPTS report (Bock *et al*., 2002), the biological dispersal of pollen and seeds within the field is simulated by means of a computer model "GENESYS" from INRA (Colbach *et al*., 2001a and b) The calculations of dispersal by handling after harvest rely on expert opinion by a panel of experts from the UK, France and Germany. The calculations are built on a large number of assumptions, which are based on the conditions at five different types of farms in France and Germany. Dispersal of GM herbicide tolerance genes is simulated. This trait is of special importance to the control of weeds and to the composition of the seed bank. Simulations for organic as well as conventional farms are made for seed production of hybrid varieties using certified seed with no GM-content as well as for crop production of self-fertile varieties using farm-saved seed. It is pointed out in the report that the results cannot immediately be transferred to other conditions than the ones assumed. It is stressed that the simulations evaluate different growing practices in relation to each other, and that one cannot use the absolute values of adventitious presence directly. French field observations have shown a higher adventitious presence than predicted from the model calculations.

With this in mind, Table 10.3 shows the variation in the estimated frequencies of adventitious presence under different control measures considering:

- Field size
- Isolation distance
- Control of volunteers
- Flowering period
- Length and composition of the crop rotation.

The report concludes that it may be technically possible but economically difficult to comply with a 0.3 % threshold for production of hybrid variety seed as well as a 1 % threshold for oilseed rape crops due to the complexity in the changes needed. A threshold for an organic crop of approximately 0.1% will be virtually impossible to achieve.

Modelling winter oilseed rape under Danish conditions

To evaluate the conclusions of the JRC/IPTS report under Danish conditions, the assumptions in the GENESYS model were studied, and simulations, partly adjusted to Danish growing conditions, were carried out (the programme was kindly made available by N. Colbach, INRA, to Hanne Østergård for this purpose).

GENESYS is developed in France for modelling gene flow via pollen, seed and volunteers from GM winter oilseed rape to non-GM winter oilseed rape. The model simulates a large agricultural area with several farms over several years and includes the following parameters and variables:

- The biology of winter oilseed rape: germination time, flowering time, germination capacity, pollen dispersal, seed loss.
- The genotype of the oilseed rape variety (GM herbicide tolerance). Both seed production of hybrid varieties as well as oilseed rape growing for production can be studied.
- The crop rotation in the individual fields.
- Cropping techniques in the crop rotation (soil tillage, sowing date and density, use of herbicides, harvest date).
- The regional location of the fields with natural vegetation between these (ditch edges, hedgerows).

The GENESYS model was, after a few adjustments to Danish conditions of the biological parameters of the winter oilseed rape, used to evaluate 1) the extent of dispersal from one GMO oilseed rape field to the surrounding agricultural area and 2) dispersal to a non-GM oilseed rape field surrounded by only GM oilseed rape fields. The central oilseed rape field was of different sizes. Current data on field size and location from the same area as in the case study in chapter 4 were used. Different crop rotations were used, characteristic of Danish conditions. In addition, there was varying degree of seed loss, difference in competitive ability for GM and non-GM oilseed rape and random dispersal of seeds in connection with handling.

Altogether, it is estimated – based on the present very sparse knowledge of Danish values of the biological parameters – that the conclusion of the JRC/IPTS report with regard to the relative effect of different control measures on adventitious presence of GM seeds will also apply to Danish conditions. Again, it is very unsafe to use the absolute values because of different conditions applying from farm to farm.

Evaluation of adventitious presence under Danish conditions
Seed: 0 % scenario with foreign GM growing:

- Adventitious presence is possible via imported seed for seed production (basic seed).

- It should be possible to keep the adventitious presence in conventional seed production below 0.3 % provided that the basic seed used is "GM free".

- It should be possible to keep the adventitious presence in organic seed below the detection limit provided that the basic seed used is "GM free".

Seed: 10 % and 50 % scenarios:

- It should be possible to keep the GM presence in conventional seed production of self-fertile varieties below 0.3 % through requirements on use of GM free basic seed, more rigorous separation distances and control of volunteer plants plus possibly separate harvesting of non-GM field marginal zones or the choice of squared fields (however, this does <u>not</u> apply to hybrid varieties).

- For seed production of hybrid varieties, it is not possible with present knowledge to recommend crop separation distances and cropping intervals, which can ensure a GM-content below 0.3 %. Large separation distances are recommended, but seed testing of all seed lots for adventitious presence before certification can make seed production possible.

- It is suggested that cropping intervals between seed production of GM oilseed rape and non-GM oilseed rape should, as a starting point, be at least 8 years.

- In organic seed production, it should be possible to keep the adventitious presence at about 0.1 % through more stringent regulations on “GM free” basic seed, increased distance to GM oilseed rape fields, possibly separate harvesting of the organic field margin, regulations on field size and shape, complete control of all volunteer plants in the area around the organic farm plus limitations on machinery used jointly with GM producers. To ensure that the produced seed has an adventitious presence of less than 0.1 %, it must be tested for GM-content.

- For seed production of organic hybrid varieties, it is not possible with present knowledge to recommend crop separation distances and cropping intervals, which can ensure compliance with levels of adventitious presence below the detection limit.

- It is suggested that cropping intervals between seed production of GM oilseed rape and organic oilseed rape should, as a starting point be at least 12 years.

Production: 0 % scenario with foreign GM growing:

- Adventitious presence is possible via imported seed.

- It should be possible to comply with the threshold value in conventional production.

- It should also be possible to keep the content in organic production below the detection limit provided that the seed used is "GM free".

Production: 10 % and 50 % scenarios:

- It should be possible to keep the GM content in products from conventional fields below 0.9 % through more stringent separation distances and control of volunteer plants plus possibly separate harvesting of non-GM field marginal zones or the choice of squared fields.

- It should be possible to keep adventitious presence in organic fields at about 0.1 % through more stringent regulations on "GM free" seed, increased distance to GM oilseed rape fields, possibly separate harvesting of the organic field margin, regulations on field size and shape, complete control of all volunteer plants around the GM field plus limitations on machinery used jointly with GM producers.

- It is suggested that cropping intervals between production of GM oilseed rape and conventional oilseed rape should, as a starting point, be at least 8 years, and between GM oilseed rape and organic oilseed rape at least 12 years.

Need for further knowledge

- Data on seed persistence and dispersal at field level, including an extensive description of the composition and dynamics of seed banks, for example using DNA markers.

- Data on the extent and significance of dispersal by machinery, in order to quantify this dispersal route, for example using DNA markers.

- Data and models for studying pollen dilution of GM pollen in a non-GM field as a function of distance from the source field as well as field sizes and shapes. Implications of separate harvesting of field margins for GM content in seeds of the remaining crop.

- Data on the importance of honeybees in pollen dispersal between oilseed rape fields within the foraging range of honey bees and across large distances by moving honey bee colonies, for example, between GM winter oilseed rape and non-GM spring oilseed rape.

- A continued collaboration with INRA to adjust the GENESYS model to Danish conditions. This requires the measurements of many of the biological parameters for oilseed rape under Danish conditions.

- Monitoring of dispersal from future GM fields in order to continuously review and adjust control measures.

Conclusion

- It is concluded that control measures beyond good farming practice will be required to ensure co-existence between GM oilseed rape and non-GM oilseed rape with the proposed threshold values. The control measures need to be on the “safe side”, as the available studies show large variations in requirements to achieve the threshold values and as data for specifically Danish conditions do not exist.

- An important factor in pollen dispersal between GM and non-GM oilseed rape fields is the mutual location, shape and size of the fields. Further information is needed from field experiments and models on the relationship between isolation distance, buffer zones (separate harvesting of field margins) and field size. Using this information, it may be possible to modify the separation distance requirements for large squared fields or fields with buffer zones. As discussed in chapter 9, this may be appropriate in some situations.

- Important factors in seed survival and dispersal are crop rotations and type of soil tillage. Depending on the choice, different modifications of the requirements on the cropping interval between GM oilseed rape and non-GM oilseed rape may be made.

- Seed dispersal through handling can be limited through carefully organised use of shared machinery (such as harvesting the non-GM oilseed rape before GM oilseed rape), transport in oilseed rape seed tight wagons and separation of harvested seed lots at all stages. Handling methodology is an important subject for the training of the GM producer.

- Overall, there will be a need of optimising the collaboration between farms to remove oilseed rape volunteers and weeds such as wild turnip on the GM farm and in neighbouring fields and their surroundings. Especially the latter, if there is a suspicion of pollen dispersal or seed loss.

- Continuous monitoring and model refinements are important to adjust the control measures. As an example, observations of changes in the composition of the seed bank can yield data on whether the cropping intervals are of a suitable length. An evaluation should be made at 7 years to determine whether the seed bank has depleted sufficiently.

- Though spring oilseed rape is not grown to a particularly large extent in Denmark, it is important to include both winter and spring oilseed rape in continuing experiments and models. Spring oilseed rape is still found in the Danish seed bank, and as spring oilseed rape forms part of many of the foreign studies, it is important to be able to compare them with Danish results.

(See also Table 2.1).

10.3 Maize

Background
Maize (*Zea mays*) is an annual and primarily cross-pollinating by wind dispersal. The male flowers develop first. Bees can collect pollen but do not seek out female flowers as these lack nectar.

Crop area, Denmark, 2002

Conventionally grown maize:	93,000 ha
Conventionally grown maize - seed:	None
Organically grown maize:	3,300 ha
Organically grown maize - seed:	None
Maize in total:	96,000 ha

Maize is 3.6 % of the total cultivated area. Organic maize is 2.2 % of the converted area on organic farms. The concentration of maize is largest in the western part of South Jutland and in the northern part of Central Jutland with up to 25 % of the agricultural area used for maize (Figure 10.3). The distribution of the organic maize growing roughly follows the same picture. Where largest, the distribution is approx. 0.3 % of the agricultural area (Figure 10.4). The average size of maize fields is 4.6 ha.

According to the Danish Agricultural Advisory Centre the maize area is expected to increase by 10-15 % in 2003. Maize seed for the Danish market is produced especially in France and Germany.

Growing practice
Half the maize is grown in continuous cultivation and the rest in a crop rotation with cereals and grass. Practically all maize in Denmark is grown for feed, where the whole plant is harvested for silage before grain ripening. There is only a limited production of sweet corn for human consumption.

- In Denmark, maize is almost exclusively a hybrid crop where new seed is purchased every year. A hybrid crop is the offspring of crossing between two different inbred parent lines.

- It is currently not relevant to grow insect resistant maize containing the B.t. gene (see below) in Denmark, as the specific target pests are not present.

- Herbicide tolerant maize varieties might be expected to gain a certain distribution because cheaper and easier weed control can be achieved by using these varieties.

Weed control is necessary in maize fields because maize in its first growth stages is not competitive against dicotyledonous weeds.

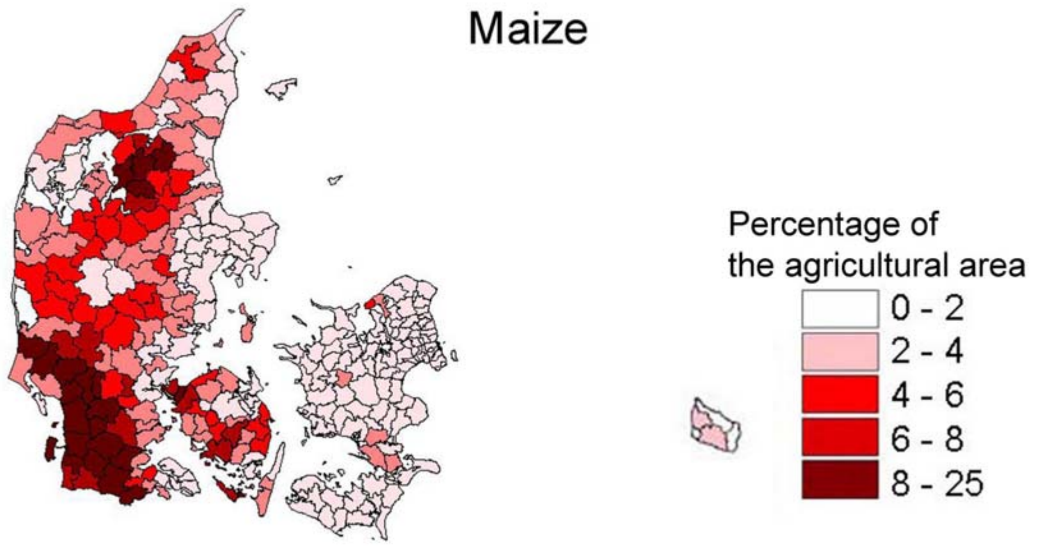

Figure 10.3. Distribution of maize areas in Denmark, 2002. (Dalgaard & Kristensen, 2003).

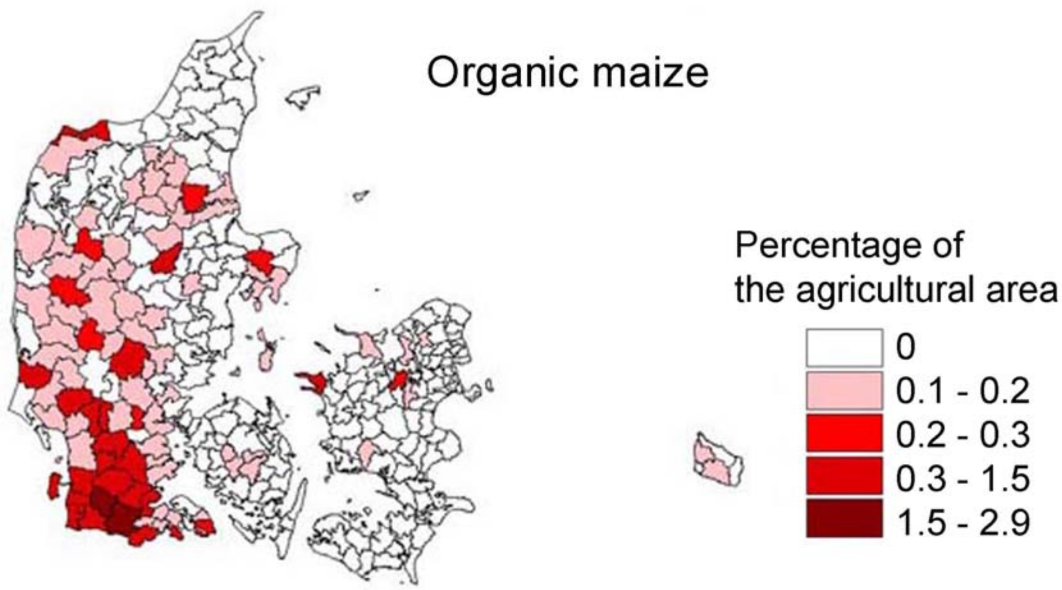

Figure 10.4. Distribution of organic maize areas in Denmark, 2002. (Dalgaard & Kristensen, 2003).

Experience with GM maize
In 2001, GM maize with insect resistance and/or herbicide tolerance was grown on 9.8 mill. ha, and of this 8 mill. ha in the USA. The rest was primarily grown in Canada, Argentina and South Africa.

Herbicide tolerance consists of tolerance to glufosinate ammonium (Basta, trade mark *Liberty Link*) and glyphosate (Roundup, trade mark *Roundup Ready*). Insect resistance is based on different genes encoding the B.t. toxin from the insect pathogenic bacterium *Bacillus thuringiensis*.

In 2002, the GM maize area in the USA grew to 10 mill. ha and was 34 % of the total maize area. Preliminary calculations indicate that the area grew to 40 % in 2003.

According to the release directive, it is permitted to grow GM maize in the EU, using the following genetically modified lines:

- ”Event 176 (insect and Basta resistant)”.
- ”T25 (Basta resistance)”.
- ”MON 810 (insect resistance)”.

Until now, the following varieties were entered in the variety catalogue in the EU:

- ”Event 176” in France and Spain.
- ”T25” in the Netherlands.
- ”MON810” in France.

The insect and Basta resistant line ”Bt11” is approved for import into the EU.

In addition, 7 GM maize applications are being considered in the EU. All are resistant to either the herbicides Basta or Roundup and/or contain B.t.-based insect resistance.

In the EU, there is commercial growing of GM maize only in Spain. This production includes insect resistant B.t. maize on 20,000-25,000 ha. This area has been constant since the introduction in 1998 and is about 4-5 % of the Spanish maize area. In regions with high insect pressure such as Catalonia the genetically modified maize is, however, 13 % of the maize area. The maize is only used for feed and is mixed with conventional maize.

There has been 482 experimental releases in 11 countries in the EU (including Denmark). In addition, there are plantings in Japan, New Zealand, Brazil, Mexico, Chile, Egypt, the Philippines, Indonesia, Bulgaria, Russia and the Ukraine.

Especially under private management, a large number of maize lines have been produced which are genetically modified for a very large number of different characteristics, such as disease resistance and improved quality characteristics. Maize is also extensively used in experiments as a bioreactor for the production of pharmaceutical products.

Dispersal sources

- Maize is a wind pollinated species and primarily cross-pollinated. The male flowers develop first. Self-pollination does, however, also occur (5 %).

- Maize is shatter proof and rarely sheds seeds. Under Danish conditions of forage harvesting there is only a small risk that maize cobs or maize grain are left in the field.

- Maize has high heat requirements and has no seed dormancy. Consequently, volunteer plants have very little opportunity to grow and reproduce under Danish conditions.

- In the Danish flora, maize has no relatives with which it can cross. The main dispersal route is therefore dispersal to neighbouring maize fields via pollen. Bees can collect pollen but do not seek out the female flowers as those do not produce nectar.

- Maize cannot establish permanent populations outside cultivated fields but may appear sporadically as individual plants.

Measures for managing crop purity

- Separation distances and cleaning of harvest machinery used on several farms.

- Separate harvesting of the outside rows of the maize field bordering a GM maize field.

- Sowing neighbouring fields with varieties with a different flowering time. However, under Danish conditions, that may mean that the late flowering varieties will have too short a growing season.

- Purchasing seed with a very low GM content.

- Agreements between neighbours on the location of fields with conventional, organic or GM maize (see section on production).

Adventitious presence

The reasons for presence of GM material in conventional or organic crops may be GM content in seed, outcrossing with GM crops, volunteers, admixture during sowing and harvesting, and further handling and processing (see chapter 8).

- As regards Danish maize growing, seed purity and outcrossing are the most relevant. By far the major part of Danish-produced maize is used as silage, harvested unripe, and therefore volunteers are not anticipated.

- There is no seed multiplication in Denmark for either conventional or organic maize production.

The evaluation of the co-existence problems between GM maize and conventional/organic maize production in Denmark is based on the following:

- The EU threshold value for adventitious presence of GM maize in conventional seed (expected to be 0.5 %).

- Regulations on multiplication of seed.

- A comprehensive literature regarding certification regulations and introduction via pollination for conventional and GM maize.

- Computer modelling of a number of GM maize scenarios, published by JRC/IPTS (2002).

Regulations on seed multiplication

Almost all maize production in the EU is based on hybrid maize. Open pollinated lines are primarily heterogeneous mixtures of local landraces. For example, only one of 200 maize varieties in the German variety catalogue is open pollinated. The requirements on multiplication of C1 seed are a degree of purity of 99.8 % and a minimum distance of 200 m to other maize (Table 10.4).

Table 10.4. Maize seed production regulations for basic seed and certified seed: isolation distances, cropping intervals and varietal purity (maximum presence of another variety).

MAIZE	Basic seeds			Certified seed (C1)		
	Separation distance	Presence	Cropping Interval	Separation distance	Presence	Cropping Interval
Inbred lines and simple hybrids	200 m	≤ 0.1 %	2 years	200 m	≤ 0.2 %	2 years
Open pollinated	200 m	≤ 0.5 %	2 years	200 m	≤ 1 %	2 years

Outcrossing in maize
There is extensive literature on outcrossing frequency between maize fields. However, many of the studies deal only with pollen dispersal and do not include evaluations of the effects of field size. Often simple genetic characters are used for measuring outcrossing frequencies, such as colour and shape of the grain, so-called "xenia".

The summary below is based on a number of surveys in which the available information was collected and evaluated to suggest appropriate separation distances between GM maize fields and conventional/organic maize fields.

Ingram (2000) concludes that – assuming field sizes of more than 2 ha – the introgression via pollination for a field would be kept below 1 % for sweetcorn at a distance of 200 m between neighbouring fields. For silage maize a distance of 130 m is estimated as sufficient, assuming that the maize grain are max. 50 % of the silage. To reduce the introgression via pollination percentage to 0.5 %, distances of 300 m for sweet corn and 200 m for silage maize, respectively, are recommended.

Feil & Schmid (2003) conclude that separation distances of 200 m and 300 m between GM maize and non-GM maize should be sufficient to keep the adventitious presence below 1 % and 0.5 %, respectively.

Treu & Emberlin (2002) conclude that outcrossing frequencies of up to 0.2 % can occur at a distance of 800 m.

The Advisory Committee on Releases to the Environment (ACRE, 2001) concluded that separation distances of 80, 130 and 290 m will ensure an upper limit of 1 %, 0.5 % and 0.1 % of adventitious presence as a result of introgression via pollination in feed maize in the so-called Farm Scale Evaluations in the U.K. These recommendations are based on the maize used being heterozygote for the inserted gene and that the maize grains constitute a maximum 50 % of the silage. However, these calculations do not take into account the possible GM maize content in the seed.

Results based on computer modelling
In the report JRC/IPTS (2002), two scenarios are evaluated in which maize grain is used as animal feed. One scenario is intensive growing of feed maize in Italy and France (50-80 % of the agricultural area is planted with maize) and the other is a non-intensive growing (20 % of the cropping area).

The evaluations (Table 10.5) were carried out assuming:

- A GM maize presence of 0.3 % in the seed on the conventional farms.

- That 10 % and 50 %, respectively, of the cropping area is used for growing GM maize.
- A distance of a few m between neighbouring fields in the intensively cultivated areas.
- A distance of 500 m for the non-intensively cultivated areas.
- That GM lines are homozygous for the herbicide resistance.

Table 10.5. Maize under different cropping scenarios by using present practice*: expected percentage admixture of GM maize.

	Farm type**	**1**	**2**	**2'**	**3**	**4**	**4'**	**5**
10 % GMO	Cross-pollination %	0.25	0.02	0.10	0.03	0.04	0.05	0.20
	Total expected presence %	1.00	0.10	0.18	0.68	0.09	0.12	0.95
50 % GMO	Cross-pollination %	1.50	0.10	0.50	0.15	0.15	0.25	1.00
	Total expected presence %	2.25	0.16	0.58	0.80	0.17	0.32	1.75

*) By present practice is meant that no measures are used to reduce the GM content.
**) Farm types:
1) Intensive conventional maize monoculture in France in fields of 3-4 hectares.
2 and 2') Organic maize growing in the same area in crop rotations in fields of the same size (2) or smaller (2').
3)Non-intensive conventional maize growing in a crop rotation.
4 and 4') Organic maize growing in the same area in crop rotations in fields of the same size (4) or smaller (4').
5) Intensive conventional maize monoculture in Italy with partial crop rotation and field sizes of 6-120 hectares. Harvest machinery is shared with other growers.

A number of general conclusions can be made based on this report. Reservations must, however, be made about these conclusions as they are computer models that are not fully confirmed via comparison with actual experiments. Reservations are also made regarding French and German cropping conditions not being completely comparable with Danish conditions.

- Cross-pollination is a major cause of GM pollen dispersal.

- In areas with intensive maize monoculture (farm types 1 and 5), the following scenario is obtained:
  - A total expected GM presence of 2.25 % and 1.75 % in conventional production at 50 % GM maize in the region.
  - A total expected adventitious presence of 1.0 % and 0.95 % at 10 % GM maize.

- In areas with intensive maize production, separation distances between maize fields are an effective way of reducing cross-pollination. At distances of 200 m, the admixture percentages for farm types 1 and 5 are reduced to 0.86 % and 0.69 % in the 50 % scenario.

- The GM presence in the organic fields (farms 2 and 2') in areas with intensive maize production are estimated to be considerably lower due to:
  - Lower GM level in the seed.
  - Distance to the neighbouring field due to an organic crop rotation.
  - A segregation system during harvest and further handling.

- In areas with non-intensive maize production (farm type 3), an adventitious GM presence of 0.8 % is calculated in the 50 % GM scenario and of 0.68 % in the 10 % GM scenario. For those areas an average distance between neighbouring fields of 500 m is assumed. Those farm types typically share harvest machinery, and the presence may be reduced by 0.5 % if a suitable segregation is established during harvest and further handling.

- The GM presence for the organic fields (farm types 4 and 4') in areas with non-intensive maize production are estimated to be considerably lower for the reasons stated for farm types 2 and 2'.

Evaluation of adventitious presence under Danish conditions

Seed:

- There is no conventional or organic seed production in Denmark.

Production: 0 % scenario with foreign production of GM seed:

- The threshold value is expected to be 0.5 % for the adventitious presence of GM maize in conventional seed in the EU.

- As maize is not multiplied in the crop rotation, no problems are expected regarding keeping the GM maize content below 0.5 %.

- A GM presence of ~0.1 % may be achieved in organic maize production provided that "GM free" seed with GM content below 0.1% is purchased.

Production: 10 % scenario:

In conventional farming, a separation distance of 200 m from GM maize is proposed for growing for silage crops. This corresponds to the regulations for the seed production of certified seed with a purity of 99.8 %. However, a necessary prerequisite is that the GM maize is heterozygous for the engineered gene, so only half of the GM maize pollen contains the inserted gene.

- It is also a part of the evaluation that the maize grains constitute maximum 50 % of the finished silage and that a thorough cleaning of the harvest machines takes place between harvesting GM maize and non-GM maize. Under these preconditions, it should be possible to keep the total GM presence in a conventional maize field, which is at a distance of 200 m from a GM maize field, at a maximum level of adventitious presence of 0.7 % (0.2 % from pollination from neighbouring fields and 0.5 % from the seed). No further measures in the form of cropping interval after GM cultivation should be necessary.

- As regards organic farming, it is estimated that the GM presence through pollination from neighbouring GM maize fields can be reduced to ~0.1 % through a separation distance of 300 m, and if GM free seed is used, the final GM presence can be maintained at ~0.1 %.

Production: 50 % scenario:
Organic and conventional farming

- The maize cropping area is increasing and is concentrated around the cattle farms in Jutland. It must therefore be expected that at a 50 % scenario, problems may arise to meet the necessary separation distances in regions with an extensive cultivation of maize. As a result of this, further control measures may become necessary in the form of purchasing seed with a lower GM content plus agreements with neighbours concerning the mutual placing of fields.

- It is emphasised that the levels of pollination in a non-GM maize field from a GM maize field will depend to a very great extent on the relative size and dimensions of the two fields and especially on the depth of the non-GM maize field in the direction away from the GM maize field.

Need for further knowledge

- Evaluation of pollen dispersal and outcrossing under Danish climatic and field conditions. Predictions of adventitious GM presence are to a very great extent based on small model experiments, experiments in other climates and computer modelling.

- Evaluation of the possibilities of managing outcrossing levels by field arrangements and field size. Those studies can be carried out relatively easily using experimental plots in commercial maize fields, adjacent to pollen sources of maize with specific phenotypic markers *e.g.* grain colour, grain shape *etc*. This information might subsequently be used in the development of computer models to predict GM presence under a number of different production conditions.

Conclusion

- Under a 0 % scenario, the only source of GM presence in conventional and organic production will be from imported seed. The threshold value for GM maize presence in conventional seed under EU management is expected to become 0.5 %. For organic production a lower level of adventitious presence, may be achieved provided import of seed with a lower GM presence.

- Under a 10 % scenario, GM genes may occur in the conventional and organic production via pollination from GM maize in neighbouring fields. As a starting point, a separation distance of 200 m from a GM maize field to a field with conventional maize production and 300 m to organic maize fields is recommended. It is estimated that this can reduce the admixture percentages from outcrossing to about 0.2 % and 0.1 %. It is emphasised that the total outcrossing percentage for a given field will depend very much on the size and shape of the field, especially the depth of the conventional/organic maize field in the direction away from the GM maize field. If sowing and harvesting machinery is used in both GM maize fields and conventional/organic fields, a suitable cleaning programme must be established for this machinery.

- Under a 50 % scenario, problems may be expected in meeting the required separation distances in regions where maize growing is widespread. These problems may to a great extent be remedied by joint planning of field placing and field shape among neighbours who want to use the different production methods.

(See also Table 2.2).

10.4 Beet

Background

Beet (*Beta vulgaris* ssp. *vulgaris*) is primarily grown for sugar and cattle feed. In addition, *B. vulgaris* is grown in horticulture in the form of beetroot and spinach beet. Sugar beet for industry is grown on contract. The largest factories are located in Lolland, Falster and Funen. Formerly, the growing areas were close to the factories, but factory closures have increased the transport distance for many growers.

Crop area, Denmark, 2002

Conventionally grown sugar beet:	55,000 ha
Conventionally grown fodder beet:	10,000 ha
Conventionally grown beet seed:	63 ha
Organically grown fodder beet:	68 ha
Organically grown sugar beet:	139 ha
Organically grown beet seeds:	None
Beet in total:	65,000 ha

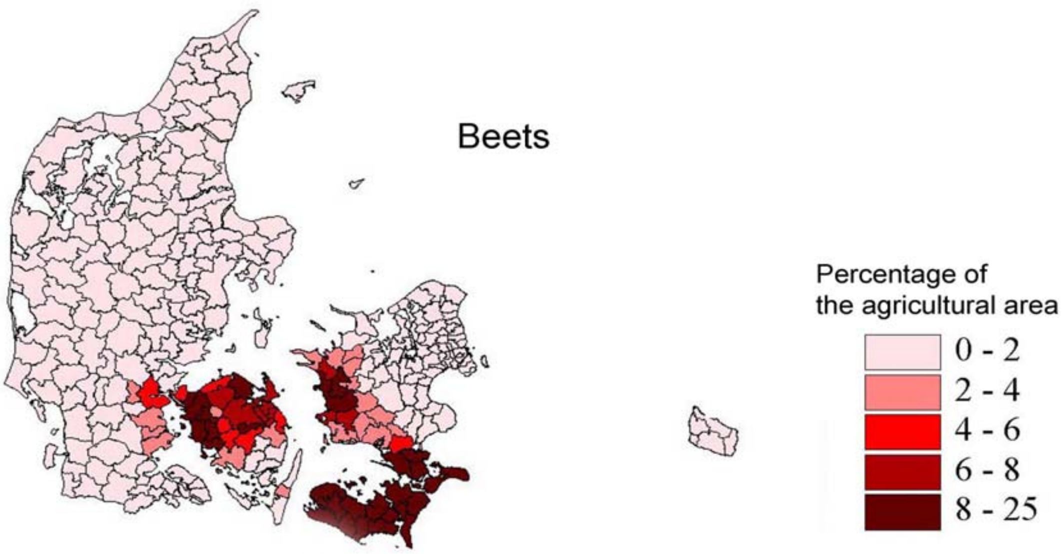

Figure 10.5. The distribution of beet in Denmark, 2002 (Dalgaard & Kristensen, 2003).

Beet cultivation constitutes 2.4 % of the total cultivated area in Denmark. Only 0.3 % of the beet crop is organically grown. Production of beet seeds takes place primarily in Southern Europe. Beet is primarily grown in Zealand, Lolland-Falster and Funen, concentrated around areas with sugar processors (Figure 10.5). Where density is largest, beet makes up 20-25 % of the agricultural area. Fodder beet is dispersed over the country and is linked to cattle farming. The average field size in 2002 was 3.0 ha for fodder beet and 6.2 ha for sugar beet.

Growing practice
The life cycle of cultivated beet is biennial – *i.e.* the plant does not flower until its second year (unless stimulated by very cold weather early in the season) In cultivation, beet is harvested after the first season's growth. (Wild and weed beet is mostly annual).

To prevent disease and pest attack, crop rotation with at least a 3-year cropping interval between two beet crops is recommended. To discourage weeds, a programme of herbicide treatment often combined with inter-row hoeing is recommended.

Annual flowering beet plants (Bolters) and weed beet are controlled from the middle of July until the beginning of August – by pulling or cutting – to prevent weedbeets from shedding seed into the field. Sugar beet is usually harvested after the end of September. They are clamped and delivered to the factories right up to Christmas, depending on the weather conditions. Fodder beets are clamped and covered by straw and used as feed during the winter. Surplus beets are usually removed from the field, as they are a reservoir of aphid-borne viruses for subsequent crops in the region.

Experience with GM beets
In the period 1990-2001, there were more than 50 approved experimental releases of GM beet, mostly sugar beet in Denmark. In the EU, a total of 246 experimental releases of sugar beet and 29 of fodder beet have been registered, mostly in France, Italy and Britain. The beets were predominantly genetically modified for glyphosate or glufosinate tolerance, a few for virus resistance (*Rhizomania*), sulphonyl-urea herbicide tolerance or other characteristics. There have been more than 130 experimental plantings in the USA and a few in Canada; mostly with glyphosate tolerance and virus resistance.

At present, no GM beets are approved for growing in the EU. The glyphosate tolerant fodder beet developed in Denmark and two glyphosate tolerant sugar beets wait for approval for marketing.

Two herbicide tolerant GM beet varieties have been approved for animal feed in the USA, but these have not been marketed yet (Agbios, 2003). It is expected that GM beets will be introduced to Denmark during the next 5 years. The seed production is expected to take place outside Denmark.

Dispersal sources
The life cycle of cultivated beet is biennial. The leaf rosette is formed during the first year and inflorescence and seeds are developed during the second year. A few individuals can, however, flower during the first year. In Germany, Britain and France, there are populations of these annual weed beets, which can become problematic dispersal sources if GM outcrossing occurs. The proportion of annual weed beets in the small populations of bolters in Denmark has not been properly studied, but weed beet probably exists in Denmark. The

characteristic of annuality is due to a dominant gene that can cross into all wild and cultivated types of *Beta vulgaris*.

Beets have bisexual, protandrous flowers, where the stigma does not open until after the last pollen from the stamen has dispersed. Beets are solely cross-pollinated. The pollen is chiefly transferred by wind, but insects also have some importance as pollinators. Pollen dispersed by wind can be transported across considerable distances, up to 5 km from the source of dispersal.

The grown cultivars of sugar beet, fodder beet and beetroot (*Beta vulgaris* ssp. *vulgaris*) can interbreed, and they can also easily cross with sea beet (*B. vulgaris* ssp. *maritima*). Sea beet in Denmark is mainly found in the Great Belt area but is spreading. In Southern Europe, there are several other species of the *Beta* family that can cross with cultivated beets.

Sugar beet seed is produced by crossing a pollinator line with a male sterile mother plant line. Different conditions regarding the pollination system (male sterility versus bisexual plants) and the chromosome configuration (diploid, tetraploid) are used for the production of diploid, triploid and tetraploid beet varieties. Wild beets are diploid and the relationship between the ploidy of the seed parent lines and the wild beet is an important factor for the extent of hybridisation and gene dispersal. This factor is not discussed in detail this report but will require further evaluation in a possible use of worst-case scenarios. Beet seeds can contain weed beet seeds, which in turn contain genes from wild beets and possibly GM beets. There is a particular risk of adventitious presence in seeds originating from areas in Southern France and North-Eastern Italy, where hybridisation between cultivated and wild beets has been demonstrated (Bartsch *et al*., 1999). In these areas, the different seed companies are relatively close together, plus there are many weed and wild beets in the area. Therefore there is a high likelihood of hybridisation between seed production crops and weed and wild beet. There are, however, prescribed separation distances between fields planted for seed production.

Weed beet (annual beet) occurs in crop production fields in Denmark as a result of seed produced from hybridisation with wild/weed beet or from bolters from previous crops shedding seed in the field. Seed may contain genes for annuality that originate from the site of seed production in Southern Europe. Several fields in Denmark are so contaminated by weed beet that the production of sugar beet has become difficult. According to Danisco, the glyphosate tolerant beet will remedy this problem in the field. In addition weed beets (crosses between cultivated beets and sea beets) have been found growing outside the fields.

Both Danish and German experiments have shown that beet plants can overwinter and flower the next year if the temperatures during the winters are not too low. This way they constitute a potential source of persistence and dispersal. The size of the pollen source, corresponding to the number and density of bolters, is of great importance to the risk of dispersal.

Many beets are lost along roads and roadsides during transport. There is a possibility that those beets "germinate" and can form bolters the next year. Such plants could produce and disperse pollen to other beet fields and possibly to sea beet. The risk is very small, however. Beet also survives in the field as root pieces which, if not controlled, will flower the following year.

The total production of pollen in the donor field (the dispersal source) is decisive for the extent of the pollen concentration in the air and its decrease with distance (Eastham & Sweet, 2002). Experiments with pollen traps have shown dispersal distances of more than 1,000 m. Records inside in a receptor field have shown that pollen from a donor field 230 m away constitutes 0.85 % of the total pollen concentration in the air above the field. There are reports of cross-pollination between fodder beet and sugar beet fields 400 m apart of 0.42 %, decreasing gradually to 0.11 % at 600 m and 0.12 % at 800 m (*cit.* in Eastham & Sweet, 2002). In seed production, the risk of dispersal is small if the receptor field itself has large pollen production and releases pollen at the same time as the donor field. Wind direction and wind speed during the flowering period also influence dispersal patterns. However, the pollen can probably only survive for up to 24 hours after release.

Seed production
Seed production of beet seeds takes place mainly in Southern Europe, and few flowering beet fields occur in Denmark. Therefore, the risk of a possible dispersal of GM pollen to organic and conventional fodder and sugar beet fields is likely to be small. However, it is likely that admixture with GM material can take place during seed production in France or Northern Italy as described above.

It is likely that annual genotypes can act as secondary dispersal sources and will establish or already exists in Denmark, as this has been shown elsewhere in Europe. Studies have shown that GM wild/weed beet hybrids are likely to survive as non GM weed beets.

Beet production
At the current requirement of varietal purity for certified seed (< 0.1 % annual beets) and at the usual plant density of 80,000-85,000 plants/ha, there can be up to 80-85 weed beet individuals ha, producing up to 1,500 seeds/plant. However, the number of weed beets/bolters is usually considerably lower. It will, however, be necessary to strictly comply with the current precautions of removing bolters and controlling annual beets. These precautions are already recommended as a precondition of beet growing, both in Denmark and abroad. A European set of rules (Code of Conduct) to protect conventional beet seed against GM admixture was passed in Europe by the international seed traders' and breeders' organisation (ISF).

When ripe, the main part of the seeds from weed beet is dispersed in the immediate vicinity of the mother plant as mono or multigerm seeds (seeds with several germs). There is a small likelihood of dispersal and shedding of GM beet seeds in organic fields during cultivation if organic beet seed contain GM weed beet. There is also a small probability of GM dispersal by transport, if agricultural equipment is shared. Seeds may not germinate directly but may survive for a long time in the soil (more than 5 years) and germinate after ploughing. In Britain, weed beet has been a serious problem for a long time, especially in sugar beet fields. Weed beet is also a problem in spring crops such as potato and peas. Under Danish conditions, volunteers can be controlled by avoiding deep ploughing in the autumn so that the beet seeds germinate and are destroyed before the next crop.

The root of beet can be cut into parts at harvesting, each one containing one or more growing-points. These pieces of beet can under favourable conditions survive in the ground, disperse and establish bolting plants in the following season.

Measures for managing crop purity

The most important control measures to reduce GM dispersal are:

- Sampling and testing seed for GM content.

- Effective control of flowering beet (*i.e.* bolters and weed beet) to avoid subsequent production of volunteers.

- Cleaning of sowing machinery if used jointly with other growers with GM beet production.

The following control measures can also be relevant but are considered less important:

- A suitable treatment of the soil in the autumn to reduce the survival of any volunteers (weed beet) in the soil.

- Isolation distances between GM and conventional production to reduce the risk of GM dispersal via pollination of bolters.

- It should be considered whether the current regulations on the purity for seed production and morphological testing methods for certified seeds are sufficient.

- The use of guard crops of other species in seed production can only reduce the extent of GM pollen dispersed by insects. It can hardly reduce part dispersed by wind, which must be considered to account for the greater part of beet pollen dispersal.

- Experiments with tall hemp plants around the fields have proved not to be very effective.

- The risk of dispersing GM characteristics can be reduced by monitoring cultivated areas, road sides and ditches for controlling bolter plants outside the field.

Adventitious presence

Seed: 0 % scenario with foreign GM growing:

- Conventional seed is mainly produced abroad.
- There is no Danish organic seed production.

Seed: 10 % and 50 % scenarios:

- In conventional seed cultivation, it is expected that the use of inspected basic seeds and a separation distance of 2,000 m and cleaning of machinery and transport equipment will make it possible to maintain a GM content <0.3 %.

- By the use of "GM free" seeds and a separation distance of 2,000 m, a crop rotation of 8 years and the cleaning of machinery and transport equipment, it is expected that a GM content of ~0.1 % can be maintained in organic seed production.

Production: 0 % scenario with foreign GM growing:

- In conventional farming, the import of certified beet seed should result in a GM content of <0.3 % of the crop with no special measures.

- Through effective inspection of the organic seed production, it is expected that a GM content ~0.1 % can be maintained without further, special measures (Table 2.3).

Production: 10 % and 50 % scenario:

- Irrespective of the cropping system, it is recommended that weed beets and bolters both in- and outside fields should be effectively controlled to avoid GM dispersal.

- In conventional beet crops, a GM content < 0.4 % is considered achievable, primarily through the use of certified seed and the cleaning of machinery and transport equipment. Increased crop separation distances (50 m) will, to a smaller extent, reduce the level of dispersal.

- In organic beet crops, it is expected that the GM admixture can be kept ~0.1 %, primarily through the use of "GM- free" seed, the control of bolters, the cleaning of field machinery and transport equipment as well as - to a smaller extent - through increased crop separation distances (100 m) and cropping intervals (5 years) after GM growing.

Need for further knowledge

- The incidence of annual weed beets in Denmark needs to be examined. Monitoring and further control will be necessary, especially if the presence of (genetically determined) annual weed beets is demonstrated. Relevant management should be established to reduce the likelihood of weed beet populations acquiring GM genes.

- The significance of pollination systems and the chromosome composition of beet varieties on outcrossing frequencies should be analysed for a range of beet varieties and types.

- Knowledge is needed of the probability of cross-pollination by GM pollen into (male-sterile) seed production fields in relation to distance from GM pollen source and the area of surrounding non-GM pollinator barrier plants.

Conclusion

- The largest risk of GM dispersal for both conventional and organically grown beet production is via seed. More inspection would therefore become necessary – especially with regard to organic seed.

- At and around the growing areas, monitoring and careful control of bolters and weedbeets will be necessary in order to minimise the risk of dispersal. This applies to both GM and non-GM farms.

- If GM use becomes widespread, increased separation distances and cropping intervals may become necessary to reduce the risk of dispersal.

(See also Table 2.3).

10.5 Potatoes

Background

The cultivated potato *(Solanum tuberosum)* is able to multiply both vegetatively and by seeds. In our part of the world, potato is almost exclusively multiplied as an annual crop by seed potatoes (cloning) and not via true seeds as in some developing countries.

Crop area, Denmark, 2002

Conventionally grown potatoes for human consumption:	12,000 ha
Conventionally grown potatoes for starch production (potato flour):	20,000 ha
Conventionally grown seed potatoes:	4,000 ha
Organically grown potatoes for human consumption:	750 ha
Organically grown potatoes for starch production:	15 ha
Organically grown seed potatoes:	130 ha
Potatoes in total:	37,000 ha

In Denmark, potatoes are grown on about 1.4 % of the agricultural area. Organic production is 2.5 % of the total potato production or 0.6 % or of the total organic area. Potato growing is very intense locally, especially in Central and Western Jutland. Denmark is generally self sufficient for seed potatoes and in recent years, there has been a surplus of organic seed potatoes.

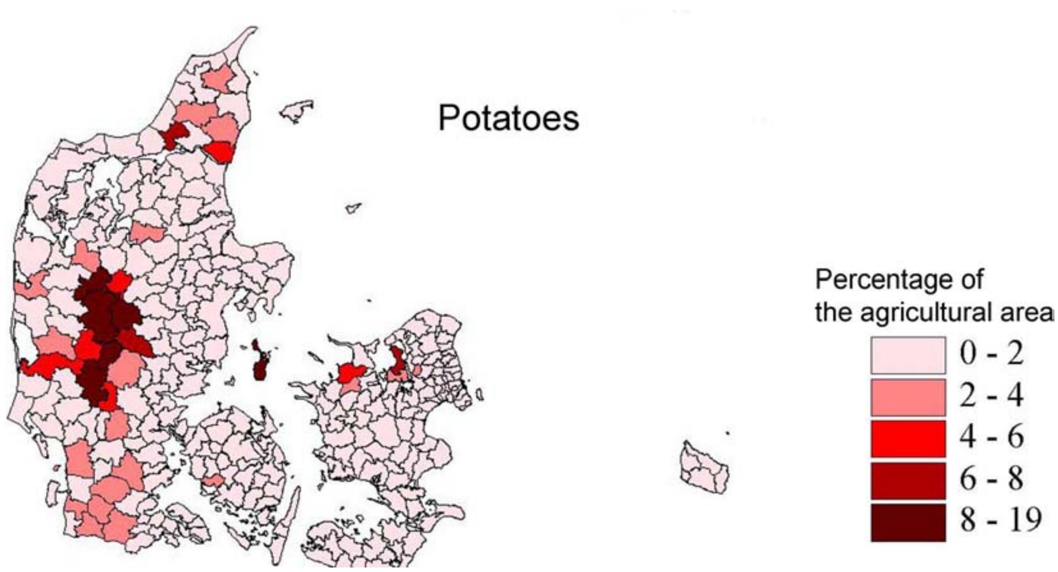

Figure 10.6. Distribution of potatoes in Denmark, 2002. (Dalgaard & Kristensen, 2003).

Growing practice

Danish potato growing is largely concentrated in Jutland where several potato processing industries are also situated. In several municipalities, the local concentration exceeds 6 %, and where the concentration is highest, it is up to 13 % of the area (Figure 10.6). The share of potatoes can be considerable at specialised farms. Early fresh market potato growing is concentrated on the island of Samsø and North Zealand. Organic potato production is relatively evenly distributed across the country.

Seed potatoes

Part of the seed potato production has moved to more heavy soils where the density of potatoes is lower. Denmark exports about half of its seed potatoes, but small quantities of seed potatoes from special varieties are imported from the Netherlands and Germany.

Regulations on growing seed potatoes ("Ministerial order on potatoes" no. 124)

Seed potato growers and grading stations must be licensed. In addition, there are comprehensive regulations on the use of machinery and cleaning. Seed potatoes of different origin or grade are required to be kept separate by growers and grading stations.

Field multiplication is divided into 10 grades within the three categories of pre-basic, basic and certified seed potatoes. For every crop year, the potatoes are declassified at least one grade, which means that they are continuously replaced. To avoid diseases and pests, a comprehensive statutory inspection and sampling for analysis is implemented.

The separation distances from 15m up to 50 m dependent on seed category to other not inspected potato fields (Table 6.1) are primarily established due to the risk of virus infection. The separation distance of up to 6 m between different varieties in the same field is established to avoid mixing different lots. In the current system, the maximum allowed foreign variety content is 0.0 % and 0.05 %, respectively, depending on grade. Purity is evaluated on morphological differences.

Production

Potato Producers themselves often multiply purchased seed potatoes, but are not allowed to multiply them for more than one year before they are used for production. Potatoes for sale and consumption may, according to the regulations, contain a maximum of 2 % foreign variety in quality grade 1 and 4 % in quality grade 2.

Experience with GM potatoes

There have been 212 experimental releases of GM potatoes in the EU, including 10 in Denmark. The GM potatoes planted in Danish experiments had either a changed starch composition or were virus resistant. In the EU, the experiments involved potatoes with resistance to diseases, pests and stress as well as changed tuber quality and growing characteristics (EU/JRC, 2002).

Limited commercial production of insect-resistant GM potatoes (containing B.t.-toxin against the Colorado potato beetle) occurs in the USA and a few Eastern European countries. In 1999, the area under GM potatoes was approx. 25,000 ha in the USA and Canada and approx. 2,000 ha in Eastern Europe. In 2000, however, growing was halved in the USA following the decision by the restaurant chain McDonald’s and several large producers of potato crisps and chips not to use GM potatoes.

As far as it is known, commercial growing of B.t. GM potatoes in the USA and Canada has stopped whereas the development of GM varieties with Roundup and virus resistance continues. There is currently an application from Sweden to the EU for the marketing approval of a GM potato with a changed starch composition.

There are no Danish applications for marketing of GM potatoes, neither is the growing of GM potatoes in Denmark, based on present GM characteristics, expected in the next few years. New characteristics such as resistance to potato late blight or special ingredients for industrial purposes can, however, change this picture.

Contractual obligations, including ISO certification for growing and transport of potatoes, are widespread, and if GM potatoes are introduced in Denmark, the seed potato companies and the industry are certain to make contractual demands to their growers which take the possibility of adventitious GM presence into account.

Dispersal sources

In potato growing, GM genes can be transferred in tubers, seeds and pollen (Højland & Poulsen, 1994). Possible sources are:

Seed (seed potatoes):

- Purchased seed is a possible source of GM presence in the production and at the farm. GM presence will manifest itself in a similar level of adventitious presence in subsequent cultivation. The Danish Plant Directorate’s inspection of seed potato growing gives an indication of the possible influence of this source. In the years 1999-2002, 0.4-1.2 % of the seed potato area was rejected because of the presence of foreign varieties in the cultivation and because of the presence of volunteers or “groundkeepers”, over wintering potatoes from previous cultivation in the fields (see below). By comparison a total of 6-11 % was rejected in the same period. Thus, contamination with foreign varieties and groundkeepers are a minor but significant part of the causes of rejection.

Machinery, equipment and storerooms:

- Machinery, equipment and storage facilities are possible sources of adventitious presence if these have previously been used for processing or storing GM potatoes. The possibility of admixture is greatest if a grower has both GM and GM free production.

In this report is assumed, however, that there is no GM as well as conventional production of the same crop in the same growing season on the same farm.

Over wintering potatoes (groundkeepers):

- Groundkeepers are potatoes left in the field at harvest, which remain and survive in the soil growing in the following and subsequent years and thus contaminating subsequent potato crops. The extent of potatoes left in the field varies and under Danish conditions, it can be 500-40,000 potato tubers/ha (Møller, 2000). Groundkeepers are unwanted because of they could be disease reservoirs and can be a significant source of admixture for several successive years. See also below concerning potatoes originating from "true seed" plants.

Pollen transfer between crops:

- There is a large varietal difference regarding flower production, flower fertility and the ability of the flowers for self and cross -pollination. Cross-pollination between plants in the field occurs at a low frequency (0-20 %) (Plaisted, 1980). Pollen is primarily transferred by wind. Bumblebees and other insect are possible dispersers, but potato flowers do not contain nectar and are therefore not particularly attractive to bees (Sandford & Hanneman, 1981).

- In experiments, limited dispersal between fields has only been shown over short distances up to 10 m from the edge of a crop (Tynan *et al*., 1990; McPartlan & Dale, 1994). However, another experiment (Skogsmyr, 1994) showed dispersal over larger distances but was dismissed by Connor & Dale (1996).

Pollen transfer to other species:

- Potato does not cross-pollinate with the weed species black nightshade (*Solanum nigrum*) and woody nightshade (*Solanum dulcamára*) (Eijlander & Stickema, 1994), and these are the only closely related wild species in the nightshade family (Solanaceae) that are found in Denmark. Neither does it cross-pollinate with other related cultivated plant species in the family such as tomato (*Lycopersicon esculentum*).

Establishment of plants and tubers from "true seeds":

- Depending on climatic and light conditions, some varieties form berries with seeds by self-pollination, whereas other varieties only rarely or never form seeds. Potato varieties with sterile flowers or without flowers, can be grown without any risk of dispersal by both pollen or seeds.

  Even though a GM crop disperses viable pollen to a nearby crop, it does not have an effect on the potato product from this crop. If seeds are formed, they fall to the ground, form part of the soil seed bank and can germinate in the following years. In the soil, potato seeds can retain their germinating capacity for at least 7 years (Lawson, 1983). If the plants mature, they will set small potatoes. These potatoes may over winter, germinate and persist for several growing seasons to be admixed the next time potatoes are grown in the same field. Seed plants and their tubers are not usually regarded as being a major problem in Danish agriculture, and potatoes do not form feral populations in Denmark.

Measures for managing crop purity

- Analyses and inspection of seed will be an important tool to prevent GM potatoes from entering a farm.

- In organic growing and for conventional growers who wish "GM free" growing, the introduction of GM potatoes can be avoided by not purchasing and using seed from areas where GM potatoes are grown. In the growing of organic seed potatoes, the use of organic seed potatoes in all grades will be a very effective control measure to prevent adventitious presence.

- In areas where there is GM growing, cleaning of sowing and harvesting machinery and transport equipment is important on all farms but especially where machinery is shared or there are machine pools. If practicable, it will be an advantage to handle organic and conventional non-GM crops first, before the GM crops.

- Pollen dispersal between GM and non-GM potatoes could be minimised if there are regulations on separation distance. A distance of 20 m between the GM experiment and other potatoes was used in experimental releases (Connor & Dale, 1996). This is also suggested in this report to avoid pollen dispersal and establishment of GM seed plants in neighbouring fields. By comparison, the separation distance between fields with certified seed potatoes and uncontrolled potato fields is 15 m and for pre basic seed 50m. This is due to the risk of virus contamination. For non-flowering GM potato varieties, a smaller separation distance can be sufficient.

- As mentioned above, the control of volunteers (groundkeepers) is important to avoid multiplication and persistence of GM potatoes in fields, and especially when the field is going to be used later for conventional or organic potato production.

Groundkeepers can be controlled by:

- Collecting as many potatoes as possible at harvest (Møller, 2000; Holm, 1977; Lutman, 1977).

- Increasing the length of the cropping interval, choosing crops with a good competitive ability in the crop rotation and applying chemical control.

- Repeated shallow soil treatment (harrowing) in the autumn and winter after a potato crop in order to bring as many leftover tubers as possible to the surface to expose them to frost.

- Crops sown in rows gives a possibility of inter-row weeding and mechanical weeding to remove emerging groundkeepers, which especially will be relevant to organic crop cultivation.

- Deep ploughing is usually not recommended after potatoes but can be used in “cattle” crop rotations (for example in organic growing) where grass and/or whole crop cereals are established immediately after potatoes are harvested.

- Chemical control with Roundup (glyphosate) has a good effect on growing potatoes. If GM potatoes with Roundup resistance are marketed, these cannot be controlled with Roundup. Starane (fluxopyr) can also be used in cereals to control groundkeepers tubers but are used less due to a long clearance periods after treatment.

Adventitious presence

Considerations in foreign countries

Based on examples in France, Britain and Northwest Germany, European experts (JRC/IPTS, 2002) estimated probable levels of adventitious presence in potatoes at farms (Table 10.6). Model calculations were not used. The examples includes:

1. Production of conventional consumption potatoes.
2. Production of organic consumption potatoes.
3. Production of conventional early season fresh market potatoes.
4. Production of organic early season fresh market potatoes.

The starting point was a distribution of GM potatoes of 20-50 %. The admixture estimates are partly based on current growing methods, partly after using selected control measures to reduce admixture.

The following conclusions were drawn:

- For both conventional farm types 1 and 3, the estimated GM presence would be below the threshold value of 0.9 % in food under the current growing conditions. By using control measures, the GM content could be halved.

- For organic production of consumption potatoes (2), the estimated GM content is approx. 0.1 % using current cultivation practices.

- For organic production of early season potatoes (4), an admixture of up to approx. 0.2 % is estimated using current cultivation practices, and a little lower when control measures are applied.

- Seed and volunteers are generally considered to be important sources.

Table 10.6. Farm scenarios for potato production: Estimated contributions to GM admixture from different stages in production (JRC/IPTS, 2002).

Farm type	% probable admixture							
	1		2		3		4	
	Current	With control measures	Current	With control measures	Current	With control measures	Current	With control measures
Seed, farm-saved included	0.05+/- 0.02	0.05	0.02	0.02	0.1+/- 0.05	0.05	0.04+/- 0.02	0.04
Sowing	0.02	0.02	0	0	0.03	0.03	0.01	0.01
Equipment	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
Cross-pollination	0	0	0	0	0	0	0	0
Volunteers	0.1+/- 0.08	0.01	0.02+/- 0.02	0.01	0.1+/- 0.08	0.01	0.04+/- 0.03	0.01
Harvesting	0.02	0.02	0.01	0.01	0.1	0.05	0.02	0.02
Transport from field to farms	0.02	0.02	0.01	0.01	0.04	0.04	0.01	0.01
Cleaning of storeroom	0.08+/- 0.05	0.01	0.01	0.01	0.1+/- 0.08	0.05	0.01	0.01
Packing	0.04	0.01	0.01	0.01	0.04	0.02	0.01	0.01
Transport from the farm	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.01
Expected total admixture, sum	0.36% (+/- 0.15%)	0.17%	0.1% (+/- 0.02%)	0.09%	0.54% (+/- 0.21%)	0.28%	0.16% (+/- 0.05 %)	0.13 %

Minimum admixture in a production stage is estimated at 0.01.
Conventional farms 300 ha/150 ha – cropping interval 4-5 years
Organic farms 75 ha – cropping interval > 5 years
Farm type 1: Conventional consumption potatoes grown for direct consumption and processing
Farm type 2: Organic food potatoes grown for direct consumption and processing
Farm type 3: Early season potatoes grown for direct sale
Farm type 4: Organic early season potatoes grown for direct sale.

These described conditions are different from Danish conditions, as here the cropping intervals are shorter, and the winter climate is harsher. In the foreign study, the exchange of farm-saved seed among farmers with mixed production is assumed, which is a potential source of admixture. The exchange of farm-saved seed is not allowed in Denmark.

Evaluation of adventitious presence under Danish conditions

Seed (seed potatoes): 0 % scenario with foreign GM growing:

- The only source of adventitious GM presence will be imported seed, which would have to be tested if originating from areas where GM potatoes are grown. The suggested threshold value for seed potatoes in the EU is 0.5 %.

- In organic farming, the use of seed from areas without GM growing will ensure no GM presence.

Seed (seed potatoes): 10 % and 50 % scenarios:

- The production of potato seed in Denmark already has legal constraints regarding regulations on crop separation distances, cropping intervals, use of machinery, *etc*. The present level of varietal impurity is maximum 0-0.05 %, depending on grade. The control is, however, based on external characteristics and not on genetic analysis.

- In conventional farming, it is expected that GM presence in Danish seed potatoes can be kept at a very low level through controlled use of seed, control of groundkeepers, separation distances to GM potatoes and an increased cropping interval for certified seed potatoes. A conversion from GM potato growing to non-GM potato production necessitates the introduction of a greater cropping interval for the fields.

- For organic seed potatoes, it is estimated that adventitious GM presence can be kept below ~0.1 % with the additional measure of using organic seed potatoes in all grades. Further, the above-mentioned cropping interval between growing GM potatoes and before organic potato production should be increased, as compared with the proposed corresponding cropping interval before conventional potatoes can be grown.

Production: 0 % scenario with foreign GM growing:

- The only source of GM presence would be foreign seed potatoes, see above section on seed.

Production: 10 % and 50 % GM scenarios:

- There is a regulation in Danish potato production that seed has to be replaced regularly and farm-saved seed can be for farm use only. It may be advisable for farmers not to use farm saved seed from fields that have previously grown GM potatoes.

- In conventional farming, these regulations, supplemented by separation distances to GM potatoes and combined with good farming practice in the form of a varied crop rotation, control of groundkeepers and cleaning of machinery, should keep GM presence at a low level. A conversion from GM potato growing to conventional growing necessitates the use of a conversion period.

- In organic farming, it is expected that with the use of further slightly more stringent measures, it should be possible to keep the level of GM content ~ 0.1 %, as long as organic seed potatoes with organic origins are used in all grades.

Production: 50 % GM scenario:

- A large distribution of GM potatoes in areas with intensive growing of potatoes will not make it impossible to comply with separation distances and other control measures but will necessitate many contacts between neighbours.

Need for further knowledge

- Studies of the extent of the problems with groundkeepers in Denmark considering the mild winters in recent years.

- Danish studies of pollen dispersal and cross-pollination, including the dispersal by insects and the extent of over-wintering tubers originating from “true seed” plants.

Conclusion

- GM potatoes are not expected to be marketed in Denmark within the next few years.

- Potato is vegetatively multiplied in cultivation, but can have self-pollinated and cross-pollinated flowers and form true seeds under normal field conditions.

- Potatoes have a low risk of dispersing GM characteristics. Dispersal can occur through admixture in seed potatoes, over wintering groundkeepers in the field (volunteers) and with machinery and transport equipment. Furthermore, pollen transfer across short distances with subsequent formation of true seeds is possible under certain conditions. However, these have to germinate, develop into potato plants and over winter as tubers to result in GM presence in a subsequent potato crop in the same field.

- Even with a more extensive growing, no problems are expected in achieving the threshold values in conventional seed potatoes and industrial potatoes, if these outlined control measures are introduced.

- Similarly, it is expected that a very low contamination level can be maintained in organic production if the outlined extended control measures are introduced.

- It is important that the control measures and their effect are monitored and that they are continuously adjusted in accordance with experience of managing these crops.

(See also Table 2.4).

10.6 Barley, wheat, triticale, oats

Background

Barley and wheat are among the most widely grown cultivated plants both in North-West Europe and the world. In Denmark the two species occur in most of our cultivated area in most parts of the country and they provide for animal production as well as human use. They have a significant influence on farming systems and hence on the environment and landscape.

Crop area, Denmark, 2002

Conventionally grown barley:	809,000 ha
Conventionally grown wheat	574,000 ha
Conventionally grown triticale:	25,000 ha
Conventionally grown oats:	46,000 ha
Organically grown barley:	20,000 ha
Organically grown wheat:	7,600 ha
Organically grown triticale:	2,300 ha
Organically grown oats:	8,500 ha
Totally	1,492,400 ha

Growing practice

Barley *(Hordeum vulgare)* and wheat *(Triticum aestivum)*, occupy the largest crop area in Denmark, while oats *(Avena sativa)*, and Triticale *(Triticosecale spp.)* are smaller crops. Altogether the four cereals grown for grain cover approx. 1.5 million hectares or 56 % of the Danish cultivated area. Of these, approx. 38,000 ha is organic cereals for grain. Additionally, cereals and mixed grain are grown for silage on approx. 82,000 ha on conventional and on approx. 16,000 ha, on organically managed land. When silage crops are included they cover 59 % of the cultivated area. (Rye is discussed in Chapter 10.7).

The most frequently grown crops are spring barley and winter wheat, and the major part of all grain is used for animal feed.

The conventional seed production of the four cereals occupies 67,000 ha and 5,000 ha are organically grown.

The average field size is the largest for winter wheat (6.1 ha) and smallest for oats (3.7 ha). For spring barley, the average field size is 4.2 ha.

Varieties of these species are to a very great extent self-pollinating, with some cross-pollination for triticale.

In Denmark, the varieties of all four species grown are highly bred with a high degree of varietal purity. Usually 85-90 % of all seed used is certified seed produced under circumstances where cross-pollination, admixture, *etc*. are carefully tested. These species generally have a low cross-pollination frequency (2-10 %).

Triticale can possibly have a larger cross-pollination than the other three species. Volunteers usually survive less than one year in the soil, but can enter the soil seed bank and survive for up to 4 years. Breeding and the seed production stages are key points in the inspection of GM content for these species.

Experience of GM growing

Twenty-seven experimental releases of GM wheat are registered in 5 EU countries and 4 experimental releases of GM barley in 2 countries. None of these were in Denmark. At present, there are no approved GM varieties of the species concerned, but herbicide tolerant wheat will possibly be marketed in North America in coming years.

A large research and development effort of genetic engineering, especially in wheat, barley and triticale is being carried out by both public institutions and private companies. New types of GM-based quality characteristics (baking, malting quality), disease resistance (insects, fungi and virus) and improved seed content (vitamins, fatty acids, amino acids) are being developed. Such lines are expected to be marketed in the next 5-10 years.

Dispersal sources

The currently grown barley, wheat, triticale and oats are mostly closed flower types, which are self-pollinating. Their pollen transfer by wind and insects is small, and cross-pollination for these species will be of minor importance (de Vries, 1974; Wagner & Allard, 1991).

The species do not establish feral populations in Denmark. Wheat, barley and probably also triticale can cross with wild barley species in Europe (*Hordeun jubatum*, *H. marinum*, *H. murinum*, *H. bulbosum* and others) and wheat can cross with wild *Aegilops* species (*Ae. cylindrica*), which is growing wild in Europe (Feil & Schmid, 2002). Furthermore, the species can mutually cross, but only rarely under natural conditions (Sharma & Gill, 1983; Thomas & Pickering, 1979).

The most important dispersal agent of GM cereal material is seed. This can occur as an adventitious presence in seed, harvested grain, feed and organic manure with handling, agricultural machinery and transport as important routes for admixture.

Measures for managing crop purity

- The first most important stage in the management of GM content in the four species is to ensure pure seed. For this purpose, there is already a well-developed production of certified seeds of which the well-proven requirements of distances and rotation supplemented by the testing of basic seeds for GM content will ensure a high degree of purity. In producing certified seed, the GM presence from volunteers is minimised by requiring that the previous crop is not of the same species.

- Experience of seed production in barley, wheat and oats show that no special distances are required between fields to avoid cross-breeding and GM presence beyond a marked boundary or a cultivated zone of minimum 0.5 m. To produce certified triticale seeds, a distance of 20 m is required due to larger cross-pollination in this species. These isolation distances can be used to ensure purity both for seed and crop production.

- Since transfer of pollen between production fields will be very limited (to the outermost rows of plants) for barley, wheat and oats. These rows can be discarded at harvest.

- In order to avoid GM transfer with certainty to a subsequent non-GM crop production through surviving volunteers, two years of not growing GM cereals must be required. Further, the control of volunteers should be carried out by avoiding ploughing in the seed after harvest and control after germination.

- Machinery, especially harvesting machinery, can transfer small amount of GM seeds and cause seed loss and admixture in the harvested crop product. Harvesting and other machinery used in the handling of the seed should be cleaned after working with GM material to minimise the transfer of volunteers. Machinery carrying soil, *e.g.* potato and sugar beet harvesters and transporters could move cereal seed in the soil. This machinery should be cleaned to prevent soil movement. Birds, mammals and other agents can move seed from field to field. However it is considered that this is of very low significance.

- The major part of the crop production of these species is used as animal feed. If we want feed to be "GM free", it must be certified as such based on the origin of the seed lot and possibly be subjected to an analysis of its GM content.

- The seeds of the species concerned have poor viability after passing through the animal's digestive system and quickly lose their viability in normal composting of organic manure. However, fresh animal manure should not be used immediately before sowing if GM feed of the same species was used as feed.

Adventitious presence

Seed: 0 % scenario with foreign GM growing:

- No problems are expected in achieving an adventitious GM presence of less than 0.5 % in seed.

- No problems are expected in maintaining the GM presence in organic seed below the detection limit.

Seed: 10 % and 50 % scenarios:

- It will still be possible to achieve a GM content below 0.5 % in seeds and below the detection limit in organic seed production, provided that tests are performed for GM presence in all basic seed lots.

Production: 0 % scenario with foreign GM growing:

- The only source of GM is imported seed.

- No problems are expected in keeping the GM content in conventional production below 0.5 %.

- Neither are major problems expected in keeping the GM content in organic production below the detection limit.

Production: 10 % and 50 % scenarios:

- It should be possible to keep the GM presence in conventional production below 0.6 %.

- It will still be possible to keep the GM content in organic production below the detection limit. Compliance with the threshold values will require an effective segregation throughout the production system.

Need for further knowledge

The importance of sources of adventitious presence caused by volunteers, harvest, transport, and storage operations is not well documented. For the evaluation of adventitious presence due to harvest, transport, and storage operations, we used estimated values based on oilseed rape, which has far smaller seeds and a quite different volunteer biology than cereals.
The survival ability of these cereal species in the soil seed bank and the subsequent appearance of volunteer populations is insufficiently studied.

Conclusion

0 % scenario:

- Provided that there is no GM production in Denmark of the cereals concerned, the only source of adventitious presence will be imported seed and possibly volunteers from manure after imported animal feed.

- GM presence from both sources will be very small. Therefore a threshold value of 0.9 % will presumably be easy to comply with in conventional farming without further measures. Similarly, a GM content below the detection limit can be achieved in organic farming if the current regulations on organic farming are used. One must ensure, however, that all seed used on organic farms is “GM free”.

10 % and 50 % scenario:

- With the increasing growing of GM crops, the risk of GM dispersal by volunteers, harvest, transport and storage will also increase. The trend of GM presence in seed will also increase.

- Under a 50 % GM scenario for one of the major cereals (barley or wheat), the likelihood of GM presence, particularly due to admixture during handling of large amounts of grain, must be expected to increase. Careful management of segregation of crops should allow samples to achieve a GM content of less than 0.9 % in the finished non-GM products.

- For organic farming, it should also be possible, under both scenarios, to keep the GM content below the detection limit using the current regulations on organic farming, provided that only “GM free” certified seeds are used.

(See also Table 2.5).

10.7 Rye

Background

Rye (*Secale cereale*) is a cross-pollinating species. In the years 1999 - 2001, 50,000-60,000 ha annually of rye (winter rye) was grown in Denmark giving an annual yield of 250,000-330,000 tonnes. Of the Danish production of rye, 60,000-70,000 tonnes per year are used for the production of bread and the rest for feed.

Crop area, Denmark, 2002

Conventionally grown rye (grain):	43,000 ha
Conventionally grown rye (whole crop, silage):	6,000 ha
Conventionally grown rye (seed):	1,600 ha
Organically grown rye (grain):	2,700 ha
Organically grown rye (whole crop, silage):	2,300 ha
Organically grown rye (seed):	500 ha
Rye in total:	56,000 ha

Rye is 1.6 % of the cultivated area of Denmark. Organic rye growing is approx. 12.5 % of the crop area. The average field size for grain rye is 4.1 ha and for silage rye is 3.9 ha.

A few rye varieties are hybrids. In Denmark, only 65 ha are used for the multiplication of hybrid rye and exclusively for certified seed production.

Growing practice

Only winter rye is grown in Denmark. About 80 % is grown in Jutland. The largest concentration of rye growing (5-16 % of the cultivated area) is in municipalities in the regions North Jutland, Aarhus and in North Zealand (Figure 10.7). Rye for silage cereal is primarily grown in South and West Jutland. In some municipalities, for example North Zealand, there is a high concentration of both conventional and organic rye (Figures 10.7 and 10.8).

Experience with GM rye

There is no commercial growing of GM rye worldwide. Scientific papers on genetic modification of rye are published, but there are no publicly available data that describe the outcome of experimental releases.

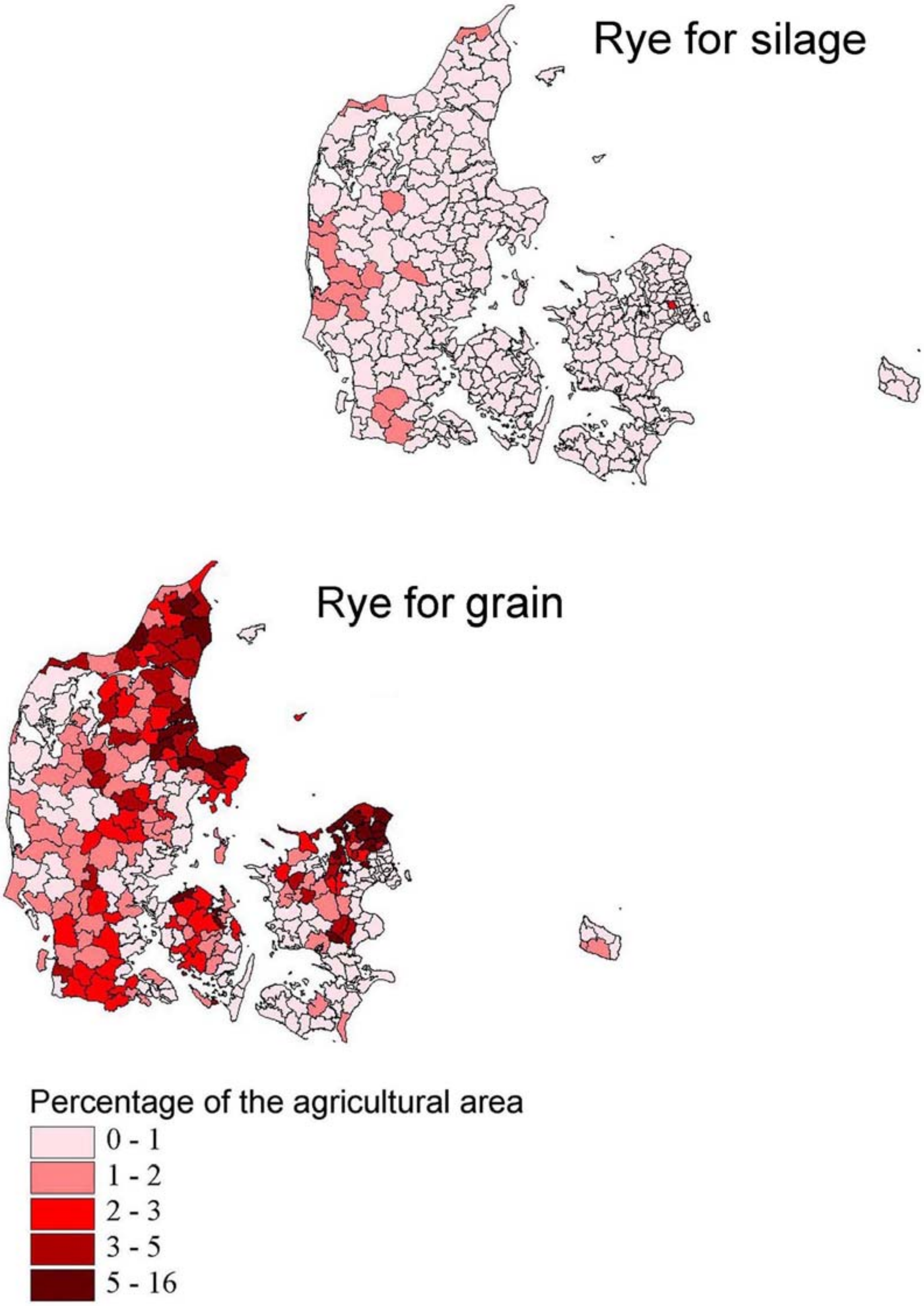

Figure 10.7. Distribution of rye for grain and rye for cereal silage in Denmark, 2002 (Dalgaard & Kristensen, 2003).

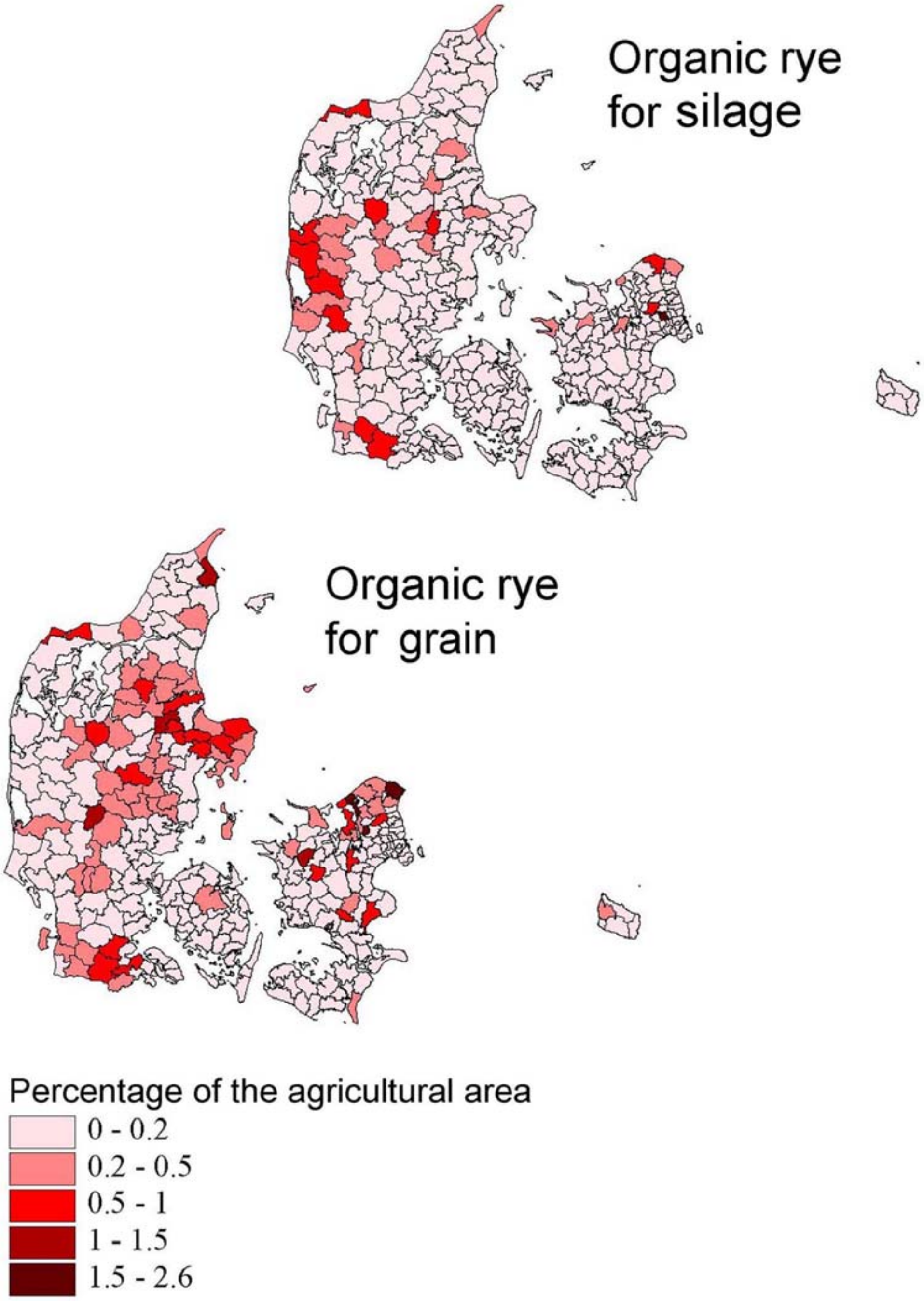

Figure 10.8. Distribution of organic rye for grain and rye for cereal silage in Denmark, 2002 (Dalgaard & Kristensen, 2003).

Dispersal sources

- The primary method of dispersal will be dispersal to neighbouring fields via pollen.

- The seeds usually survive less than one year in the soil. Rye does not occur as a weed in the crop rotation and is therefore not expected to multiply in the field. Any volunteers can very easily be identified and eliminated in a crop rotation. If the seed is ploughed in and kept without a supply of oxygen, it can, however, in some cases survive for more than a year and thus constitute a risk of dispersal.

- There is also a possibility of admixture from seeds during harvest, storage and further handling.

- Rye is a cross-pollinator, but it does not cross with weed species or other cultivated plants in Denmark.

Measures for managing crop purity

- Separation distances.
- Cleaning of harvest machinery.
- Segregation during post harvest handling.

As further control measures it will be possible to establish buffer zones of tall crops such as maize or hemp or buffer zones of conventional rye.

Adventitious presence

The most important sources of GM presence in conventional and organic rye fields would be pollen flow and seed admixture. By contrast, there is, little potential for multiplication in the crop rotation. There will, however, also be a possibility of GM admixture during harvest, storage and further handling and processing. There is also some rye seed production in Denmark. The purity of this seed is also important in determining GM purity of crops.

The evaluation of the co-existence problems between GM rye and conventional/organic rye production in Denmark is based on:

- The EU threshold value for adventitious presence of GM rye in conventional seed (not yet established but expected to be in the interval of 0.3-0.5 %).

- Regulations on the multiplication of seed (Table 10.7).

- Available literature on certification regulations and crossing of conventional rye (data for GM rye are not available).

Table 10.7. Regulations on separation distances, varietal purity and cropping interval in multiplication of rye for basic seeds and certified seeds (C1 generation), respectively.

RYE	Basic seed			Certified seed (C1)		
	Separation distance	Presence other varieties	Interval	Separation distance	Presence other varieties	Interval
Ordinary rye (Not hybrid)	300 m	1 plant/ 30 m^2	1 year	250 m	1 plant/ 10 m^2	1 year
Rye hybrids	600-1,000 m	1 plant/ 30 m^2	1 year	500 m	1 plant/ 10 m^2	1 year

Rye is sown at a density of 200-250 plants/m^2. A presence of 1 plant per 10 m^2 or per 30 m^2 at a density of 200 plants/m^2 will therefore correspond to a presence of 0.05 % and 0.017 %, respectively.

Feil & Schmid (2002) reviewed the available literature on pollen dispersal in rye and the recommended separation distances for the production of certified seeds from open-pollinated and hybrid varieties.

Recommended separation distances for open-pollinated rye: 200-300 m
Recommended separation distances for hybrid rye varieties: 500 m
For multiplication of the parent lines of the hybrids, the separation distance is: 600 -1,000 m

The authors conclude that sufficient data for formulating reliable separation distances for GM rye are not available, but it is estimated that distances of at least 1,000 m between GM and non-GM rye will be necessary to ensure a GM content below 0.5 %. The causes of these deviations from the certification regulations are not discussed. In addition the size and shape of the conventional/organic rye fields in relation to the GM rye field were not taken into account.

Adventitious presence under Danish conditions

Seed: 0 % scenario with foreign GM growing:

- The threshold value for adventitious presence of GM rye in conventional seed has not been decided but will probably be 0.3-0.5 %. GM rye could be introduced via imported seed, but as rye does not multiply in the crop rotation, there will be no problems in the Danish seed production of conventional varieties.

- It will be possible for organic farmers to achieve a lower GM content ~0.1 % if they use seed with corresponding specifications.

Seed: 10 % and 50 % scenarios:

- As a starting point, it is recommended that growers comply with the separation distances and cropping intervals that are stated for seed production. However, it should be stressed that no knowledge of GM rye seed multiplication is available.

Production: 0 % scenario with foreign GM growing:

- Unexpected presence of GM rye will solely be a result of its presence in seed, as rye cannot multiply in the crop rotation. The threshold value for adventitious GM presence in conventional seed is expected to be 0.3-0.5 %, *i.e.* considerably below the threshold value of 0.9 % in the end product.

- In organic rye production, a GM content of ~0.1 % can be achieved by purchasing seed with corresponding specifications for the content of GM rye.

Production: 10 % scenario:

- In conventional farming, the general recommendation for the production of certified seed from open-flowering varieties is a separation distance of 250 m . According to experience from the production of certified seed, this should ensure a very low cross-pollination percentage through pollen dispersal.

- According to experience from the production of open-flowering certified varieties, a separation distance of 250 m to a GM rye field will ensure a very low GM presence in organic growing . A precondition for this level is that "GM free" seed is used.

Organic and conventional farming

Production: 50 % scenario:

- In 2002, the total rye area was only 1.6 % of the cultivated area, 12.5 % of which was cultivated organically. However, there are regions, especially in North Jutland, Aarhus and North Zealand, where there is a relatively high concentration of rye. It should therefore be expected that problems to comply with the necessary separation distances could arise under a 50 % GM scenario. As a result of this, further control measures may become necessary in the form of using seed with a lower GM content and agreements between neighbours on the location of GM and non-GM crops.

Need for further knowledge

- There is very limited knowledge about the potential outcrossing between GM rye and conventional or organic rye fields.

- An evaluation is needed of the pollen dispersal and outcrossing at different distances under Danish climatic and field conditions.

- An evaluation of co-existence measures in the form of the planning of field spacing and impact of field size is required. These studies can be performed relatively easily if a number of trial fields are planted with rye possessing dominant visible markers (*e.g.* shape or colour of the seed) and conventional rye in neighbouring fields. This information can subsequently be used for developing computer models to predicting admixture percentages under a number of different production conditions.

Conclusion

- Under a 0 % scenario, the only source of GM presence in conventional and organic production is through imported seed. The threshold value of the presence of GM rye in conventional seeds is expected to be 0.3-0.5 %. In organic production, a low level of adventitious presence can be ensured by using seed with such specifications.

- Under a 10 % GM rye scenario, GM presence can occur in the conventional and organic production via pollination from GM rye on neighbouring fields. As a starting point, a separation distance of 250 m from a GM rye field to a conventional or organic rye field is recommended. This is estimated to reduce the GM content via crossing to about 0.2 %, and 0.1 %, respectively.

- If a harvesting machine is used on both GM and conventional/organic fields, appropriate cleaning should be made between the harvest of the different types.

- Under a 50 % scenario, increasing problems can be expected of maintaining separation distances in regions with extensive rye growing. This problem can to a large extent be remedied by mutual planning of field locations and field shapes among neighbouring farmers who want to use different types of production.

It should be stressed, however, that these evaluations are subject to great uncertainty because:

- There is limited knowledge about the crossing frequency between neighbouring fields. No field experiments with GM rye have been carried out yet.

- As for other wind-pollinated crops, the crossing percentage at field level will depend on field size and shape, especially along the field axis of the conventional/organic field at right angles from the GM rye field. A field with little depth will, have a higher field-level crossing percentage than a field that stretches several hundred metres away from the GM rye field.

- A few rye varieties are hybrids. As with maize, these could be heterozygous for the engineered gene, as only one of the parent lines of the hybrid is genetically modified. In consequence, only half the pollen grains of the hybrid rye will contain the novel gene, resulting in correspondingly lower cross-pollination.

- A considerable proportion of rye is used as silage. By crossing with GM rye pollen, only the grain will contain the GM character, and the GM content in the silage cereal product will only be about 50 % of the GM content in the grain.

(See also Table 2.6).

10.8 Forage and amenity grasses

Background

Most grasses are self-incompatible, which means that pollen cannot pollinate the ovules in the same flower. Pollination takes place with pollen from other plants of the same variety/species. Most grasses are predominantly cross-pollinators, and they are wind-pollinated. The degree of self-incompatibility varies among varieties of the same species, and it is rarely 100 %. Italian ryegrass (*Lolium multiflorum*) and perennial ryegrass (*Lolium perenne*) have cross-pollination levels of 92 % (Arcioni & Maritti, 1983). Some species of the genus *Poa* have apomixis, which means that they have asexual reproduction of most of their seeds and are "self-fertile". Thus, annual meadow grass (*Poa annua*) has cross-pollination of only 15 % (Ellis, 1974).

Crop area, Denmark, 2002

Conventional grass/clover grazing fields in crop rotation:	189,000 ha
Conventional permanent grassland:	137,000 ha
Conventional set-aside areas with grass:	192,000 ha
Conventional seed production (various grass species):	63,000 ha
Organic pastures in crop rotation:	34,000 ha
Organic permanent grassland:	20,000 ha
Organic set-aside areas with grass:	4,000 ha
Organic seed production (various grass species):	1,600 ha

Grass areas, including set-aside, are altogether approx. 640,000 ha or approx. 24 % of the agricultural area.

Pastures usually consist of perennial grass species, and the composition depends on the usage of the field (grazing, silage or hay), duration and the growing conditions in the specific field.

The most commonly used forage grasses are:

- Perennial ryegrass (*Lolium perenne*).
- Italian rye grass (*Lolium multiflorum* Lam).
- Red fescue (*Festuca rubra*).
- Smooth-stalked meadow grass (*Poa pratensis*).
- Meadow fescue (*Festuca pratensis*).
- Timothy (*Phleum pratense*).
- Cocksfoot (*Dactylis glomerata*).
- Rough-stalked meadow grass (*Poa trivialis*).

and an increasing use of hybrid ryegrass and festulolium, a hybrid between ryegrass and fescue.

Grass production and utilisation
Pastures are most extensive in Western Denmark and in areas where the concentration of dairy farms is large. However, the increased interest in the production of beef cattle, especially on part-time farms, has resulted in more pastures also in Eastern Denmark. A large proportion of the organic farms keep cattle. Of the total pasture area production on organic farms is approx. 55,000 ha, which corresponds to more than 30 % of the total production area on organic farms.

Grasses are very common in the recreational sector – golf courses, sports grounds, parks and private lawns. The grass area for these purposes is approx. 15,000 ha, and their area is increasing (the Danish Forest and Landscape Research Institute, 2003). Golf courses are typically located in agricultural areas outside the major towns, while sports fields are on the outskirts of towns and near schools. There are just below 7,000 sports fields of approx. 1 ha in Denmark.

The most commonly used grasses in recreational areas are:

- Perennial ryegrass (*Lolium perenne*).
- Red fescue (*Festuca rubra*).
- Smooth-stalked meadow grass (*Poa pratensis*).
- Common bent (*Agrostis capilaris*).
- Creeping bent (*Agrostis stolonifera* var. *palustris*).

Through breeding, specific amenity types and forage types within the same species have been developed. Different types within the same species are able to cross-pollinate.

Denmark is the largest exporter of grass seed in the world, and more than 40 % of the total grass seed production in the EU is located in Denmark. Seed production of amenity types accounts for approx. half of the Danish production of perennial ryegrass, red fescue and smooth-stalked meadow grass. Almost 100 % of the seed production of common and creeping bent is for amenity purposes.

All grass seed production in Denmark is contracted and is carried out according to the Ministerial order on seeds[1]. The varieties that are multiplied in Denmark are both Danish-bred, and also foreign varieties. Perennial ryegrass, red fescue and smooth-stalked meadow grass are the three major species. They occupy more than 80 % of the total area (average 1993-2002). Perennial ryegrass has a 40% share of production, red fescue has 30 % and smooth-stalked meadow grass 10 %.

[1] Ministerial order on seeds no. 52 of 24 January 2000 with later amendments.

Seed production of perennial ryegrass is prominently located in Western Denmark, partly because of larger precipitation and partly because this production to some extent can be combined with livestock farming. Seed production of red fescue and smooth-stalked meadow grass is primarily located in Eastern Denmark.

Danish seed companies have established the first, organic grass seed production in Europe and from 2001, organic ryegrass seeds were available for export.

The financially most important grasses belong to the genus ryegrass, fescue and meadow grass, of which varieties of ryegrass and fescue can interbreed, which is exploited commercially in (festulolium). Smooth-stalked meadow grass and red fescue can also multiply vegetatively, as they form rooting stolons.

All the grasses mentioned occur naturally in Denmark, and beside the commercially exploited species, there are varieties that occur as weeds/wild relatives (for example *Poa annua*, *Festuca ovina* and *Agrostis canina*).

Experience with GM grasses

At present, there is no commercial growing of GM grasses in the EU, but there have been experimental releases of perennial ryegrass and tall fescue (*Festuca arundinacea*) in the EU. In 2002, multiplication of GM grasses was carried out in the USA (creeping bent with herbicide resistance) and according to very detailed specifications.

The biotechnological development of grasses in the USA is particularly concentrated on grasses for recreational activities – and on traits such as herbicide resistance, drought tolerance, disease resistance, *etc*. In Denmark, biotechnological development of grasses is carried out to improve forage quality.

Dispersal sources

Pollen dispersal

Grasses generally produce large amounts of pollen. It is released at flowering, which in grasses can occur over an extensive period. Flowering lasts for one week on one reproductive stolon and it can last up to 2 weeks on one plant (Jones & Newell, 1946). Observations of flowering in grass seed fields show that the flowering in one variety can last 3-4 weeks.

The life span of a pollen grain depends on climatic conditions such as temperature and humidity. The longest life is achieved at low to moderate temperature and high humidity. There are varying records of pollen life from a few hours to 1 day for ryegrass and smooth-stalked meadow grass and 3 days for cocksfoot.

It appears from Danish studies that pollen dispersal (*i.e.* the content of pollen in the air) from seed fields of ryegrass, timothy and cocksfoot was 14 %, 25 % and 27 %, respectively, of the released pollen at a distance of 200 m from the donor field (Jensen & Bøgh, 1942). At a distance of 300 m from the donor field, the pollen content in the air was 14 %, 16 % and 18 %, respectively.

Other sources also state that approx. 20 % of the released pollen is dispersed more than 200 m from the donor field. In the same Danish study, ryegrass pollen was found up to 1,200 m from the donor field (5 % of the released amount). Studies of pollen dispersal in creeping bent in connection with experimental plantings in the USA indicated similar distances (Wipff & Fricker, 2001).

Generally, the pollen content in the air decreases rapidly as a function of increasing distance from the donor field. However, factors such as wind direction, wind force and turbulence can change the pollen dispersal patterns (Giddings *et al.*, 1997a and 1997b).

Whether pollen dispersal leads to a successful pollination and hence to gene dispersal depends on the viability of the pollen, the probability that it lands on a mature ovule with which it can hybridise and the degree of self-incompatibility. In other words, studies of pollen dispersal give an expression of the potential gene dispersal, but in most cases they will overestimate the actual gene dispersal.

There are published studies of gene dispersal in perennial ryegrass (Griffiths, 1950), brome grass (Knowles & Ghosh, 1968), meadow fescue (Rognli, 2000) and creeping bent (Christoffer, 2003).

In perennial ryegrass, gene dispersal was measured in relation to the distance from the pollen source and to the number of receptor plants (Table 10.8). A distinct reduction of gene dispersal was found at increasing distances from the pollen source (from 5.88 % to 1.39 % at the distances of 182.8 m to 365.6 m). When the number of receptor plants increased from 6 to 30 plants, the gene dispersal was reduced further (from 0.95 % to 0.52 %). The authors state that this reduction in gene dispersal primarily is due to a dilution of pollen from the donor field by the pollen from the receptor plants themselves. This is supported by Dutch studies, which show that 40 % pollination of a ryegrass plant takes place from the neighbouring plant and 74 % from the 3 neighbouring plants in each of two rows next to the receptor plant (Wit, 1952).

Table 10.8. Effect of distance from pollen source and the number of receptor plants on gene dispersal in perennial ryegrass (Griffiths, 1950).

	Distance from pollen source	
	182.8 m	365.6 m
6 receptor plants	5.88 %	1.39 %
30 receptor plants	0.95 %	0.52 %

Furthermore, gene dispersal was studied at the edge of the field and at increasing distances from the edge (up to 3.66 m). In keeping with other studies, it is concluded that harvesting of the outermost rows (buffer rows) has no or very little significance at large isolation distances. However, the results of the experiment show that gene dispersal at 3.66 m into the field is halved compared with the outermost row despite of the isolation distance.

Similarly, experiments with meadow fescue (Rognli, 2000) show a very large decrease in gene dispersal with increasing distance from the donor field (451 plants planted at 72 m^2). The gene dispersal was 10 % at a distance of 75 m from the donor, but from 75 to 250 m (the outermost boundary of the experiment) the gene dispersal decreased only very little. The experiment with meadow fescue also confirms the influence of pollen density in relation to the receptor plants. Experiments with pairwise plantings of receptor plants reduced the gene dispersal by 80-90 %. At a distance of 155 m from the donor, gene dispersal was reduced from 5.9 % in single plants to 0.7 % in pair wise plantings.

In experiments with herbicide resistant creeping bent, a gene dispersal of 49 and 27 % was found in 2001 and 2002, respectively, at a distance of 1-3 m from donor plants (Table 10.9). Much less gene dispersal was found to other species in the genus of *Agrostis*.

Table 10.9. Effect of distance from pollen source on gene dispersal in creeping bent, measures in 2001 and 2002, respectively (Christoffer, 2003).

	Year	
	2001	2002
1–3 m	49 %	27 %
185 m	0–0.38 %	0.01–0.19 %
354 m	0–0.15 %	0–0.11 %

Gene dispersal was measured in 6 directions, and the results show a considerable variation in the current gene dispersal from year to year and among the different axes. The lowest and the highest value are shown in Table 10.9. There were 200 donor plants. The author states, however, that the outcrossing frequency is probably twice as large, as the transgenic pollen donor was hemizygous.

The few experiments with pollen and gene dispersal in grasses show that the experimental design has a very large influence on the result – especially the number of plants in both the donor and receptor fields are important. Generally, it can be concluded, that pollen dispersal can take place across very large distances (> 1,000 m). Further, the extent of pollen dispersal is unpredictable, as it depends on wind direction, wind force, turbulence and a number of local conditions (geography, plantation, building in of the area, etc.). In the reported experiments, gene dispersal was considerably lower than the pollen dispersal, and the gene dispersal is heavily reduced in relation to increasing pollen density in the receptor field itself. The extent of gene dispersal in the reported experiments is shown in Table 10.10.

Table 10.10. Extent of gene dispersal in grass experiments.

Species	Distance	Gene dispersal	Reference
Perennial ryegrass	182.8 m	0.95 %	Griffiths, 1950
	365.6 m	0.52 %	
Meadow fescue	155.0 m	0.70 %	Rognli, 2000
Creeping bent	185.0 m	0.07 % (highest single value, 0.38 %)	Christoffer, 2003
	354.0 m	0.03 % (highest single value, 0.15 %)	

Under Danish growing conditions, it is important to evaluate gene dispersal in fields and at farm and regional levels. These aspects are not included in the present studies.

- Gene dispersal from field to field can typically take place through pollen dispersal.

- Gene dispersal at farm level can take place as a result of pollen dispersal between seed fields and pastures.

- At regional level, dispersal and gene crossing from field boundaries, recreational areas, *etc*. will be of importance for gene dispersal, partly through a widespread use of GM varieties and partly after continuous use of GM varieties. For example, the semi-rough and rough areas at golf courses are not cut. These areas can therefore act as a source of gene dispersal to the cultivated areas if GM varieties are used on golf courses.

By an extensive use of GM varieties and/or use of GM varieties for several years, GM hybrids will occur in field boundaries, recreational areas, set-aside areas, *etc*. In the long term, pollen from these areas will be a source of GM crossing, but the size of it is unknown and will depend on the distribution and viability of the GM hybrids.

Seed dispersal
The fact that grasses are mainly pollinated by neighbouring plants means that the presence of volunteers from previously grown varieties/species is very important to gene dispersal.

At grass seed production areas, a number of seeds are lost as the seeds in the individual heads ripen unevenly. The smallest seeds at the top of the head ripen first and are often lost before the crop is harvested. Even though the seeds are small, they will in many cases be viable.

Furthermore, seeds are lost during harvesting. If the crop is not sufficiently ripe, not all seeds will be threshed from the head. If the crop is not sufficiently dry, the seeds will stick to the straw. Some seeds will not be picked up by the combine harvester, either because of wrong adjustment or because the seeds are too small. It is very difficult to state an average extent of seed loss before and during harvest, however, losses of 200-400 kg of seeds/ha are not unusual. In comparison, the required amount of seed for the establishment of a grass seed production field typically is 6-10 kg/ha and for the establishment of pastures 25 kg/ha is used – the latter, however, consists of a mixture of different grass species.

At the establishment of pastures, seeds are added to the seed bank, as only a part of the seed sown will germinate within that year. Usually, a field germination percentage of 50 % is considered to be very satisfactory for grasses. In other words, half the seeds sown do not give rise to plants in the year of sowing. Whether these seeds survive is not known, but generally, the viability of grass seeds in topsoil layers is limited. The causes for the disappearance of the seeds can be:

- They germinate without establishing a plant.
- They perish after establishment due to diseases or pests.
- Seeds are destroyed before germination due to diseases or pests.

It is therefore estimated that the major part of the seeds that do not result in established plants has disappeared whereas a minor part is added to the seed bank of the soil. Most grasses have one or more forms of dormancy, which typically does not end until exposure to low or varying temperature, moisture, light, scarifying of the seed coat, *etc*.

Most grasses have a relatively limited viability in the soil whereas some can survive for up to 10 years. Recent Danish studies show a relatively large variation among grasses (Jensen 2002). Timothy has a germination capacity of approx. 20 % after 3 years in the soil at a depth of 25 cm, whereas perennial ryegrass has a corresponding germination capacity of < 1 % (Jensen, 2002). Generally, after 3 years in the soil, > 10 % viable seeds were found in timothy and rough-stalked meadow grass but < 5 % in all other species tested.

As regards grasses, most of the published studies of seed viability in the soil are primarily performed on seeds that were buried at a certain depth and where the soil had not been disturbed during the period before a germination test was carried out. In cultivated soil, various forms of soil treatment will be carried out, depending on crop rotation and cropping techniques. These operations partly can displace the seeds in the ploughed soil layer and partly change the germination conditions, especially for seeds that are at the top of the ploughed soil layer. Several studies show that the viability of the seeds of most grass species is considerably lower for seeds located on or near the soil surface.

At locations near the soil surface, a very limited number of viable seeds from smooth-stalked meadow grass and ryegrass were present after 1 year, whereas at 25 cm, corresponding to ploughing depth, approx. 2/3 of viable seeds were still viable. On the soil surface, only traces of rough-stalked meadow grass and timothy were left.

For volunteers of grass crops in cultivated soils where the seed are displaced regularly during soil treatments, the viability is more limited than reported from studies in undisturbed soil. It is therefore estimated that only volunteers from rough-stalked meadow grass and timothy will be able to have viable seeds in the soil seed bank for many years. As for the other cultivated grasses, a seed bank of viable seeds will not be sustained if there is effective control of germinated plants so that they cannot replenish the seed bank.

However, recent Danish studies show that there is insufficient control of volunteers in the intervening crops in many crop rotations. This is due to either insufficient attention or an insufficient effect of the applied control methods.

Crop rotation and the control of volunteers

The form of the crop rotation is of major importance influencing the establishment and seeding possibilities of volunteers - irrespective of whether these volunteers originate from re-established plants from the growing year (terminated grass seed crops or pasture) or from seeds in the soil seed bank. The following conclusions can be made from recent Danish studies regarding the effect of herbicides:

- In winter cereals, there are generally good possibilities of controlling cultivated grasses. The only exception is red fescue, which is difficult to control chemically.

- In oilseed rape, beets and potatoes, there are generally good possibilities of controlling cultivated grasses.

- A number of new herbicides – for example for use in maize - have not been tested on cultivated grasses.

Glyphosate can control all cultivated grasses, which means that the introduction of glyphosate resistant crops will increase the possibilities of controlling volunteers of cultivated grasses, naturally provided that the cultivated grasses do not also possess or develop resistance to glyphosate. Glufosinate is also effective on cultivated grasses, but not as effective as glyphosate.

In organic farming, mechanical weeding is the only possibility of controlling grass volunteers.

Measures for managing crop purity
Pollen dispersal can be limited - but not avoided - by complying with separation distances. For cross-pollinating grass species, separation distances to other pollen sources is 200 m for growing of certified pre-basic and basic seeds. For the growing of certified seeds in fields of 2 ha, this distance is 100 m or less and 50 m in fields of more than 2 ha. Under "other pollen sources" other grass seed fields, arable fields and uncultivated areas (recreational areas, roadsides, set-aside areas, coverts, *etc*.), containing species/varieties with which the plants in the field concerned can cross-pollinate, are included.

To reduce pollen dispersal to these sources, it will be necessary to cut flowering grass seed heads inside the required separation zone from the GM field.

Seed dispersal can be reduced by complying with cropping intervals in the crop rotation – both for seed production and arable fields. In the departmental order on seeds, it is assumed that 3 calendar years pass between successive plantings of the same crop. This does not prevent seed dispersal, but it is very much reduced. Furthermore, incorporation of seeds in the soil seed bank should be avoided or reduced as much as possible. The relevant growing strategy will be to postpone the ploughing of the harvested seed field until late autumn or possibly until next spring. In that way, a very large number of volunteers will germinate and these can be controlled chemically and/or by ploughing under. It is also of very great importance to carry out an effective control of volunteer plants in the intervening crops in the crop rotation so that these volunteers do not produce seeds (false crop rotation).

To avoid the introduction of weeds and weed hybrids from field boundaries, verges, *etc*., a zone (working width) of bare soil or a spring-sown crop such as spring barley can be established round grass seed fields to prevent volunteers from weed hybrids entering the field. Furthermore, a certain reduction in gene dispersal can probably be achieved by discarding grass seed from the outside edge of the field.

Grasses constitute a relatively large share of the production in Danish agriculture for both forage and seed production. Grasses also form a large share of the recreational areas and they are found naturally in the Danish nature. As a result of this, there is a large risk of adventitious presence of GM plants in the various grass species.

It is thus apparent that grasses have numerous dispersal routes, which are important at field, farm and regional levels. It is therefore estimated that the control measures mentioned above must be used in combination in order to reduce dispersal of GM plants to conventional, and organic grass crops.

Knowledge is non-existent or very limited on the extent of the different dispersal routes (especially seed dispersal at farm level, seed and pollen dispersal at regional level among seed fields, pastures, recreational areas, *etc.*) and hence value of the various control measures. It will therefore be necessary to monitor gene dispersal and the effect of possible control measures for a number of years in order to collect data for the re-evaluation and refinement of the suggested control measures.

Adventitious presence

The threshold value of adventitious presence of GM seeds in conventionally produced grass seed has not yet been determined though 0.3% has been proposed. The following assessments were made on the basis of an expected threshold value of 0.3 %.

All grass seed production in Denmark is carried out as contract growing in accordance with the Ministerial order on seeds[1]. The highest accepted content of another variety/species in certified seed is 0.1 % (except for smooth-stalked meadow grass that is 0.6 %). The results of the Plant Directorate's variety inspection show, however, that some lots do not comply with these regulations on varietal purity (Table 6.3).

The inspection of varietal purity is based on external characteristics (morphological characteristics) and not on genetic analyses. These morphological characteristics can sometimes be determined by single genes, in other cases by the interaction between different genes. As grasses are cross-pollinators, they are genetically very heterogeneous – even those that belong to an approved variety (see chapter 6). A grass variety that appears homogeneous for morphological characteristics can consist of closely related plants, which can only be distinguished by genetic analysis.

Inspection of varietal purity is carried out partly in the control field at the Plant Directorate and partly through analysis of single plants. The variation in a given morphological character can be large. For example, plants of smooth-stalked meadow grass must exhibit a difference in stem height of >27 cm in order to be characterised as significantly different from each other (the Department of Variety Testing). The guidelines for the production of certified seed aim to preserve the variety in the form (purity) in which the variety was reported.

As morphological characters in grasses are often determined by several genes, a genetic analysis of the presence of one transgene will possibly show a larger crossing percentage (less varietal purity) than is normally found by analysis for morphological characters. Studies have been carried out to study the relationship between morphological characters and genetic analyses, but so far the results are ambiguous (Roldan-Ruiz *et al*., 2001; Gilliland *et al*., 2000).

The present evaluation of adventitious presence is based on guidelines developed for the production of certified seed. It will be necessary to re-evaluate these estimates when results on the relationship between morphological characteristics and genetic analyses are available.

[1] Ministerial order on seeds no. 52 of 24 January 2000 with later amendments.

Seed (seed production): 0 % scenario with foreign GM growing:

- Foreign seed lots are multiplied in Denmark. If these lots contain GM seed, additional measures should be implemented.

- It is expected that it will be possible to comply with the requirement of an adventitious presence of GM seed of <0.3 % and <0.1 % for conventional and organic production, respectively, during seed production in keeping with the Ministerial Order on seeds

Seed (seed production): 10 % and 50 % GM scenarios:

- At a moderate distribution of GM varieties, it is expected that further measures must be implemented in conventional seed production in order to comply with an adventitious presence of GM plants of <0.3 %. These additional measures will be the use of "GM free" basic seed or seed with a very low GM content, compliance with increased separation distances, and increased cropping intervals (depending on the viability of the grass seed in the soil and on the possibilities of controlling volunteers).

- At an extensive distribution of GM varieties, additional measures could be necessary to achieve a GM content of <0.3 %. These measures could include the use of buffer zones of bare soil/spring-sown crop/cutting and separation of field margin at harvest, guidelines for the control of volunteers and guidelines for the sequence of crops, as well as the control of grass weeds in the crop rotation.

- At a moderate distribution of GM varieties, a precondition of achieving a GM content of < ~0.1 % for organic seed production would require that the field could be established by using organic (GM free) seed as well as by compliance concerning separation. A cropping interval of 5-7 years will have to be observed, during which volunteers are effectively controlled. Further, machinery, drying plants, and stores should be carefully cleaned, and machinery should not be shared between GM and non-GM growers.

- At an extensive distribution of GM varieties, it is expected that it will be necessary to monitor contributions to admixture from field boundaries, grazing fields, the soil seed bank and long-distance pollen dispersal as a result of local and current conditions (wind direction during flowering, *etc.*). It is recommended that the certified seed should be tested for GM presence.

Production (pastures in crop rotation): 0 % scenario with foreign GM growing:

- There is a very limited import of grass seed of forage types.

- Certified seed is used when sowing production fields, and there should be no problems in complying with an adventitious GM presence of <0.8 % in conventional production and below ~0.1 % in organic production. The latter, however, is subject to the use of "GM free" seed at sowing.

Production (pastures in crop rotation): 10 % and 50 % GM scenarios:

- In connection with the distribution of GM varieties, it should be possible to comply with a level of adventitious presence of <0.8 % through the use of certified seed at sowing. It is recommended to control grass plants effectively at the conversion of pastures and to control any volunteers in the intervening crops. However, it is a prerequisite that the GM varieties used do not possess a competitive ability significantly higher that that of non-GM varieties.

- The maintenance of organic pastures with a GM content of <0.1 % is conditional upon access to organic or conventional GMO free (tested) seed. If there are GM fields within the current separation distances, any flowering seed heads must be grazed or cut off.

Need for further knowledge

It is considered possible to establish guidelines on GM growing at a moderate production/introduction of GM grasses, but at present there are no studies combining the different control measures at field, farm and regional levels. Generally, the number of studies on grasses is very limited, especially studies at field level, and those have typically been carried out considering one parameter and few grass species.

Due to the wide distribution of grasses in Denmark – both the number of species and varieties – it is at present not possible to elaborate guidelines on rules that allow co-existence between GM, conventional and organic crops that take long-term gene dispersal at regional level into account. Important aspects such as dispersal between pastures and seed production fields, the extents of gene crossing from field boundaries, recreational areas, *etc.* are not sufficiently known. It will therefore be relevant to initiate studies on:

- the importance of the degree of self-incompatibility/capacity for self-pollination of grass species/varieties in relation to gene dispersal

- the degree of invasion, establishment and introgression of genes/plants into perennial or permanent grass swards depending of the nature of the sward and its management

- the effect of separation distance combined with different plant densities in both donor and receptor fields

- the importance of seed dispersal and the possibilities of controlling volunteer plants in different cropping systems and crop sequences

- the importance of gene dispersal at a regional level (seed fields, pastures, field boundaries, recreational areas, set-aside fields, *etc.*) and the effect of buffer zones

- a phased introduction of varieties with identifiable characteristics (both morphological and genetic) for monitoring gene dispersal at field, farm and regional levels.

The development of cropping systems that ensure varietal purity in seed fields would be of great importance in maintaining Denmark's position as the leading exporter of conventional and organic grass seed.

Conclusion

- Grasses have both pollen and seed dispersal, and constitute a relatively large share of the production in Danish agriculture for both forage and seed production. Grasses also occupy a large part of the recreational areas and they occur naturally. As a result, there is a large risk of dispersal of the GM varieties in both cultivated areas as in nature.

- To avoid adventitious presence, it is considered necessary to introduce further control measures for the production of GM grass seeds, such as increased separation distances, increased cropping intervals and possibly the use of buffer zones. However, these suggestions are built on very limited knowledge. It is further considered possible to maintain a conventional production of pastures with an adventitious presence <0.8 % by using certified seed at sowing.

- For organic production, it will be a precondition of maintaining an adventitious presence <0.1 % that organic (GM free) seed is available – for both pastures and seed production fields.

(See also Table 2.7).

10.9 Grassland legumes

Background

This chapter considers the crops white clover (*Trifolium repens*), red clover (*Trifolium pratense*) and lucerne (*Medicago sativa*).

White clover and red clover

White and red clovers are cross-pollinators, almost completely self-incompatible and are insect-pollinated by honeybees and naturally occurring bumblebees.

White clover can also multiply vegetatively through rooting stem stolons. White and red clover occurs mainly in mixtures with grass for forage production and also naturally in Denmark. White clover prefers relatively nutrient-rich soil with high soil water retention while red clover is especially found in dry, uncultivated grassland areas.

Lucerne

Lucerne is a cross-pollinating species, and is pollinated by insects. Lucerne is mainly used for forage production. The species also grows wild in Denmark, and crosses with yellow lucerne, which is found in large parts of the country.

Crop area, Denmark, 2002

Conventional clover in mixtures with grass:	189,000 ha
Conventional white clover (seed production):	2,852 ha
Conventional red clover (seed production):	381 ha
Organic clover in mixtures with grass:	34,000 ha
Organic set-aside:	34,000 ha
Organic white clover (seed production):	554 ha
Organic red clover (seed production):	246 ha
Conventional lucerne (forage production):	2,400 ha
Conventional lucerne (seed production):	6 ha
Organic lucerne (forage production):	800 ha
Organic lucerne (seed production):	0 ha

There are no specific statistics about the clover content in pastures. As white clover is included in most pastures in rotation, approx. 223,000 ha or 8 % of the total Danish agricultural area could be under a grass/clover mixture. Approx. 18 % of this is organic clover. White clover is used extensively as a manure crop in organic crop rotations. In organic production, set-aside areas can also include clover.

Growing practice

White and red clover is used in Danish agriculture partly in rotational (short term) pastures and partly in permanent pastures.

White clover is the most frequently used clover in rotational pastures. The distribution and duration on perennial pastures of white clover depends on nutrient status and soil conditions. There is a considerable white clover seed production and a smaller red clover seed production in Denmark.

On organic farms, white and red clover is also used extensively as green manure and cover crop.

Very fine-leaved white clover varieties are bred for use in recreational mixes. These mixes are sown, for example on sports fields.

Grass/Clover Pastures

Pastures containing clover are mostly found in Western Denmark where the concentration of dairy farms is large (Figure 10.9). In this area, grass/clover fields constitute 10-20 % of the agricultural area. In addition the increasing interest in the production of beef cattle, especially on part-time farms, has resulted in more of these pastures in Eastern Denmark. In Northern Zealand, grass/clover pastures are 5-10 % of the total agricultural area. A large percentage of organic farms keep cattle, and grass/clover pastures have a large share in organic crop rotations. The distribution of organic grazing fields is similar to the distribution of conventional grazing fields in Western Jutland and North Zealand (Figure 10.9).

Lucerne

Lucerne is used for dried pellets in cattle production and as a green manure crop.

Seed production

Clover

Denmark has a considerable production of white clover seeds, producing about 80 % of the total production of white clover seed in the EU. Seed production of clover takes place chiefly in Eastern Denmark at specialised arable farms, and white clover seed is particularly produced in the county of West Zealand and Storstrøm (Figure 10.10). This area is favoured by more sunshine and less precipitation during the summer than other parts of Denmark.

Production of organic clover seeds is being developed and Danish agriculture is almost self-sufficient in organic red clover seed, whereas growing white clover seed is very difficult. The average yield of organic white clover seed production is only approx. 25 % of the average yield in conventional seed production. The organic white clover seed fields are mainly located in West Zealand and Storstrøm and in North Zealand. To some extent, the production of organic white clover seeds is combined with animal husbandry. There are grass/clover pastures on the same farm and in the same region, for example in North Zealand (compare Figures 10.9 and 10.10).

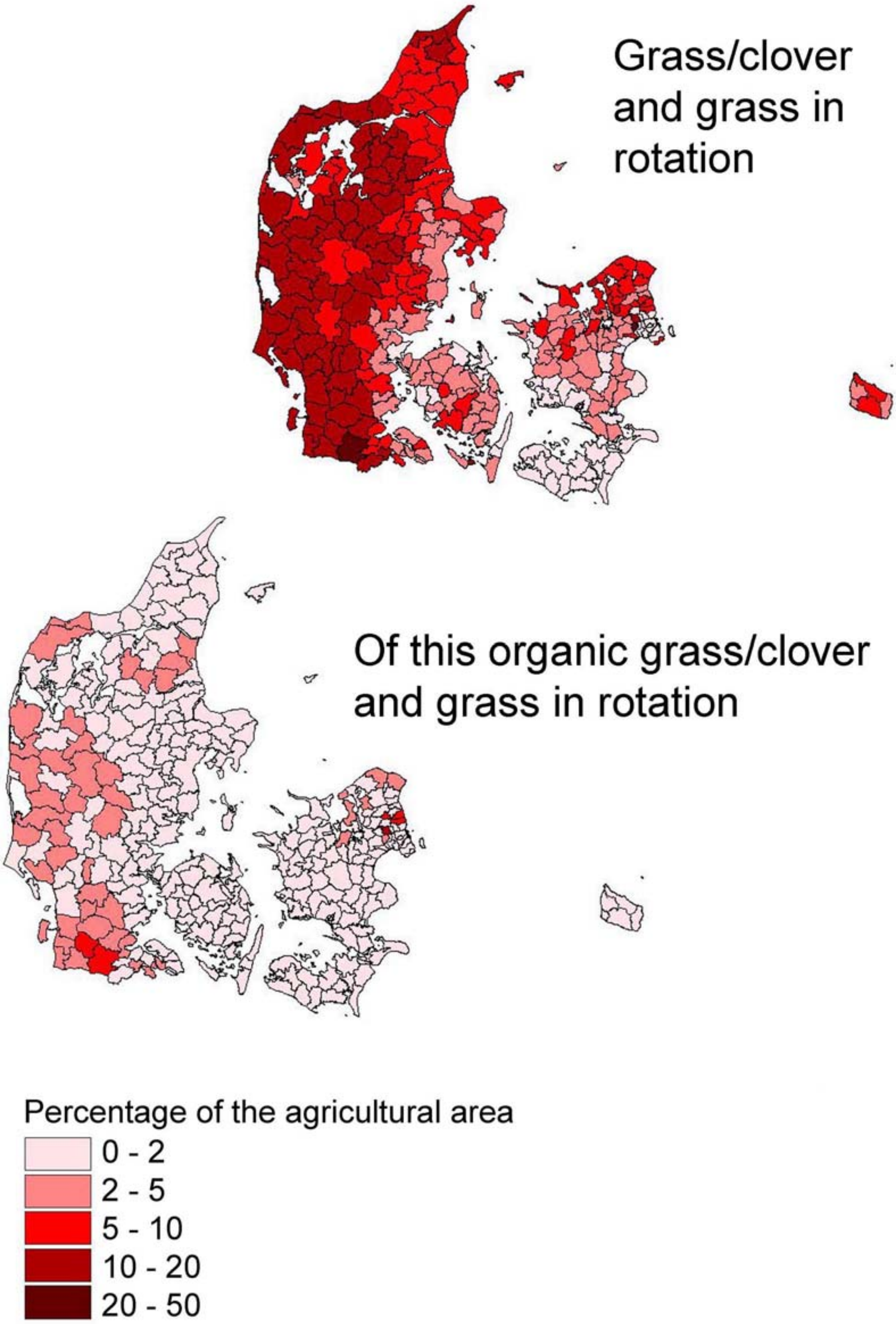

Figure 10.9. Geographical distribution of grass/clover rotational leys in Denmark, 2002 (Dalgaard & Kristensen, 2003).

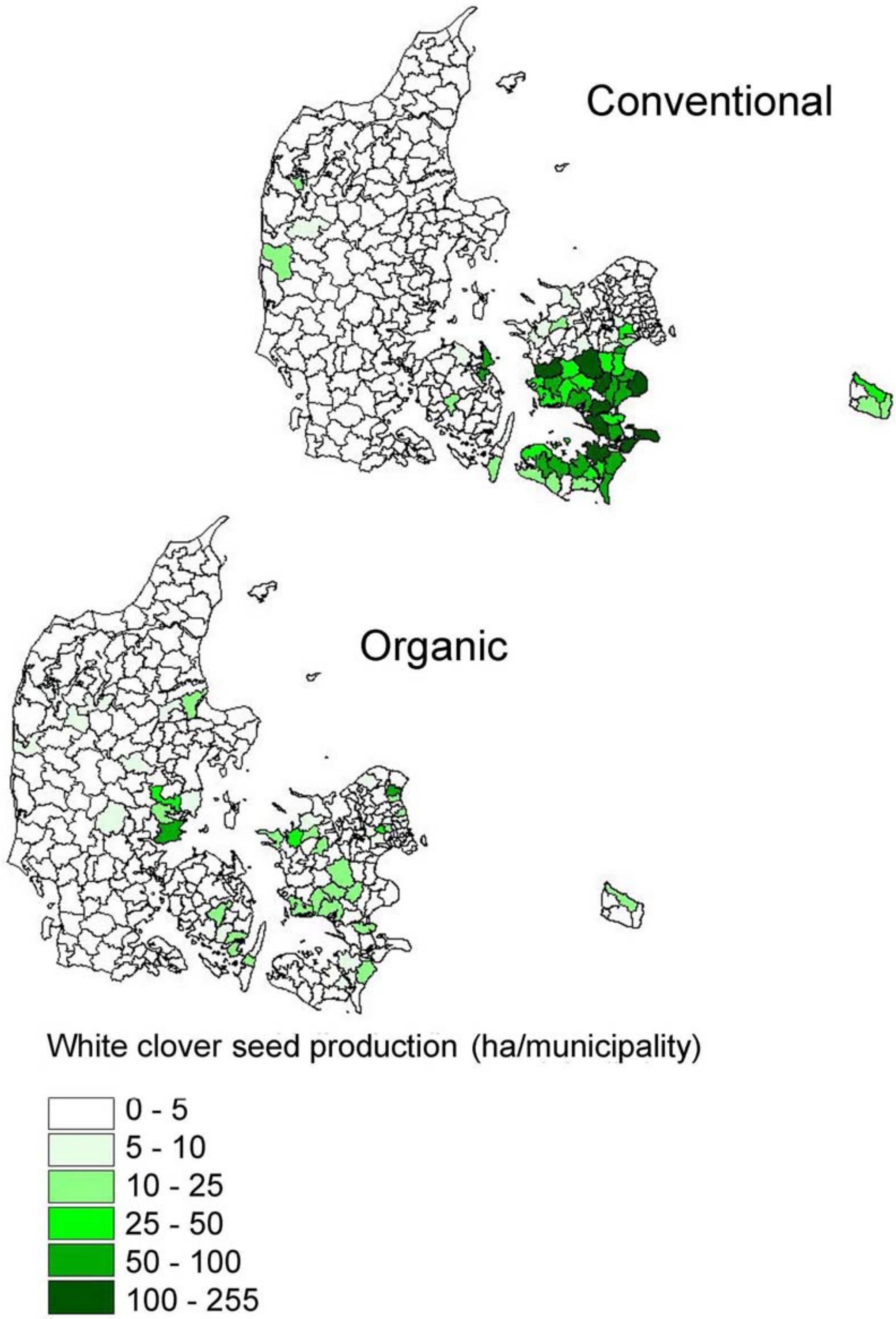

Figure 10.10. Distribution of white clover seed production in Denmark, 2002 (Dalgaard & Kristensen, 2003).

Seed production

Lucerne

Lucerne seed production is not of importance in Denmark. Organic lucerne seed is not currently available, but production is being attempted in France.

Experience with GM field legumes

At present, there is no commercial growing of GM clover in the EU, but there have been experimental plantings in Australia and Canada. GM varieties under development have drought resistance, virus resistance and improved quality characteristics.

There is no commercial growing of GM lucerne either, but there have been experimental plantings of GM lucerne in Spain, the USA, Canada, Argentina, New Zealand, South Africa and Bulgaria. In Canada, herbicide resistant lucerne varieties are ready for marketing.

Dispersal sources

Pollen dispersal

Clover

Clover crops depend on pollination by bees. The yield in red clover is thus 7-8 times higher in fields with bee pollination than without. In Denmark, clover pollination predominantly takes place through introduced honeybee hives, for which the farmer pays bee keepers, but naturally occurring bees are also very important to pollination.

White and red clover pollen is dispersed with the pollinating insects. Usually, the bees collect nectar and pollen as close to the beehive as possible, but where food supply is limited or if they find more attractive sources of pollen and nectar, they will fly far from the hive, up to 5 km (Williams, 1998). Similarly, bumblebees will fly up to 10 km. There is a certain degree of self-pollination of white clover flowers, but the deposited amount of pollen is insufficient to the development of ovules. Seeding depends on several visits by pollinating insects to the same flower (Rodet *et al*., 1998). Therefore, evaluations of pollen dispersal will tend to overestimate the gene dispersal (for elaboration, see chapter 10.8, pollen dispersal).

Generally, insect pollination is a more effective way of pollen dispersal than wind pollination, as the probability of seed set is higher (Levin & Kerster, 1974).

Only very few experiments have been carried out to determine the extent of gene dispersal as a result of insect pollination in white clover, and these were not carried out at the field level.

Studies have shown that pollination most often occurs with pollen from the flower that the bee visited last (Michaelson-Yates *et al*., 1997; Osborne *et al*., 2000). Pollination by bumblebees results in more extensive gene dispersal than dispersal by honeybees

(Michaelson-Yates *et al*., 1997), but honeybees are more effective pollinators (Marshall *et al*., 1999).

White clover has no wild relatives in Denmark, but it grows wild in field boundaries, verges, and similar habitats often in close proximity to cultivated types.

Clover pastures are perennial. Even though they are grazed intensively, flowering white clover can be found in clover pastures during the summer and autumn. Pollen dispersal between seed fields and grazing fields can occur. If pollination results in seeding, these seeds will have a chance of establishing in the pasture – especially if the plant density is low. The extent of this is not known.

Lucerne
Lucerne is also cross-pollinated by insects. Leaf-cutting bees are sometimes used for pollination in commercial seed production. As lucerne occurs naturally to a limited extent, pollen and gene dispersal can occur to these wild plants, for example yellow lucerne and hybrids with this species.

Bee-keeping
In 2002, the Danish Institute of Agricultural Sciences conducted a survey among a group of Danish expert bee-keepers of their attitude to GM crops in general and their significance for bee-keeping ("Tidsskrift for Biavl" 8/2002).

The result of this study, which is similar to experience from the USA, shows that there is a profound scepticism among Danish beekeepers of the presence of GM products in honey. This is due to both the personal attitude of the beekeepers and to the fear of problems with marketing honey, which is the main source of income for Danish beekeepers.

It is therefore foreseen that it will be difficult for growers of clover seed to persuade beekeepers to place their bee colonies in GM clover for pollination purposes. Indeed it is likely that beekeepers would actively move their beehives away from areas with known GM clover fields. As a bee colony can forage for pollen and nectar over an area of 28 km^2, the effect of the beekeepers' attitudes towards GM crops could be profound in relation to bee pollination of agricultural crops.

Seed dispersal
Clover
Clover seeds can develop "hard seeds", which can survive in the soil for up to 20 years (Thompson *et al*., 1997). The average presence of hard seeds over ten-years (1992-2001) in Danish-grown lots of white and red clover is 9.4 % and 6.7 %, respectively (Danish Plant Directorate, 2002). The share of hard seeds is largest in years with dry and hot weather during the seed ripening period. In studies from New Zealand, the share of hard seeds is 60-71 %

(Clifford, 1985). In the same study, the amount of hard seeds in the soil was 20 - 138 kg seeds/ha in areas in which seeds had been harvested within the previous four years.

The field germination percentage for white clover is about 50 % and a little higher for red clover. The low field germination percentage could be a result of the presence of "hard seeds", sowing in an unfavourable seedbed or sowing too deep. The seeds that do not germinate in the year of sowing or do not perish for other reasons are added to the soil seed bank and can germinate later and multiply in the crop rotation.

During the process of harvesting white clover seeds, large quantities of seeds could be lost. Studies from New Zealand report the loss at an average of 200 kg seeds/ha, of which 130 kg/ha are hard seeds. There are no recordings of seed loss under Danish conditions, but the loss is estimated to be lower than reported from New Zealand.

Length of viability of hard seeds is considered to depend on genotype, weather conditions during the development of the seeds and their location in relation to the soil surface (Hayley *et al*., 2002). Seeds of white clover, stored in the soil for 3 years in the ploughing layer without being disturbed, show a survival of <1 % (Jensen, 2002). This is not in compliance with other data. For example, Chancellor (1985) records that there were still viable seeds of white clover present in an area after growing annual field crops for 20 years with effective control of clover plants. This observation is supported by Lewis (1973) who found viable seeds of both white and red clover and lucerne after 20 years storage in undisturbed soil. Likewise, in a study by Roberts & Boddrell (1985), where simulated soil treatment took place, a fraction of seeds was viable 5 years after sowing. There are no data of hard seed content at the start of the above studies, and some of the discrepancies in the results could perhaps be due to a varying content of hard seeds in the initial seed material.

In addition to pollen and seed dispersal, white clover has vegetative dispersal through rooting stolons. All three species mentioned are difficult to control mechanically in other crops in organic crop rotations.

Chemical control of volunteers and plants in subsequent crop rotation
Only few of the approved herbicides can control clover. The most effective of the marketed active ingredients in Denmark are the so-called hormone-type weed killers. Mechlorprop and dichlorprop are more effective than 2,4-D and MCPA (Rolston, 1987). Danish experience has shown that white clover is more sensitive to MCPA than to 2,4-D, whereas the opposite applies to red clover (Ravn, 1973). A good effect can also be achieved with the active ingredients clopyralid and dicamba. All hormone-type weed killers are most effective when applied in the early stages of plant development.

The sulphonylurea herbicides, for example Express and Ally, have an effect on clover if they are used in full dosage. Application experience with sulphonylurea herbicides shows that the effect is often insufficient, which perhaps partly can be attributed to the frequent use of reduced dosages of these herbicides.

Contrary to the cultivated grasses, glufosinate is more effective against clover than glyphosate (Rolston, 1987), *i.e.* glufosinate resistant crops will give better possibilities of controlling clover volunteers than glyphosate resistant crops – provided that the clover is not herbicide resistant.

Lucerne
Like the clover species, lucerne can develop hard seeds (Hill *et al*., 1997).

Measures for managing crop purity
Separation distances
Pollen dispersal via pollinating insects will always be very difficult to reduce and impossible to completely avoid in seed production fields and pastures. To some extent, adjusting the number of beehives in the seed production field would reduce pollen dispersal. However, the seed grower will attempt to have a sufficient number of beehives to achieve a high seed yield. This also applies in years where the pollination period is very concentrated due to weather conditions. If the temperature is low for a period of time, the nectar production in clover is reduced and may stop altogether. In such cases, the bees will seek food at a larger distance from the beehive (5 km or more). Wild bees can have great importance for the seed set in clover. These bees have a foraging radius of 10 km.

As white clover fields are concentrated in certain regions of the country, it will not be possible to place these fields at distances that prevent pollen dispersal. Provisional calculations based on data from the Municipality of Haslev show that an increased separation distance will mean that fields cannot be placed freely in the crop rotation of the farm. There will very soon be a need for agreements between neighbours on locating white clover seed fields of up to 3 ha, but also for larger fields (15 ha) (Danish Institute of Agricultural Sciences, Department of Animal Breeding and Genetics, 2003). In the Municipality of Haslev, white clover seed production occupies 2.1 % of the agricultural area.

It is not possible to effectively prevent pollen and gene dispersal by cutting clover flower heads in grazing fields, verges and coverts, as the flower buds are usually positioned very low on the plant, and after repeated cutting, the flower stem becomes shorter. Provisional calculations based on data from the Municipality of Fredensborg-Humlebæk show that compliance with a separation distance of 250 m between seed production fields and pastures will cause problems in more than 80 % of all fields with a field size of 3 ha (DIAS, Department of Animal Breeding and Genetics, 2003). At a field size of 15 ha, it will cause problems in more than 50 % of the fields. A separation distance of 1,500 m would mean that no fields could be freely placed irrespective of its size. Fredensborg-Humlebæk has a large share of grazing fields (6.8 % of the agricultural area), with relatively many white clover seed fields (3.1 % of the agricultural area), and organic production (15.4 % of the agricultural area).

These provisional calculations do not include the impact of associated non-agricultural grass/clover areas.

Cropping intervals
To reduce the number of seeds that are added to the soil seed bank, areas should be left untilled after seed harvest until the end of the autumn or next spring. The purpose is to allow the decay of as many of the shed seeds as possible. However, this strategy would give the white clover the possibility of developing a densely ramified net of rooting stolons. Red clover and lucerne do not form rooting stolons, but they both have very well developed and deep root systems. Conversion of fields previously under grass/ legumes (both seed production fields and pastures) therefore presupposes careful ploughing. In order to minimise multiplication in the crop rotation, it is important to comply with the cropping intervals (5-7 years for growing of pre-basic/basic seeds and 3 years for growing of certified seeds) mentioned in the Ministerial Order on seeds, and to carry out an effective control of volunteers in the intervening years.

Buffer zones
Gene dispersal via seeds and rooting stems between the cultivated soil and clover in field boundaries can be reduced by maintaining a border of bare soil or a spring-sown cereal crop (working width).

It is uncertain whether a border of bee attracting plants around both donor and receptor fields will reduce gene dispersal.

Adventitious presence
The threshold value of adventitious GM presence in conventionally produced clover and lucerne seeds have not been established. The following assessments are carried out using an expected threshold value of 0.3 % for conventional seed and <0.1 % (the detection limit) for organic seed.

Clover
Seed: 0 % scenario with foreign GM growing:

- It is expected that it will be possible to comply with a GM content of <0.3 % in conventional seed production and <0.1 % in organic seed production in accordance with the Ministerial order on field seed.

Seed: 10 % and 50 % scenarios:

- At a moderate distribution of GM varieties, it is expected that additional measures must be initiated in order to achieve a GM content of <0.3 %. These additional measures consist of larger separation distances and increased cropping intervals.

- On the current basis, no guidelines can be suggested that would ensure organic clover seed production (especially white clover) <0.1 % GM contamination if GM white clover is introduced to Denmark. This is due to:

  - Pollinating insects being able to disperse pollen from GM fields across very large distances (up to 5 km).

  - The presence of hard seeds contributing to maintaining volunteers in intervening crops.

  - White clover being widely distributed on organic farms (in pastures, as manure crops and seed crops).

  - The impossibility of removing all flowering white clover heads effectively by cutting.

  - The difficulty of controlling white clover in organic farming.

Production (pastures): 0 % scenario with foreign GM growing:

- At the establishment of a pasture, certified seed is used, and no problems are expected to keep adventitious GM presence <0.8 % in conventional production.

- It should be possible to comply with a presence of <0.1 % in organic production fields provided that organic ("GM free") seed can be used for establishment, the suggested separation distances to GM fields are complied with and a cropping interval is introduced. At present, the supply of organic white clover seed is insufficient.

Production (pastures): 10 % and 50 % scenarios:

- If there is extensive use of GM varieties in conventional production, it is not currently possible to suggest control measures that would ensure an adventitious GM presence below the threshold value in perennial pastures.

- At moderate use of GM varieties, it is on the present basis not possible to suggest measures that ensure a GM presence of <0.1 % in organic clover/grass pastures.

Lucerne

Seed:

- There is no or only a small seed production of lucerne in Denmark.

Production: 0 % scenario with foreign GM growing:

- It is expected that it will be possible to maintain an adventitious presence of GM plants of <0.8 % in conventional production without introducing additional measures, provided that the field is established with organic or conventional "GM free" seed.

- It is expected that it will be possible to maintain an adventitious presence of GM plants <0.1 % in organic production without introducing additional measures.

Production: 10 % and 50 % scenarios:

- It is expected that it will be possible to maintain an adventitious presence of GM plants of <0.8 % in conventional production by using certified seed at establishment.

- It is expected that it will be possible to maintain an adventitious presence of GM plants of <0.1 % in organic production by using organic or conventional "GM free" seed at establishment.

Need for further knowledge

- Due to the wide distribution of white clover in Denmark, more knowledge on factors determining cross pollination and the extent of gene dispersal at the field level will be necessary to propose effective separation distances.

- The degree of invasion, establishment and introgression of genes/plants into perennial or permanent clover/grass swards depending of the nature of the sward and its management.

- Clover persists for a very long time in the soil - especially because of its ability to develop hard seeds. Initiatives to prevent/reduce the presence of hard seeds should be developed. Factors that influence the persistence of hard seeds should be studied to develop a model for predicting the presence of hard seed in the soil, in relation to cropping intervals and conversion time.

- In the long term, gene dispersal in clover at the regional level (clover seed fields, grass-clover leys, field boundaries, *etc.*) will be important for the level of adventitious presence. Therefore a monitoring programme to determine the extent of this gene dispersal should be initiated.

- The development of cropping systems to maintain varietal purity in seed fields will be of great importance to maintain Denmark's position as the leading clover seed producer in the EU both in conventional and in organic seed production.

- The possibility of making voluntary, regional agreements on the placing of GM white clover fields in relation to organic farms and pasture should be examined which take account of white clover being widespread in both conventional and organic farms and seed production taking place in areas using clover in pastures.

Conclusion

- White and red clover often have both pollen and seed dispersal, and white clover occupies a large proportion of Danish agricultural land for both forage and seed production. It also occurs commonly in non-cultivated areas in Denmark. The flower heads of white clover cannot be effectively removed by cutting, as flower buds develop very close to the soil surface, and the flower stems become shorter after frequent trimming. As a result, there is a high likelihood of dispersal of GM varieties both in and outside cultivated areas.

- For organic white clover seed production and both conventional and organic clover pastures, it is currently not possible to suggest control measures by which the adventitious presence of GM in the end product can comply with the specified thresholds.

- The possibilities of making voluntary agreements concerning the use and placing of GM areas in relation to seed productions areas should be examined. The reason for this is that it is judged very difficult to maintain a GM admixture level of <0.3 % and/or <0.1 % in future production in areas where white clover is used in pasture, green manure fields and in seed fields.

- Lucerne is almost exclusively used for forage production. Its distribution in Danish agriculture is relatively restricted, but it occurs outside cultivated areas in Denmark. Due to its limited distribution and use of lucerne, which is solely for forage it is not considered necessary to introduce further control measures to avoid adventitious GM presence.

(See also Table 2.8).

10.10 Field peas

Background

Field peas are usually grown for consumption and for silage crop, where it is used as a source of protein in feed mixes.

Crop area, Denmark, 2002

Conventionally grown grain peas:	34,000 ha
(of this seed 8,000 ha)	
Conventionally grown silage peas:	12,000 ha
Conventionally grown green peas:	3,000 ha
Organically grown grain peas:	3,000 ha
(of this seed 1,300 ha)	
Organically grown peas for silage:	4,000 ha
Organically grown green peas:	100 ha
Pea growing in total:	56.000 ha

Pea growing for various purposes occupies 2.1 % of the Danish agricultural area. Approx. 12 % of this is organic production. A large share of pea growing is concentrated in certain areas of Zealand and in Jutland (Figure 10.11).

Growing practice

Peas are primarily grown on medium or light soils, as peas perform relatively poorly compared to other crops on heavy soils.
Due to the risk of root diseases, there are at least 4-5 years between successive plantings. Peas generally precede cereals in crop rotations. The harvesting of silage crop peas is in July and grain peas usually takes place in August.
The domestic production of peas provides an alternative source of animal feed protein, to

farmers.

Experience with GM peas

There has only been one field release of GM peas in the EU. This was an experiment in Germany with a pea with altered starch synthesis and glufosinate tolerance. Experiments with GM peas in other countries include virus resistance, altered starch content, herbicide tolerance, insect and fungal resistance. GM peas have not yet been marketed.

As there has been a relatively limited GM experimental activity with field peas, no GM varieties are expected to be marketed in the EU in the next 5 years.

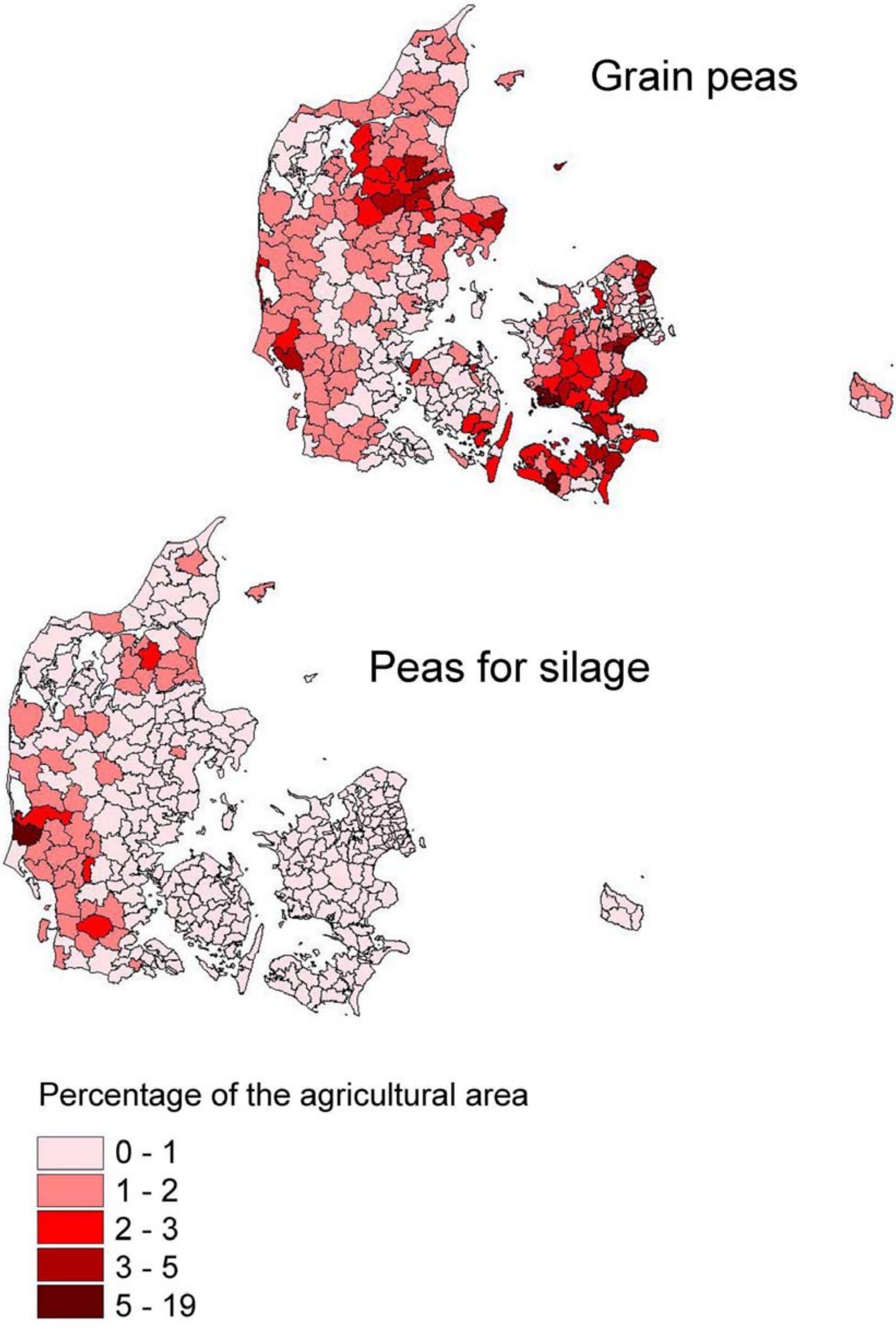

Figure 10.11. Distribution of pea growing in Denmark, 2002 (Dalgaard & Kristensen, 2003).

Dispersal sources
Peas do not have vegetative dispersal. The plant is an annual and usually does not overwinter in Denmark. The flowers are usually self-pollinated before they open. There is a very small amount of cross-pollination by bees. There is no cross-pollination with weeds or any wild relatives in Denmark.

As pea seeds are large and easily decomposed by heat and fungal attacks, the risk of dispersal with organic manure is small.

The seeds have no natural dispersal mechanism. Dispersal by seed-eating birds is assumed not to have any major importance, as the seeds cannot pass through bird gizzards without being damaged.

If the pods are ripe before harvest, they can burst at harvesting. Seed loss in the field during harvest of 310-600 kg seed/ha can occur (Højland & Poulsen, 1994). There is also a certain amount of seed loss during transport.

Under Danish conditions, the seeds will germinate, rot or freeze during autumn/winter and consequently the seeds do not survive cold winter conditions (Højland & Poulsen, 1994). There is therefore no risk of multiplication in the crop rotation.

Peas have a low competitive capacity compared with other species and will therefore only be established on exposed soil and survive for a short time outside cultivated fields in Denmark.

Measures for managing crop purity

- The most important control measure to reduce GM dispersal is the analysis and testing of seed for GM content.

The following control measures can also be relevant but are of less importance:

- The current separation distance is 1 m for both basic and certified seed. Based on the uncertainty of the extent of cross-pollination by insects, it should be considered whether the separation distances should be increased further to 10-50 m, depending on the circumstances. The largest separation distance should be when growing seed. This will considerably reduce the risk of GM dispersal.

- The current cropping interval of minimum 2 years is considered sufficient to avoid problems with volunteers.

- Admixture during transport and handling can be reduced through suitable labelling and segregation.

- Buffer crops (zones) could be an important alternative or supplement to separation distances.

- Monitoring and testing of gene dispersal from GM varieties to non-GM or organic fields will be appropriate if the current limited separation distances are maintained.

Adventitious presence
For imported seed, the main method for restricting GM presence are sampling and testing the seed. We suggest that the threshold value for seed is set at the lowest practical level for example 0.3 % for conventional seed.

The main measures for managing co-existence in production, consumption and feed are discussed below. Suggestions for managing different scenarios are shown in a summarised version (Table 2.9).

Seed: 0 % scenario with foreign GM growing:

- The use of conventional pea seed to supplement the need for organic seed will involve a small risk of GM presence, estimated, however, at < 0.3 %.

- By using "GM free" seed, the GM presence in organic seed production can be kept at ~0.1 % without using special control measures.

Seed: 10 % and 50 % scenarios:

- Use of certified seed, separation distances of 50 m and the cleaning of machinery and transport equipment are expected to restrict the presence to a maximum of 0.3 % in conventional seed growing.

- By using "GM free" seed, separation distances of 50 m and the cleaning of machinery and transport equipment, the GM presence in organic seed production can be kept at ~0.1 %.

Production: 0 % scenario with foreign GM growing:

- For conventional pea production, the GM presence is expected to be less than 0.3 % of the crop without additional measures.

- For organic pea production, the total GM content is expected to be ~0.1 % with the use of organic certified seed and without special measures.

Production: 10 % and 50 % scenarios:

- It is anticipated that the GM presence in conventional pea crops can be kept below 0.5 %, primarily through the use of certified seed, and to a smaller extent through the use of increased separation distances (10 m) as well as the cleaning of field machinery and transport equipment. It could also be appropriate to supplement these with the use of buffer zones.

- It is expected that the GM presence in organic pea production can be kept at ~0.1 %, primarily through the use of "GM free" seed, to a smaller extent through increased separation distances, the cleaning of field machinery and transport equipment. It could also be appropriate to supplement these with the use of buffer zones.

Need for further knowledge

The extent of cross-pollination in peas and the biological conditions on which it depends are insufficiently known. Additional knowledge on pollen dispersal by bees is necessary to establish critical separation distances.

Conclusion

- For both conventional and organic farming, the greatest risk of GM dispersal of peas comes from GM presence in seed. Through suitable precautions and seed testing, it is expected that it will be possible to maintain the GM content at low levels.

- Additional control measures in the form of moderately increased separation distances, the cleaning of farming implements and transport equipment can reduce the GM content to very low levels for both conventional and organic production.

(See also Table 2.9).

10.11 Field beans (Faba beans) and lupin

Background

The following species are considered: Field bean (*Vicia faba*) and lupin (white lupin (*Lupinus alba*), yellow lupin (*L. luteus*), blue lupin (*L. angustifolius*), and narrow-leaved lupin (*L. mutabilis*)). These species are predominantly cross-pollinated by insects, mainly bees. Some of the species also self-pollinate to a large extent without the use of insects.

Crop area, Denmark, 2002

Conventionally grown field beans:	700 ha
(of this 309 ha seed)	
Organically grown field beans:	250 ha
(of this 136 ha seed)	
Field beans in total:	950 ha
Conventionally grown lupin:	550 ha
(of this 64 ha seed)	
Organically grown lupin:	1,600 ha
(of this 395 ha seed)	
Lupin in total:	2,150 ha

Organic growing is approx. 27 % of the field beans growing and approx. 74 % of the lupin growing.

Growing practice

Field beans and lupin seeds have a high protein content and provide alternative protein sources to replace imported soybeans in animal feed.

In Europe broad bean covers only approx. 155,000 ha and lupins approx. 55,000 ha.

These species are of great interest in organic production because of their nitrogen-fixing capacity, their utility as protein feed and their useful effect in the crop rotation.

Experience of GM growing

In both field bean and the lupin species, basic research is carried out with insertion of different genes, but as yet no GM varieties are ready for registration. The species concerned are relatively poorly adjusted to the climate and growing practice in Denmark. Consequently, their yield is often variable. Bean and lupin have some problems with pests and diseases. In addition they contain some metabolites and amino acids, which reduce the use of the feed. It is likely that GM-based solutions to some of these problems will be suggested in the future.

Dispersal sources

- Pollen from feral populations.
- Imported seed with admixtures.
- Sowing and harvest machinery.
- Transport equipment from field to store.
- Storage and handling equipment.

The species are mainly cross-pollinated by insects, predominantly bees. Some of the species are also mostly self-pollinating without the use of insects. The consequence of bee activity is that pollen can be transported and transferred across large distances, whereas pollen is not transferred by wind pollination.

Field bean volunteers have a short lifetime in the soil under normal conditions, whereas some types of lupin form hard seeds, which are dormant and can survive for a long time in the seed bank.

For both species, 2 years' interval between crops of the same species is required in the production of certified seeds to avoid contamination of seed with volunteers.

Under Danish conditions, lupin can establish feral populations in field boundaries and in uncultivated areas, which can hybridise with crops. Hybrids can, establish and subsequently become a source of admixture for cultivated non-GM crops. By contrast, none of the species tend to appear as weeds in cultivated areas.

The species occur as wild plants in southern parts of Europe where outcrossing from genetically modified types could form the basis of introgression of GMOs in the seed production areas.

Possible control measures

As long as there is no growing of GM varieties of these species in Denmark or in the areas from which seeds are imported, there is no possibility of adventitious GM presence.

If the growing of GM varieties becomes common, adventitious presence of GMOs can be restricted by:

- Inspection of seed purity.
- Distance between fields with and without GM crops of the same species.
- Use of border zones with non-GM crops of the same species.
- Control of volunteers by avoiding deep cultivation and burial of the seeds.
- Regulations on intervals between GM and non-GM crops.
- Careful separation of GM and non-GM products.

Adventitious presence

Unlike oilseed rape and maize, there are no studies of dispersal frequency for field beans and lupin. The evaluation of separation distances to reduce adventitious admixture in organic or conventional crops must therefore mainly be based on experience from the production of certified seed.

Cross-pollination by bees will probably chiefly follow the patterns known from studies of oilseed rape (especially since beans and lupins are very attractive to bees). Insects can move and cross-pollinate with rape pollen at distances of up to 4 km or more. The frequency of this cross-pollination decreases quickly with increasing distance between the fields.

During the production of certified seed, a distance of 200 m from other fields with the same species is required for field beans whereas the corresponding distance for lupin is 100 m. With our present limited knowledge, it is uncertain whether these distances can ensure sufficient purity in the certified seed if GM varieties become commonly grown. A possibility could be to use a 400 m separation distance for the production of basic broad beans seed and growing of these crops. The same distance of 400 m could be used in future growing of GM varieties of these crops to protect against crossing into conventional and organic fields. This separations distance would probably restrict outcrossing from GM fields to conventional and organic fields below the detection limit of 0.1 %.

Control of volunteers in the autumn, 2 years' cropping interval between GM and non-GM crops of the same species, and control of germinated surviving seeds and of feral populations will maintain adventitious presence due to volunteers to insignificant levels.

If effective segregation of crop products is carried out, admixture during the handling of the material will be negligible. Many different, small lots in the hands of a large number of growers can significantly complicate effective segregation by merchants. However, in many cases, the crop is used directly as feed at the site of production, and if farm-saved seeds are not sown, there will not be any serious problems with adventitious presence.

Seed: 0 % scenario with foreign GM growing:

- It should be possible to keep the GM presence in conventional seed below 0.3 %.
- It should be possible to keep the GM content in organic seed at ~0.1 %.

Seed: 10 % and 50 % scenarios:

- It should be possible to keep the GM presence in seed for conventional production below 0.3 % with the present regulations on separation distance (400 m) and cropping intervals for the production of basic seed.

- In order to keep the GM presence in organic production at ~0.1 %, it is suggested that the seed is produced in special areas with no other cultivation of these species.

Production: 0 % scenario with foreign GM growing:

- It should be possible to keep the GM presence in conventional production below 0.9 % provided that imported seed is tested.

- It will also be possible to keep the GM presence in organic production at ~0.1 %, provided that only "GM free" certified seed is used for production.

Production: 10 % and 50 % scenarios:

- It should be possible to keep adventitious presence in conventional non-GM production below 0.9 %, provided that there is testing of imported seed, separation distances of 400 m and two-year cropping intervals.

- GM presence in organic production can also be kept at ~0.1 %, provided that there is testing of imported seed, separation distances of 400 m, a two-year cropping intervals after growing GM crops and the exclusive use of organic certified seed in the production.

Need for further knowledge

- The extent of cross-pollination and the variation between varieties is not well documented. Further knowledge on the effect of pollen dispersal by insects on the pollination and the decrease of dispersal with increasing distance into the field is necessary in order to determine separation distances.

Conclusion

- With the current lack of GM varieties of the species concerned, there is no risk of adventitious GM presence in conventional or organic production. This could change, if the 0 % scenario is maintained in Denmark but GM varieties are grown elsewhere. In that way, adventitious GM presence can occur through imported seed. In this situation, however, it should be possible through testing of imported seeds to keep the level of GM presence below the detection limit of 0.1 %.

- With a larger amount of GM crop growing, there will be more possibilities of adventitious GM presence. There will be an increased risk of adventitious presence in seed lots and especially admixture as a result of poor or inappropriate management, handling and transport.

- While these crops are not extensively grown in Denmark it should be possible to comply with required separation distances between GM and non-GM types of the species. Adventitious GM presence of due to cross-pollination can be kept very low. Therefore, it should be possible to keep adventitious presence below 0.9 % in most cases in conventional production without further precautions.

- Adventitious GM presence below the detection limit in organic products, by trading and use of the products should be achievable through the regulations of organic production and through only using certified organic seed for crop production.

(See also Table 2.10).

10.12 Vegetables seed production

Background
This chapter is limited to financially important vegetable species and species, which through the use of GM varieties could result in dispersal to other, cultivated crops

Crop area, Denmark, 2002

Conventionally grown carrots:	1,600 ha*
Organically grown carrots:	300 ha*
Carrot seed:	300 ha
Conventionally grown spinach seed:	3,000 ha
Organically grown spinach seed:	Small production

* Year 2000

Altogether approx. 5,300 ha of different vegetables are grown in Denmark corresponding to 0.2 % of the total cultivated area.

Denmark is the world's largest producer of spinach seed, and varieties (both open-pollinated and hybrid varieties) are propagated from both Danish and foreign variety owners.

The vegetable producers' requirements for seed are often very specific with regards to the form of production and distribution. Therefore access to a broad variety of material is crucial. Hybrid varieties of seed are in demand, as they typically give higher yields and very homogeneous products.

The supply of organic vegetable seed is generally very scanty, and the supply of "suitable varieties" is non-existing for many of the important vegetable species. For important vegetable species such as carrots, leek, onion and cabbage, organic seed of suitable varieties in 2002 was only available for leek and cabbage.

Experience with GM vegetables
Development of various GM varieties of cabbage, carrot, lettuce, onion and peas are going on in both Europe and the USA. (Pea is discussed in chapter 10.10).

Dispersal sources
Spinach
Spinach (*Spinacea oleracea*) is a cross-pollinator and is wind-pollinated. Denmark has an ideal climate for multiplication of late spinach varieties whose share of production has increased over the years. Multiplication of varieties from many foreign variety owners is carried out in Denmark, and the number of varieties for multiplication is very large.

These varieties interbreed very easily. In addition, there is a large share of hybrid seed production. Vegetable seeds, including spinach, are primarily approved as standard seeds where there are no official separation distances in the production of seeds, but the variety owners make strict demands for both varietal purity and for freedom from weed and other seeds.

Carrot

Carrot (*Daucus carota*) is a cross-pollinated by insects and can cross with wild carrot, which is widespread all over Denmark. The reproductive (flowering) form of carrot can occur, to a limited extent, during vegetable production. There is, also some limited carrot seed production in Denmark. The seeds can persist in the soil for a long time. At present, organic carrot seed of a "suitable variety" is not available. Therefore, GM characteristics can be introduced into organic farms via conventional seed, but carrot does not multiply in the crop rotations. There have been three GM experimental releases in the Netherlands.

Cabbage

The group of cabbage (*Brassica ssp.*) includes white cabbage, kale, red cabbage, sprouts, cauliflower, broccoli, savoy cabbage and kohlrabi all of which are cross-pollinated by insects and can interbreed. Cabbage flowers are very attractive to honeybees, and other flower-visiting insects. Within this group, there have been ten GM experimental releases in the EU. Denmark is an important producer of cabbage seed – especially of white cabbage. Currently there is no organic seed production. Introduction of GM into organic crop rotation can occur via imported seed with GM presence, as there is not a sufficient supply of organic seed of suitable varieties. (See also chapter 10.2).

Black radish and radish

Black radish and radish belong to the same species, *Raphanus sativus*, are cross-pollinated, interbreed and can cross with wild radish. There has been one GM experimental release in France. Seed production of both varieties takes place in conventional areas in Denmark. Black radish is sometimes used as catch crop in both conventional and organic crop rotations.

Possible control measures

The above-mentioned species are all cross-pollinated, and therefore pollen dispersal is an important route for dispersal. Possible control measures include regulations on the use of tested seed, separation distances, increased cropping interval and possibly the use of buffer zones (specifically the use of plants attractive to bees) and separate harvesting. Pollen and gene dispersal can also be avoided by growing in pollen-tight systems, for example in greenhouses or plastic tunnels. The rouging of flowering plants (for example flowering carrot umbels) will prevent GM dispersal to seed production areas within the same species and hybridisation with wild forms.

Adventitious presence

It is considered necessary to use “further measures” in the seed production of all crops mentioned above to achieve a GM content below 0.3 %. This could include seed testing, the use of separation distance, buffer zones, cropping intervals and crop rotation sequence. In vegetable seed production, initiatives for the limitation of pollen and seed dispersal already exceed good farming practices in most cases. This is mostly because most producers insist on very high levels of varietal purity in the material.

Need for further knowledge

- Several of the species mentioned above cross-pollinate with other Danish cultivated plants and weeds.

- Studies of pollen dispersal and frequency of gene dispersal are required in order to define the separation distances and of buffer zones required to restrict hybridisation with GM-crops.

- Development of cropping systems to maintain varietal purity in vegetable seed-growing areas, including studies of growing in pollen-free facilities.

Conclusion

- Not all vegetable species are discussed in detail in the present report. However, it is stressed that if the presence of GM is to be limited, it is necessary to initiate further measures beyond the current regulations. The control measures used can include seed testing, increased separation distances and cropping intervals, the removal of sexually reproductive plants in vegetable fields (for example carrot fields) and the use of buffer zones.

- The variety owner’s demands for purity and quality in these crops are already very high, and the production of vegetable seeds therefore already conforms to strict growing regulations, which surpass the current official regulations on distance, cropping intervals, *etc*.

- To maintain organic vegetable production free of GM plants, it is necessary to provide organic seed or conventional "GM-free" seed for varieties that comply with the production demands of the organic vegetable growers. Seed production in pollen-tight environments (for example in plastic tunnels) could provide this.

11. Economy

11.1 Costs to the first stage of distribution

As described in chapter 8, the dispersal of GM traits to non-GM crops can occur through seed, seed dispersal, pollen dispersal and outcrossing.

Introduction of GM traits can be avoided or minimised by adopting a number of measures in the growing and handling of the crops, as described in chapters 9 and 10.

On the basis of the measures previously stated, the extra costs of complying with a given threshold value for adventitious presence of GM material in crops are evaluated below.

The scope of the evaluations
For all the discussed crops, the evaluations include the costs in the primary production and at the individual farm until the 1st stage of distribution, *i.e.* when the first buyer assumes responsibility of the crop, corresponding to the part of the total production chain that is included in the Working Group's evaluations.

The Working Group is aware that there can also be considerable costs to maintain a GM free production chain from the farm gate to the consumer, as it in some cases will be necessary to establish and operate different production lines.

Three production chains for non-GM and GM production of sugar beet, oilseed rape and wheat, are considered here as examples. The production chains include the stages through to the end user. The examples chosen are representative of crops that are used directly as raw materials in the processing stages for either food or feed mixes.

Finally, an example is described of a compound food production from the reception of raw materials to the pre-packed consumer product.

The effects of any differences in the price relations between conventional and GM crops are not included in the evaluations.

Economic evaluation of co-existence management measures
The required measures can be summed up in 4 main areas:

- Use of GM-tested seed.
- Production management and daily routines.
- Planning of crop rotation and separation distances.
- Buffer zones, if any.

The use of GM-tested seed and possible buffer zones for particularly exposed crops are measures for conventional and organic growers to take.

By contrast changes in production management and daily routines can be relevant for all farms, whereas planning of crop rotations and separation distances are mainly measures for the GM-growers.

GM-tested seed and seed material

If a given threshold value in the primary production is to be ensured, seed and seed material must comply with threshold values of GM content. Therefore, it is necessary to carry out analyses of seed and seed material. This is especially relevant to the organic production where the use of GM material is not permitted. Here, it must be expected that all seed and seed material is to be tested. The costs of these tests vary according to whether it is detection of a GM presence or for quantification of the GM content in a seed lot.

For example, can be taken test of an oilseed rapeseed lot produced in Denmark and intended for certified organic seed. Provided that the ordinary seed test sample can also be used for the GM test, there will be no extra sampling costs.

The GM detection test costs 1,400 DKK/lot, and if the analysis is negative, there will be no extra testing costs. If the analysis is positive, there is the option of carrying out an analysis of the level of GM content so that the lot could be used for conventional seed (if it is below the threshold value). This analysis costs 1,100 DKK/lot.

If no original sample is available (foreign, certified seed), a sampling fee in the order of 800-900 DKK must be added the prices above.

A GM analysis of all seed and seed material will increase the price of seed and seed material, and the final level of testing will depend on the threshold level and must be expected to be determined on the basis of a risk assessment. However this increase in price will be moderate for most crops and depend on the amount of seed used for the individual crop.

The increased costs of GM testing of seed and seed material were not calculated for individual crops and are therefore not included under the individual crops.

Farms that today use farmyard manure, slurry and straw from other farms can with an extensive growing of GM crops envisage an increased demand for GM free farmyard manure, slurry and straw. This has not been taken into account in the evaluations.

Starting point for the evaluations
As described, adventitious presence can be avoided/minimised by adopting a number of measures at farm level. They typically fall into two categories:

- Production management and daily routines.
- Planning of crop rotation and separation distances.

Production management and daily routines
The control measures are described in chapter 9 and 10 with a starting point corresponding to "good farming practice", which means that the described measures are additional measures to "good farming practice".

As a starting point, a farm size of 50 ha with an average field size of 5 ha is used, by and large corresponding to the average farm size for both conventional and organic farms and the average of field sizes in the applications for area payments. However, it must be taken into account that the real size of the field often exceeds 5 ha, as several sub-fields often are grown with the same crop as a whole field.

The extra costs here mainly consist of:

- Cleaning of machinery and storerooms.
- Extra care in separation of crops during transport and storage.

Basic testing, documentation and record keeping are presumed to be included in "good farming practice". There will, however, be considerable differences in costs from farm to farm of complying with the regulations and the measures adopted.

For farms producing certified or basic seed or other contract productions, the management routines will already be familiar.

It is assumed that certified and GM-tested seed and seed material are used in all crop production.

Table 11.1 shows the estimated costs of the individual measures on a 50 ha farm with an average field size of 5 ha. This is higher than the average Danish field size of 3.8 ha, but it must be taken into account that fields that lie close together are often cultivated jointly.

Table 11.1. Conventional and organic farm – estimated costs of specific/additional measures to maintain crops below GM thresholds.

Control of volunteers conventional organic	200 DKK/ha 300 DKK/ha
Cleaning of soil treatment machinery	60 DKK/cleaning
Cleaning of sowing machines potato planters	100 DKK/cleaning 30 DKK/cleaning
Cleaning of harvest machinery/lifters oilseed rape and other small-seed crops cereals, pea, lupin and broad bean potato and beet crops for silage	 250 DKK/cleaning 185 DKK/cleaning 60 DKK/cleaning 90 DKK/cleaning
Cleaning of drying and storage facilities cereals, seed storage box for potatoes	 1,000 DKK/farm/year 25 DKK/ha
Cleaning of transport material	30 DKK/cleaning
Other:	-

Field size 5 ha. Hourly wage: 125 DKK
Farm size 50 ha.

The presented unit costs will figure in the calculations for the individual crops to the extent that they are relevant. It is assumed that the level of costs is identical for organic and conventional farms apart from control of volunteers. It must be stressed that the estimates of extra costs presented in the table cover even very large variations between the individual farms.

In the evaluations of costs, it is assumed that all machines are used for both GM and non-GM crops, as the use of contractors and joint machinery among several farms is increasing in agriculture in general. On properties with only non-GM production and own machinery, the costs will be relatively low.

When using contractors or using machinery jointly with other farms, there will be both opportunities for cost savings and an increased safety by using the machinery first for non-GM crops to the extent that this is practically possible.

Crop rotation and separation distances

Adventitious presence of GM volunteers from previous crops can be minimised through adjustments in the crop rotation and changes in soil tillage methods. The costs of crop rotation adjustments and changes in soil tillage methods are not estimated, as it is assumed that they can be made without any major economic consequences.

The distance between non-GM conventional and organic fields and GM fields is stated as one of the most important measures for restricting outcrossing. The separation distances are from 1 m up to 1,500 m for particularly vulnerable crops.

The costs of complying with the given separation distances are not estimated. It is anticipated that these adjustments can be carried out through location of the GM crop, as it is assumed that the GM grower must make sure that the separation distances are complied with.

As stated in chapter 4, the number of surrounding fields that can be affected will increase with increasing separation distances. Other things being equal, this will increase the time consumed for neighbour contacts to ensure that the separation distance to all relevant fields is complied with.

For GM crops with bee pollination, the bees can be a source of pollen dispersal between GM crops and conventional and organic crops.

Here, it may be necessary to change the traditional procedures of for example placing beehives in crops, just as it could be necessary in certain cases to use plants attractive to bees to restrict the numbers of bees entering the GM field or nearby no-GM field.

Buffer zones

For certain crops, the separation distances can be supplemented by buffer zones to achieve an additional reduction in outcrossing with the GM crop. It is generally recommended that buffer zones are placed around the recipient (ie conventional or organic) field.

A rectangular field of 5 ha (500 x 100 m) has a perimeter of 1,200 m, and it is assumed that there is a buffer zone on one side of the field and a turn strip, altogether 600 m. For certain seed crops, it will, however, be a question of buffer zones around the whole field.

The following assumptions were used in the cost evaluations:

<u>Buffer zones up to 6 m</u>

- Cutting: Cost of cutting + lost contribution margin for the cut area.
- Bare soil in the field edge: Cost of cultivation + lost contribution margin for the treated area.
- Spring barley in the field edge: Difference in contribution margin between main crop and spring barley.

- Separate harvesting of field edge: The harvested crop can be sold for 75 % of the price of the main crop, as it is a GM-mixed commodity and a very small lot. Organic crops are the same price as the conventional GM-mixed commodity.

Cutting, bare soil and separate harvesting are all almost at the same level of costs, depending, however, on the number of cultivations or cuttings during the growing season, whereas spring barley as buffer zone in most cases will result in somewhat lower costs.

As the choice between cutting, cultivation or separate harvesting will depend on the crop being grown, separate harvesting of the field edge is used as an example in the crop specific evaluations.

Crop specific cost evaluations
The analysis for the individual crops is carried out at field level taking the strategy for co-existence of the Minister for Food, Agriculture and Fisheries as its starting point, and it is assumed GM and non-GM crops (of the same species) are **not** both grown on the same property.

Based on the general costs stated above, the costs of the individual crops are evaluated on the basis of adventitious GM presence levels and control measures as described in chapter 10. The evaluations are carried out for no GM growing and for GM growing.

Winter oilseed rape

Crop: Oilseed rape – conventional

Average growing costs: 5,000-5,500 DKK/ha (budget estimates 2002)

Extra costs DKK/ha

	No GM growing	GM growing
Certified seed	-*	200 DKK/ha **
Commercial crop	-***	450 DKK/ha ****

* Regulations on certified seed.
** Effective control of volunteers.
*** Good farming practice.
**** Effective control of volunteers and cleaning of machinery and storage facilities.

With widespread growing of GM crops, separate harvesting of a buffer zone 6 m wide on the edge of the field could be required, which will cost in the order of 200 DKK/ha.

Crop: Oilseed rape – organic

Average growing costs: 4,800-5,100 DKK/ha (budget estimates for organic crops 2002)

Extra costs DKK/ha

	No GM growing	GM growing
Certified seed	-*	300 DKK/ha**
Commercial crop	-*	550 DKK/ha***

* Regulations on organic, certified seed and effective control of volunteers.
** Effective control of volunteers.
*** Effective control of volunteers and additional cleaning of machinery and storeroom.

With widespread growing of GM crops, separate harvesting of a buffer zone 6 m wide on the edge of the field could be required, which will cost in the order of 600 DKK/ha.

Maize

Crop: Maize: Conventional/organic

Average growing costs, conventional: 5,800-6,200 DKK/ha (budget estimates 2002)
Average growing costs, organic: 7,000-7,400 DKK/ha (budget estimates organic crops 2002)

Extra costs DKK/ha

	No GM growing	GM growing
Silage/feed	-*	80 DKK/ha**

* Good farming practice.
** Cleaning of machinery.

Sugarbeet

Crop: Sugarbeet– conventional

Average growing costs: 10,000-11,000 DKK/ha (budget estimates 2002)

Extra costs DKK/ha

	No GM growing	GM growing
Certified seed	-*	-*
Factory beets/fodder beets	-**	300 DKK/ha***

* Present regulations on basic seed are considered to be sufficient.

** Good farming practice.

*** Control of bolters in fields and boundaries and cleaning of machinery.

Crop: Sugarbeet – organic

Average growing costs: 10,000-11,000 DKK/ha (budget estimates organic crops 2002)

Extra costs DKK/ha

	No GM growing	GM growing
Factory beets/fodder beets	-*	450 DKK/ha**

* Regulations on organic growing.

** Control of bolters in fields and boundaries and cleaning of machinery.

Potato

Crop: Potato – conventional

Average growing costs (excl. sorting): 20,000-21,000 DKK/ha (budget estimates 2002)

Extra costs DKK/ha

	No GM growing	GM growing
Seed material	-*	-*
Production		
Food potatoes	-**	290 DKK/ha***
Processing/ Starch potatoes	-**	260 DKK/ha***

* Growing in accordance with the departmental order on potatoes.
** Good farming practice.
*** Control of volunteers and cleaning of machinery.

Crop: Potato – organic

Average growing costs (excl. sorting): 20,500-21,500 DKK/ha (budget estimates organic crops 2002)

Extra costs DKK/ha

	No GM growing	GM growing
Seed material	-*	-*
Production		
Food potatoes	-**	390 DKK/ha***
Processing/Starch potatoes	-**	360 DKK/ha***

* Growing in accordance with the departmental order on potatoes.
** Regulations on organic growing.
*** Control of volunteers and cleaning of machinery.

Cereals

Crop: Barley, wheat, triticale, oats – conventional

Average growing costs: 4,500-6,200 DKK/ha (budget estimates 2002)

Extra costs DKK/ha

	No GM growing	GM growing
Certified seed	-*	-*
Feed cereals, malt barley, bread wheat	-**	80 DKK/ha***

* Regulations on production of certified seed.

** Good farming practice.

*** Cleaning of machinery and storage facilities.

Crop: Barley, wheat, triticale, oats – organic

Average growing costs: 5,000-5,400 DKK/ha (budget estimates organic crops 2002)

Extra costs DKK/ha

	No GM growing	GM growing
Certified seed	-*	-*
Feed cereals, malt barley, bread wheat	-**	80 DKK/ha***

* Regulations on production of organic, certified seed.

** Regulations on organic production.

*** Cleaning of machinery and storage facilities.

Rye

Crop: Winter rye – conventional

Average growing costs: 4,900-5,400 DKK/ha (budget estimates 2002)

Extra costs DKK/ha

	No GM growing	GM growing
Certified seed	-*	-*
Bread rye, feed rye	-**	80 DKK/ha***

* Regulations on production of certified seed.
** Good farming practice.
*** Cleaning of machinery and storage facilities.

Crop: Winter rye – organic

Average growing costs: 4,300-4,700 DKK/ha (budget estimates organic crops 2002)

Extra costs DKK/ha

	No GM growing	GM growing
Certified seed	-*	-*
Bread rye, feed rye	-**	80 DKK/ha***

* Regulations on production of organic, certified seed.
** Regulations on organic production.
*** Cleaning of machinery and storage facilities.

Feed and lawn grasses

Crop: Feed and lawn grasses – conventional

Average growing costs: 5,700-6,200 DKK/ha (budget estimates 2002)

Extra costs DKK/ha

	No GM growing	GM growing
Certified seed	-*	-*
Production - feed	-**	-**

* Growing according to the departmental order on seeds.
** Good farming practice and use of certified seed.

If GM-crops are widely grown, it may be relevant to separately harvest a 6 m wide buffer zone at the edge of the field, which will cost in the order of 300-400 DKK/ha.

To avoid flowering seed stems, it may be necessary to trim grazing fields twice during the growing season. This will cost in the order of 600 DKK/ha grazing field.

Crop: Feed and lawn grasses – organic

5,700-6,200 DKK/ha (budget estimates organic crops 2002)

Extra costs DKK/ha

Use	No GM growing	GM growing
Certified seed	-*	-*
Production - feed	-**	-**

* Growing according to the departmental order on seeds.
** Regulations on organic growing.

If GM-crops are widely grown, it may be relevant to separately harvest a 6 m wide buffer zone at the edge of the field, which will cost in the order of 1,200-1,300 DKK/ha.

To avoid flowering seed stems, it may be necessary to trim grazing fields twice during the growing season. This will cost in the order of 600 DKK/ha grazing field.

Grassland legumes

Crop: Grassland legumes – conventional

Average growing costs: 5,500-6,500 DKK/ha (budget estimates 2002)

Extra costs DKK/ha

	No GM growing	GM growing
Certified seed	-*	-*
Production - feed	-**	-**

* Growing according to the departmental order on seeds.
** Good farming practice and use of certified seed.

If GM-crops are widely grown, it may be relevant to separately harvest a 6 m wide buffer zone at the edge of the field, which will cost in the order of 300-400 DKK/ha.

It may be necessary to cut grazing fields twice during the growing season to remove flowering heads. This will cost in the order of 600 DKK/ha grazing field.

Crop: Grassland legumes – organic

Average growing costs: 5,500-6,500 DKK/ha (budget estimates organic crops 2002)

Extra costs DKK/ha

	No GM growing	GM growing
Certified seed	-*	-*
Production - feed	-**	-**

* Growing according to the departmental order on seeds.
** Regulations on organic growing.

If GM crops are widely grown, it may be relevant to separately harvest a 6 m wide buffer zone at the edge of the field, which will cost in the order of 1,200-1,300 DKK/ha.

It may be necessary to cut grazing fields twice during the growing season to remove flowering heads. This will cost in the order of 600 DKK/ha grazing field.

Field pea

Crop: Field pea – conventional

Average growing costs: 4,200-4,900 DKK/ha (budget estimates 2002)

Extra costs DKK/ha

	No GM growing	GM growing
Certified seed	-*	-*
Feed	-**	-**

* Production according to regulations on certified seed; however, with increased separation distances if GM crops are moderately or extensively distributed.

** Good farming practice; however, with increased separation distances if GM crops are moderately or extensively distributed.

Crop: Field pea – organic

Average growing costs: 5,800-6,400 DKK/ha (budget estimates organic crops 2002)

Extra costs DKK/ha

	No GM growing	GM growing
Certified seed	-*	-*
Feed	-**	80 DKK/ha***

* Regulations on production of organic, certified seed.

** Regulations on organic growing.

*** Cleaning of machinery and storage facilities.

Field bean and lupin

Crop: Field bean and lupin – conventional

Average growing costs: 4,300-5,000 DKK/ha (basis 2002)

Extra costs DKK/ha

	No GM growing	GM growing
Certified seed	-*	-*
Feed	-**	-**

* Regulations on production of certified seed.
** Good farming practice.

Crop: Field bean and lupin – organic

Average growing costs: 5,900-6,500 DKK/ha (budget estimates organic crops 2002)

Extra costs DKK/ha

	No GM growing	GM growing
Certified seed	-*	-*
Feed	-**	-**

* Regulations on organic, certified seed.
** Regulations on organic growing.

Conclusion

- The costs of complying with the given threshold values of GM content for crops of maize (for silage), potato, cereals, field pea, broad bean and lupin are in the range of 0-2 % of the total growing costs for both conventional and organic production.

- For oilseed rape, sugarbeet, feed and lawn grasses and grassland legumes, the costs are 3-9 % of the average growing costs for conventional production. The costs for feed and lawn grasses and for grassland legumes include both buffer zones and cutting of production fields at extensive distribution of GM production.

- For organic production, the costs are 8-21 % of the average growing costs. The higher costs of the organic production are a result of the costs of controlling volunteers and buffer zones.

- The level of GM cropping has almost no affect on costs, as, based on the current knowledge, there was no basis for distinguishing between different levels of GM cropping in the choice of measures. For this reason the costs of the use of separation distance and cropping intervals are not estimated.

- It has to be noted that the stated levels of costs in many cases are based on estimates, both in relation to the choice of control measures and the costs of implementing them. With more experience and knowledge of co-existence management and impacts is acquired, the control measures will be adjusted for a number of crops and changes in costs will result.

11.2 Production chains

Examples of production chains for sugar beet, oilseed rape and wheat are described below. The purpose is to evaluate the possibilities of ensuring separation between non-GM and GM products later in the processing chain as well as the costs derived from this. The three crops chosen cover crops used directly as raw material in the further stages of processing, either in food or feed mixes.

For sugar beet and oilseed rape, herbicide resistant GM plants are used as examples, whereas for wheat it is a so-called phytase wheat with an increased phytase activity. It is assumed that the phytase wheat is treated as conventional wheat as far as growing is concerned.

The production chains for sugar beet and oilseed rape include the chain from growing to finished consumer products following processing. The chain for phytase wheat includes growing and handling the grain and milled products through to processing into a compound feed mix.

The costs of separate non-GM and GM productions are calculated for the primary producer until the first stage of distribution, and from the first stage distribution until the finished product, respectively.

The distribution of possible savings and extra costs has not been evaluated among the different participants from farm to fork, as this depends on the market position of the individual participants.

An example of introducing a GM free production line by an existing producer of processed foods' is shown below. The analysis covers the production from the reception of raw materials to the pre-packed, frozen product. The cost analysis does **not** include any changes in the cost of raw materials.

The costs of maintaining all segregated products are added to the costs of the GM production line.

Sugar production
The production chain for sugar is based on long-term contracts between the growers and the factory. Thus, there is complete awareness between the players in the chain. The beets are delivered to the factory according to a delivery schedule fixed in advance, which means that the factory controls when each grower delivers their beet.

Sugar production takes place as a campaign; that is, the processing of the beets begins in early autumn and goes on until all sugar beets are processed.

A non-GM production of 80 % and a GM production of 20 % of the total production are assumed.

A production, alternating between conventional beets and GM beets during the campaign, is not considered to be realistic, due to the very high costs of cleaning to make the change from GM beets to non-GM beets.

Therefore, a solution will be chosen in which the non-GM beets are processed first whereas the GM beets are processed last in the campaign. This is possible as the factory, as mentioned above, controls the time of delivery from the individual growers.

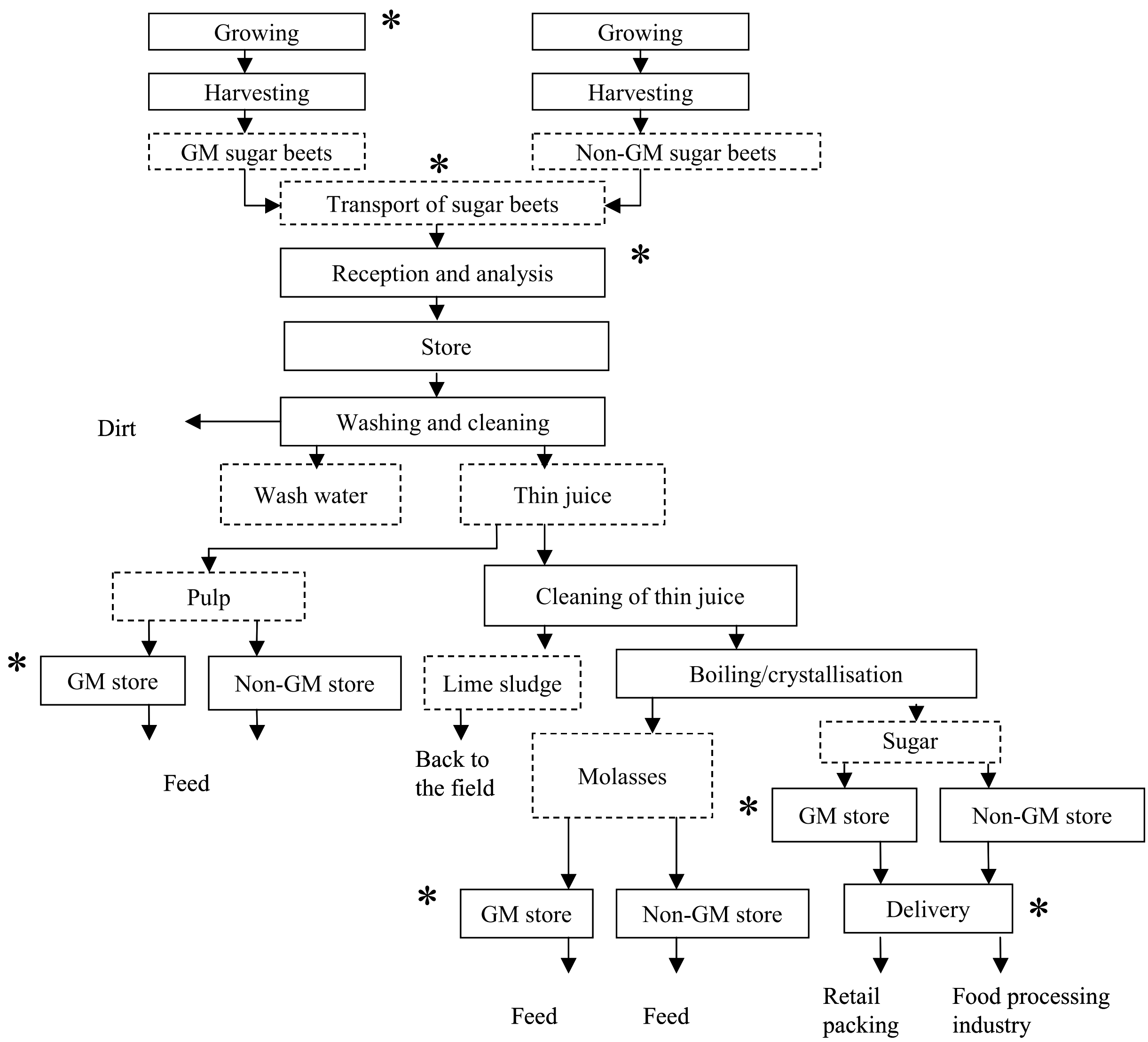

Figure 11.1. Production flow chart for sugar.
* Critical production steps

The main product is refined sugar, either directly for the retail stage or for industrial purposes. The by-products are sold as feed.

The production chain is outlined in Figure 11.1, and the critical production steps in relation to co-existence are marked with an *.

Critical production steps – sugar

Growing

A glyphosate resistant sugar beet is used as an example.

In the GM beet the use of herbicides and cost of herbicides can be reduced significantly achieving good weed control.

There will be increased costs for GM seed and co-existence measures in connection with the growing of the GM crop.

Transport

Transport can be a possible source of admixture of GM-containing material, but with the delivery schedule stated here all non-GM beets will be delivered first.

Analysis/sampling

After weighing, a sample is taken of every load, which is analysed for a number of parameters, for example sugar content and dirt content, that form the basis of payment to the individual grower. As the delivery schedule is known and therefore also the distribution of non-GM growers and GM growers, little more needs to be done to ensure co-existence.

Processed Products store

The processing of the sugar beet result in 3 products: Sugar, molasses and pulp.

As the storage facilities as a minimum must be able to hold the part of the production that is not sold during the campaign, it will be necessary to duplicate the storage facilities for handling additional GM products.

At packing and despatching, there will be a number of increased testing expenses to ensure segregation of the products.

Costs – sugar

Table 11.2 shows the percentage extra costs compared with the total costs.

Table 11.2. Extra costs of GM/non-GM sugar production.

Farmer	Percentage change in growing costs
Crop protection (savings)	-15
Seed	+2.4
Management measures	+2.8
In total	-9.8

Sugar production (factory)	Percentage increase on total costs
Costs of capital (extra storage facilities , *etc*.)	+2
Costs of capital (extra inspection, analysis)	+0.1
In total	+2.1

The extra costs have all been added to the GM production chain and must be distributed among the three products pulp, molasses and sugar.

Due to the nature of sugar production, it is relatively simple to process both conventional and GM beets at the same plant. The major costs are for extra separate storage capacity for the finished goods.

At a larger share of GM beets, it could be relevant to use a plant for GM production only, but the possible savings must be compared with the increased costs of transport for the beets.

Rapeseed oil

The oil factory buys its raw material (rape seed) partly from merchants and partly directly from individual farmers. There is therefore not complete awareness between the oil factory and the individual rapeseed producer.

Based on an 80 % conventional and 20 % GM production, it will probably not pay to establish a parallel GM line at the existing hot crushing and refinery plants. Due to the keeping time of rapeseed oil an alternating production is assumed with monthly shifts between GM and non-GM production. A shift between GM and non-GM production involves a shut down and cleaning of the processing line. As the production of rapeseed oil includes hot crushing and subsequent refining it is necessary to stop production at both processing units, the cleaning will take 6 and 12 hours, respectively. Shift between non-GM and GM production takes place without production stop.

The main product is refined rapeseed oil, which goes either directly to the consumer or to the food industry. In addition, there is a by-product in the form of rapeseed cakes, which is used in feed or feed mixes.

The production chain is outlined in Figure 11.2, where the critical steps are marked with an *.

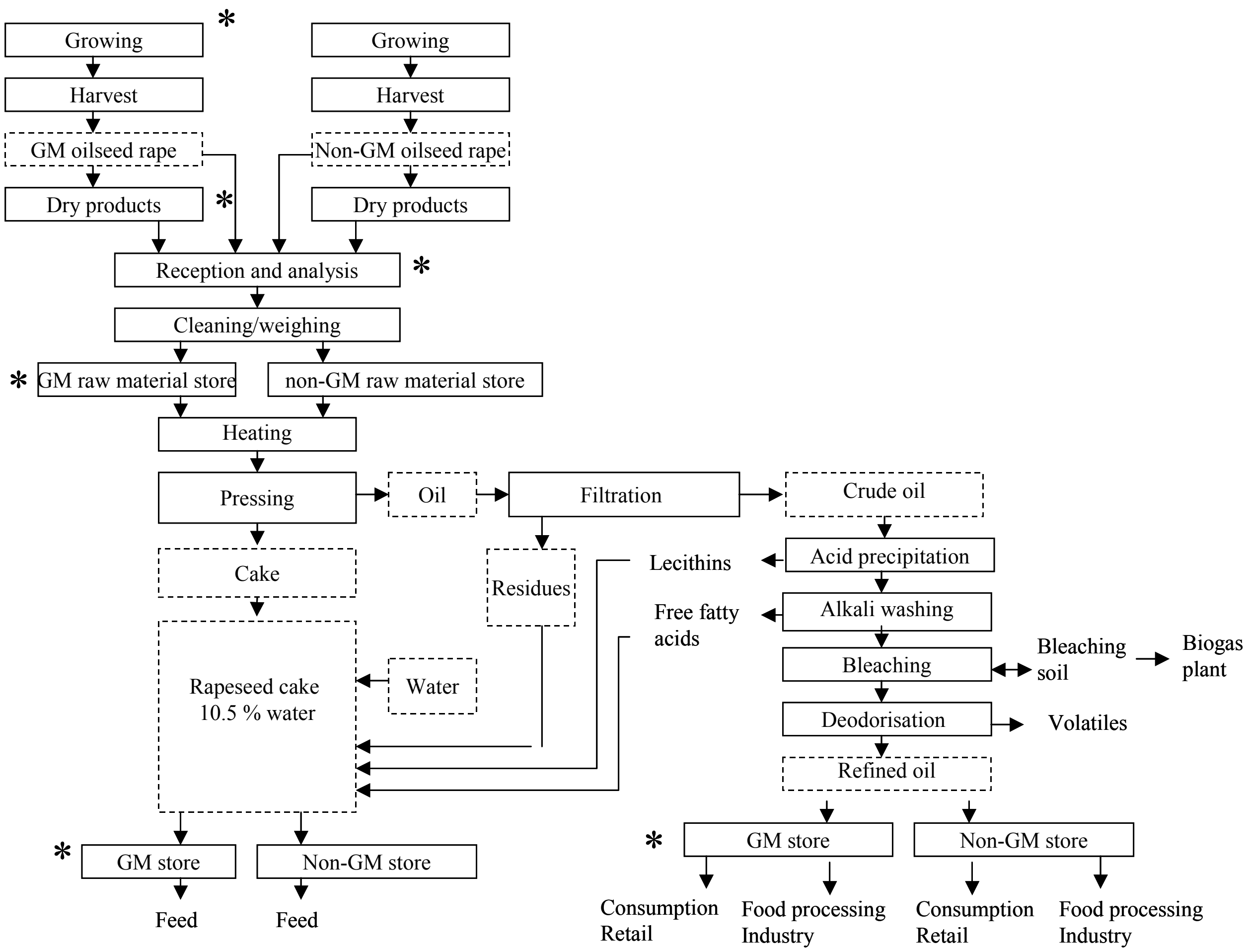

Figure 11.2. Production flow chart for oilseed rape.
* Critical production steps

Critical production steps – rapeseed oil

Growing

A glyphosate resistant oilseed rape is used as an example. In growing, a small reduction in the consumption/cost of herbicide can be expected together with a high level of weed control.

There will be increased expenses for GM seed and co-existence measures in connection with the growing of the GM crop.

Delivery to rapeseed factory

Delivery of rapeseed lots from the individual oilseed rape grower and other places of delivery (ports and grain stores) mean that the lorries must be cleaned of seeds remaining from previous loads. However, the cleaning of lorries is not regarded as an important change compared with the usual practice.

Reception
The next critical step emerges in connection with the reception of oilseed rape at the plant. Here, it will be necessary to test and analyse each lot reported to be non-GM oilseed rape. The extent of testing and analysis can vary considerably depending on the size of the lot and on the supplier. All oilseed rape that is not GM oilseed rape must be tested, and if many small lots are supplied by the individual farms, this will involve considerable additional expenditure.

Storage capacity
After processing, the oil is put into tanks, and a typical plant already has several, separate tanks installed. In that respect, it is not necessary to invest in extra storage capacity, but it will be important to clearly label and trace each batch of oil. However investment in separate storage capacity for the GM oilseed cake will be necessary. With this production, the store must cover an annual capacity of 2,000 tonnes of rapeseed cake. Rapeseed cake is used for feed, and it is assumed that it is shipped continuously from the plant.

Shipping
The rapeseed oil is delivered to the end-user and transported in tank lorries. To ensure that there is no oil residue in the tanks, each tank lorry with GM rapeseed oil must be cleaned before it can be re-used for non-GM rapeseed oil.

Costs – rapeseed oil
The total intake, in this example, is 90,000 tonnes (dry weight) of rapeseed per year; of this is produced:

- 30,000 tonnes oil and
- 60,000 tonnes rapeseed cakes.

GM oilseed rape is 20 % of the total intake of rapeseed, and it is assumed in the example that all costs are distributed between both the GM rapeseed oil and the GM rapeseed cake (that is 6,000 + 12,000 tonnes a year).

Even though the rapeseed cake to some extent can be characterised as a by-product of the production of rapeseed oil, it is reasonable to assume that the production costs are distributed between both lines, as the production of rapeseed cakes is an integrated part of the oil production. It is also assumed that the costs are not distributed among all the whole production (90,000 tonnes) but only on the GM oilseed rape.

Table 11.3 presents the total extra costs of handling a GM oilseed rape line (together with a non-GM line) seen in relation to the production of non-GM rapeseed oil only.

Table 11.3. Extra costs at handling of a GM oilseed rape line.

Farmer	Percentage change in growing costs
Crop protection (savings)	-3.5
Seed	+3.0
Co-existence measures	+8.5
In total	+8

After 1st distribution stage	Percentage increase on total costs
Inspection and analysis	4
Primary processing: Rapeseed factory	1.27
Further processing (refining)	1.1
Extra storage capacity	1.02
Washing of tank lorries handling rapeseed oil	1.62
In total	9
Administration	5
Total costs, administration inclusive	14

The extra cost of having a combined GM and non-GM production amounts to approx 14%, if the costs are solely distributed on the production of GM rapeseed oil (6,000 tonnes), the extra costs will amount to 27 % on the total process costs.

It appears from Table 11.3 that the costs of testing and analysis make up an important share of the total extra costs. This is due to the fact that it is assumed that each non-GM oilseed rape lot is tested before it goes into processing.

GM phytase wheat

GM phytase wheat is a feed wheat with a high content of phytase. Phytase is an enzyme that improves the phosphorus absorption from feed in monogastric animals. A high content of phytase in the feed can replace the addition of phosphorus in the feed and thereby reduce the discharge of phosphorus in manure.

In principle, GM phytase wheat can be handled in 2 ways:

- The phytase wheat is processed on the farm into a feed so that the farmer can save on the addition of phosphorus or phytase to the feed.
- The phytase wheat is delivered to merchants who forward it to animal feed processors, where it forms part of ready-mixed feed for pigs.

In this report, only the use in ready-mixed feed is discussed.

Phytase wheat is a crop with specific characteristics, and it will be necessary to separate phytase wheat lots from conventional wheat if the characteristics of phytase wheat are to be exploited in the production of feed.

It is therefore assumed that the phytase wheat is grown on contract and that the grain merchant knows which phytase wheat lots are being grown by which farmer, and it is also assumed that the farmers who grow GM wheat have the capacity to keep it segregated from conventional wheat. Otherwise, it will be necessary to invest in extra storage capacity and testing on the farm.

At present, both GM and non-GM feed ingredients are produced, and the non-GM feed ingredients are distributed to both conventional and organic feed producers. The production of feed mixes with GM raw materials (mainly soya protein) is about 90 % of the total production.

Phytase wheat will be used in GM feed mixes, which means that separation between phytase wheat and non-GM wheat only will be relevant in the farmer-to-merchant/or feed processor part of the chain.

Based on the structure of the feed trade, where there are more than 30 feed factories in DK at present producing pig feed mixes, it is assumed that GM feed mixes are produced at plants designated only for GM-production.

GM and non-GM feed mixes can also be produced at the same factory, but this will involve a thorough and time-consuming cleaning in the change from GM production to non-GM production as well as minor expansion of reception and issue facilities.

The handling and logistics system for GM phytase wheat and conventional wheat by the merchants and processors is illustrated in Figure 11.3. The critical production steps are marked with an *.

The chart includes the possibility of handling non-GM and GM productions at the same factory, as the possibility of separate storage is included.

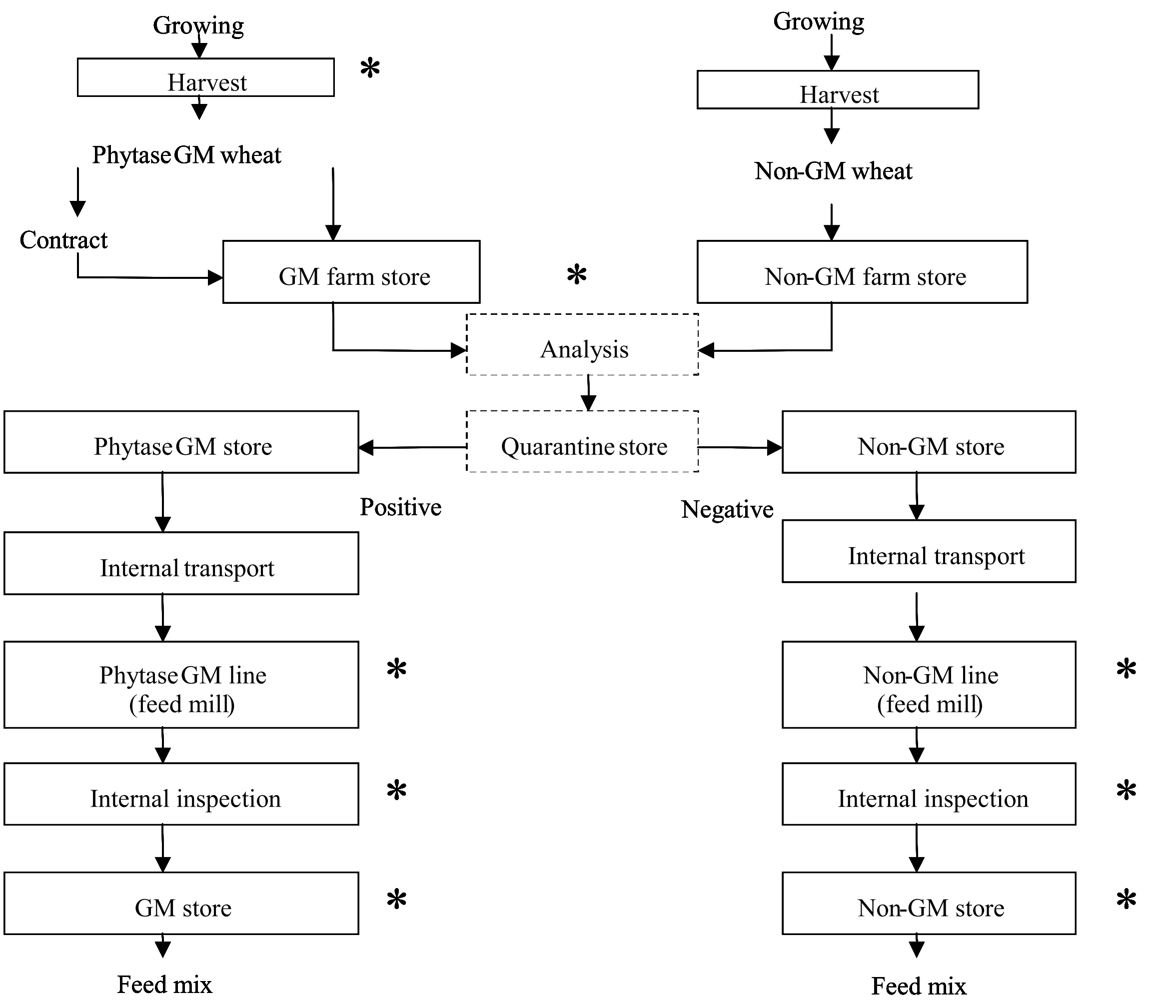

Figure 11.3. Production flow chart for GM phytase and conventional wheat.
*Critical production steps

Critical production steps – phytase wheat

Basically, there are 3 stages in the production chain that are critical in connection with the use of GM phytase wheat:

- Transport equipment must be cleaned before being used for non-GM wheat.
- Non-GM feed must be tested and analysed at reception at the quarantine store (grain store) or at the feed mill.
- Transport equipment for pig feed must be cleaned before being used for non-GM feed mixes.

Growing
It is assumed that phytase wheat is grown like conventional wheat, yield and basic growing costs are therefore not changed. There will be expenses for more expensive GM seed and co-existence measures of GM growing.

Delivery from farm store to factory quarantine store plus internal transport
On delivery of grain from the farm to factory, the transport equipment at the quarantine store must be cleaned after use, as the transport equipment possibly are needed for conventional grain later. At the same time, the cleaning of transport equipment for transport of processed feed must be ensured, but this expense is considered to be minimal (due to large lots) compared with transport between the farm store and the quarantine store.

Analysis and quarantine store
The next critical step comprises testing and analysis of the grain at the local quarantine store or at the feed mill. It is assumed that all lots are analysed unless there is a specific certificate.

There will be no extra costs for storage capacity, as it is assumed that the local merchant's store typically handles several kinds of grain lots and qualities at several stores. It is also expected that the quarantine store does not cause additional major expenses compared with normal handling. It is, however, important to stress that phytase wheat, unlike for example GM oilseed rape and GM sugar, is a GM crop with other characteristics as regards use than conventional wheat. In that respect, it is just as important that the GM phytase wheat is kept separate from other non-Phytase wheats so that the feed characteristics are preserved.

Mill
As the production of non-GM feed mixes takes place at specified industrial plants, there are no problems of separation during the actual production. If production takes place at a at a plant with production of both GM and non-GM mixes this will involve a thorough cleaning of all processing machinery and handling equipment at the change from GM production to non-GM production.

Transportation to final destination
The last critical step is the delivery from the feed mill/store to the end-user (pig farms). In this stage, it will be necessary to clean transport equipment of dust and residue before they are used for non-GM products. Transport costs can also be higher due to longer transport distances.

Administration
Production and handling of non-GM and GM feed mixes will also involve extra administrative and auditing costs.

Costs – phytase wheat
The additional costs are distributed as shown in Table 11.4.

Table 11.4. Extra costs of separating non-GM and GM phytase wheat.

Farmer	Percentage change in growing costs
Seed	+1.4
Control measures	+1.5
Increase in total	+2.9

Merchant and Feed processor	Percentage increase on total costs
From farm store	6
Analysis	3
GM store and non-GM store at local grain merchant	0
Transport to final destination	11
In total	20
Administration	4
Total inclusive administration	24

The total extra costs of co-existence between the two production lines constitute an increase of about 24 %. The costs are defined as the extra processing costs involved in logistics, analyses and production, exclusive of costs for raw materials. The costs that can be related directly to handling of phytase wheat constitute an increase in the order of 10-13 %. In combined non-GM and GM production at the same feed mill, it will be possible to keep the total extra costs at the same level, but the allocation of costs on the individual entries will change, as there will be expenses for cleaning and separation at the plant whereas the expenses for transport are expected to decrease.

11.3 Economic consequences in actual food production

To ensure the consumers a free choice between GM free and GM foods, it is necessary to effect a separation in the production process from farm to fork. Based on an example from a producer of foods, the possibilities of effecting this separation in the last processing stage of the production chain are described.

The economic consequences of separate productions in the enterprise concerned are evaluated on the assumption that 50 % non-GM production and 50 % GM production are in effect. It is a Danish enterprise, which produces frozen convenience foods/meals, and the basis of the evaluation is the enterprise’s standard product, which contains the following ingredients:

Cabbage, water, wheat flour, beef, maize starch, soya protein, rapeseed and palm oil, eggs, whey powder, soya sauce, salt, onion, bouillon, (glucose syrup, vegetables, yeast extract, animal protein, spices and vegetable extracts), spices and garlic.

In Figure 11.4 below, the production flow chart from the reception of raw materials to the finished product is illustrated.

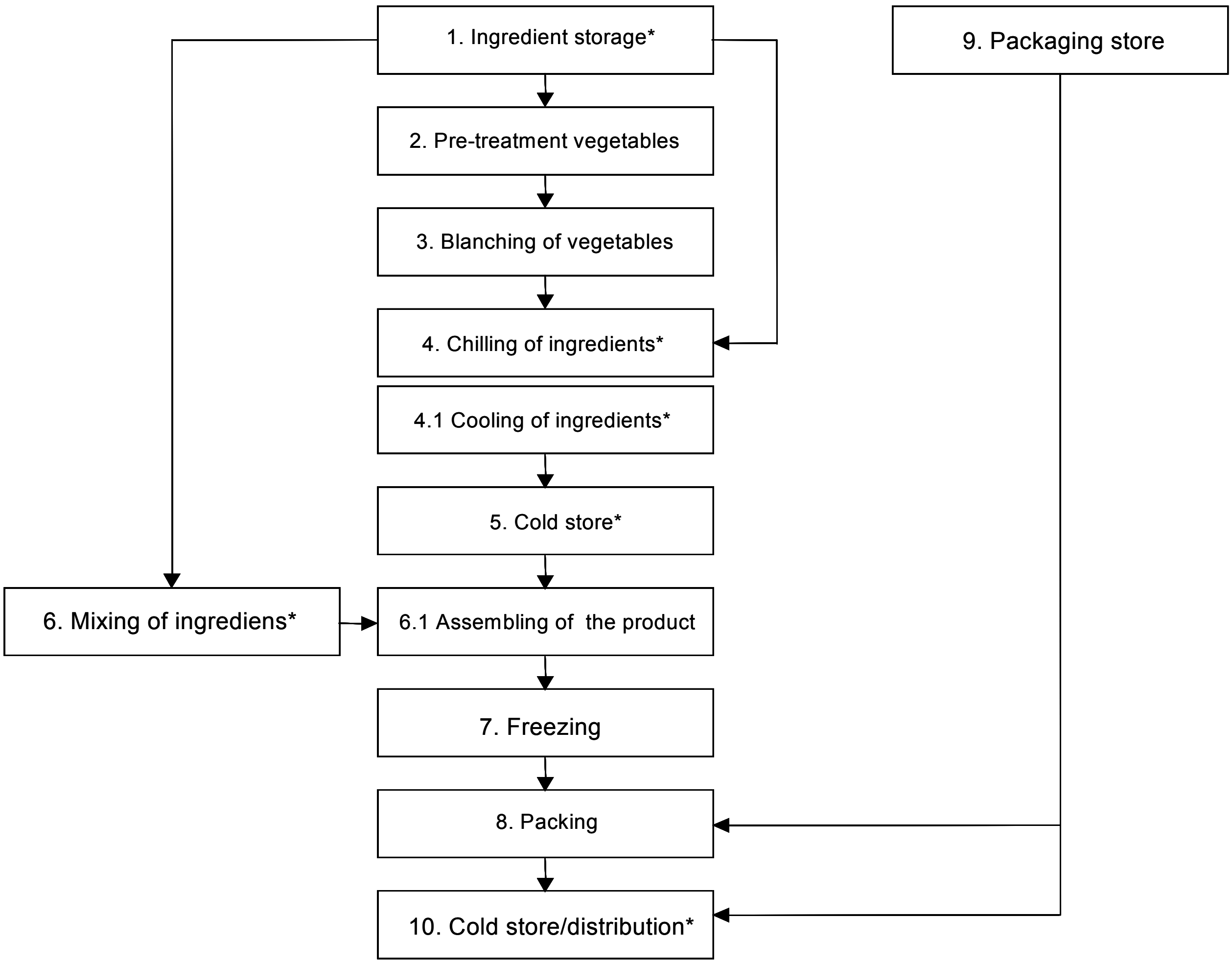

Figure 11.4. Production flow chart for a non-GM and a GM standard product.
* Critical production steps

Critical production steps

Under the individual levels in production, the critical production steps (marked with an * in the figure) and the possible corrections are described that should be made as a result of introducing a GM processing line in the enterprise's current production system.

The following 5 critical steps in the production of this product can be identified.

Storage of ingredients

- Increased separation of stores and documentation of separation of ingredients.
- Increased inspection at reception.
- Increased inspection of stores.
- Increased documentation.

Boiling/frying of ingredients / chilling of ingredients

The production at levels 2, 3 and 4 (*see* Figure 11.4) must be adjusted on the basis of general problems of separation, which also exist at present in the current production set up. In a combined production, there will for example be a possibility of producing GM products at the end of the day. This can be done because production is based on two shifts with cleaning of the production machinery during the night.

However, extra cleaning between the production shifts could become necessary, as an enterprise that produces to order will have trouble at times in planning production, so that a change in the planned production processes in relation to production time and quantity is inevitable.

Storage of chilled products

- Increased inspection of stores.
- Increased documentation.

Mixing of ingredients

Here, it is necessary to produce various ingredient mixes. This will require investment in separate stores for the GM ingredients. The remaining products are currently handled in small lots, and changes in the production process will therefore be minimal.

Cold store/store

In the processing stages 8, 9 and 10, there will be no major changes at the introduction of a GM processing line. The most important steps here will be increased inspection of stores and the documentation of inspection. However there will be minor changes at the packing stage, as separate packaging and labelling will be necessary. In addition, there will be a minor increase in the funds tied up, due to an increase of the stocks as a result of a GM processing line.

It must be mentioned that the training of staff will be an important element in the introduction of a GM processing line. In addition, a decrease in efficiency during the implementation phase must be expected. The extent of the decrease can be compared with the decreases experienced at implementation of other processing elements and branches of production. Apart from a temporary decrease in efficiency, there could also be a general decrease in efficiency due to an increased change of products in the production.

Costs – specific food production
Table 11.5 takes its basis in the enterprise's total annual production of the standard food product concerned.

Table 11.5. Survey of % relative changes in costs and % total increased costs.

Costs category	% relative changes in	% increase in total costs
Manpower (adm. and prod.)	+14 %	4.0 %
Costs of machinery	+6 %	1.0 %
Depreciations	+38 %	1.5 %
In total		6.5 %

The survey shows a total percentage increase of 6.5 % in the costs of production. The first column shows the relative changes in the individual items of expense as a result of co-existence, exclusive of expenses for raw materials. It must be noted that depreciation increases by 38 %. This is due to a number of new investments, which are necessary to ensure the non-GM processing line. The costs in the right column are defined as the total extra processing costs associated with production, exclusive of expenses for raw materials. Further, it is assumed that the costs are added to the production of GM products, which are 50 % of the total production. The total costs will of course be reduced if the costs are distributed on the total production.

11.4 Conclusion – Production chains

The above examples of production chains show that is possible both technically and administratively to effect a separation of non-GM and GM products.

The Danish processing and food industry already has very high levels of production and quality management, which means that a separation of the different productions can be effected with greater reliability for the consumer.

However, some costs are involved in introducing new separate productions. As the examples show, the costs depend to a great extent on the complexity of the production chain and the character of the products.

For sugar with a relatively simple production chain and a long-life product, one production change a year will suffice. The extra costs of separate production are therefore as low as a few per cent.

For rapeseed oil, with a more complex production chain and a product with shorter keeping time, frequent production stops for cleaning are necessary between the non-GM and the GM productions. The deliveries of raw materials from many suppliers result in considerable expenses for analyses and inspection. The extra costs of introducing a separate production are about 14 %.

The merchants and processors of feed mixes constitute a very complex production chain with many stages and checkpoints, where both production and use of feed mixes must take place continuously to ensure quality. The extra costs of separate production are about 24 % if production takes place at separate feed mills, of which 10-12 % can be directly related to handling of phytase wheat.

The costs in the processing stage are calculated exclusive of the costs of raw materials, and the farmers possible savings/costs of GM growing are therefore not included in the calculations.

The example of a compound food product with 50 % conventional and 50 % GM production shows that it is possible to effect a separate production with a high degree of reliability.

A thorough cleaning of the processing plant is carried out every day, and it is possible to start with a non-GM production every day in a clean processing line. The GM production can then be placed last in the daily production period. The extra costs are estimated at 6-7 % of the total costs, exclusive of expenses for raw materials.

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Annex 1

Table 1. Survey of approved GM plants in the EU, June 2003.

GM plant (*transformation event*)	**Characteristics**	**Use**	**Date of approval**
Tobacco (*ITB 1000 OX*)	Herbicide tolerance	Cultivation	8/6/1994
Oilseed rape (*MS1; RF1*)	Male sterility Herbicide tolerance	Multiplication	6/2/1996
Soybean (*GTS 40-3-2*)	Herbicide tolerance	Import	3/4/1996
Chicory (*RM3-6; RM3-4; RM3-6*)	Male sterility Herbicide tolerance	Multiplication	20/5/1996
Maize (*Bt-176*)	Insect resistance Herbicide tolerance	Cultivation	23/1/1997
Oilseed rape (*MS1; RF1*)	Male sterility Herbicide tolerance	Cultivation	6/6/1997[1)]
Oilseed rape (*MS1; RF2*)	Male sterility Herbicide tolerance	Cultivation	6/6/1997[1)]
Carnation (*4 lines*)	Changed colour of the flower	Cultivation	1/12/1997
Oilseed rape (*Topas 19/2*)	Herbicide tolerance	Import	22/4/1998
Maize (*T25*)	Herbicide tolerance	Cultivation	22/4/1998
Maize (*MON 810*)	Insect resistance	Cultivation	22/4/1998
Maize (*Bt-11*)	Insect resistance Herbicide tolerance	Import	22/4/1998
Carnation (*1 line*)	Increased life	Cultivation	20/10/1998
Carnation (*6 lines*)	Changed colour of the flower	Cultivation	20/10/1998

[1)]: Still not formally approved by France who originally received the applications.

Table 2. Applications for approval of GM plants under consideration in the EU, June, 2003 (from the EU home page http://gmoinfo.jrc.it).

GM plant (*transformation event*)	**Characteristics**	**Use**	**Date on the EU home page**
Oilseed rape (*GT73*)	Herbicide tolerance	Import	22/1/2003
Maize (*NK603*)	Herbicide tolerance	Import	22/1/2003
Maize (*NK603xMON810*)	Insect resistance Herbicide tolerance	Import	22/1/2003
Potato (*EH92-527-1*)	Changed starch	Cultivation	3/2/2003
Oilseed rape (*Ms8xRf3*)	Male sterility Herbicide tolerance	Cultivation	7/2/2003
Soya bean (*A2704-12* and *A5547-127*)	Herbicide tolerance	Import	7/2/2003
Sugar beet (*T9100152*)	Herbicide tolerance	Cultivation	7/2/2003
Oilseed rape (*T45*)	Herbicide tolerance	Import	10/2/2003
Cotton (*1445*)	Herbicide tolerance	Cultivation	14/2/2003
Cotton (*531*)	Insect resistance	Cultivation	14/2/2003
Oilseed rape (*Falcon, GS40/90pHoe6/Ac*)	Herbicide tolerance	Cultivation	14/2/2003
Sugar beet (*H7-1*)	Herbicide tolerance	Cultivation	14/2/2003
Maize (*1507*)	Insect resistance Herbicide tolerance	Import	14/2/2003
Maize (*GA21xMON810*)	Insect resistance Herbicide tolerance	Import	17/2/2003
Maize (*1507*)	Insect resistance Herbicide tolerance	Cultivation	17/2/2003
Oilseed rape (*Liberator pHoe6/Ac*)	Herbicide tolerance	Cultivation	17/2/2003
Maize (*GA21*)	Herbicide tolerance	Import	17/2/2003
Maize (*MON863 and MON863xMON810*)	Insect resistance	Import	17/2/2003
Fodder beet (*A5/15*)	Herbicide tolerance	Cultivation	3/3/2003

Annex 2

Legislation referred to in chapter 5

Council Directive 90/220/EEC of 23 April 1990 on the deliberate release into the environment of genetically modified organisms. *Official Journal L 117, 08/05/1990 P. 0015 – 0027.*

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. *Official Journal L 106, 17/04/2001 P. 0001 – 0039.*

Consolidated environment and genetic engineering act. Act no. 981 of 3 December 2002. http://www.retsinfo.dk/_LINK_0/0&ACCN/A20020098129 (In Danish).

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. *Official Journal L 189, 29/07/2003 P. 0036 – 0047.*

Regulation (EC) No 1829/2003 of the European Parliament and of the Council of 22 September 2003 on genetically modified food and feed. *Official Journal L 268, 18/10/2003 P. 0001 – 0023.*

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. *Official Journal L 268, 18/10/2003 P. 0024 – 0028.*

Draft Commission Directive of…….amending Council Directives 66/401/EEC, 66/402/EEC, 2002/54/EC, 2002/55/EC, 2002/56/EC and 2002/57/EC in particular as regards additional conditions and requirements concerning the adventitious or technically unavoidable presence of genetically modified seeds in seed lots of non-genetically modified varieties and the details of the information required for labelling in the case of seeds of genetically modified varieties.