ENABLING THE COEXISTENCE OF GENETICALLY MODIFIED CROPS AND CONVENTIONAL AND ORGANIC FARMING IN FINLAND
MID-TERM REPORT

31 May 2005

Expert Work Group on Coexistence
Ministry of Agriculture and Forestry
Finland

To the Steering Work Group for the coexistence of genetically modified crops and conventional and organic farming.

The Ministry of Agriculture and Forestry appointed an Expert Work Group in February 2004 to prepare the recommendations for measures and instructions for enabling the coexistence of genetically modified crops and conventional and organic agricultural products in Finland.

The task of the Work Group was to draw up a report on the 1) agronomical methods enabling the coexistence of crops, 2) economic impacts of coexistence and responsibilities, and 3) regional measures which should be applied to crop species and types of production suited for the Finnish conditions (e.g. sowing seed production vs. other crop production), 4) administrative decisions and changes in the legislation which may be needed as well as new control and inspection systems to be introduced.

The Work Group was chaired by Agricultural Counsellor Kirsi Heinonen and the secretary was Senior Research Officer Jussi Tammisola from the Department of Food and Health of the Ministry of Agriculture and Forestry. The members were (deputy members in brackets) Juha Palonen (Outi Kostama) from the Department of Agriculture and Tero Tolonen from the Department of Food and Health of the Ministry of Agriculture and Forestry, Erkki Vesanto (Tuuli Pulkkinen) from the Plant Production Inspection Centre, Alan Schulman (Mia Sahramaa) from the Agrifood Research Finland, Mervi Seppänen (Juha Helenius) from the University of Helsinki, Irma Salovuori (Jussi Joensuu) from the Ministry of Social Affairs and Health, Kirsi Törmäkangas (Marja Ruohonen-Lehto) from the Finnish Environment Institute and Eeva Fieandt (Arja Kaiponen) from the National Food Agency.

The work is to be completed by 30 December 2005.

The mid-term report covers mainly points 1, 3 and 4 of the commission. The draft report was sent to the Steering Group for comment twice. The Expert Work Group respectfully submits the mid-term report to the Steering Work Group.

Helsinki 31 May 2005

Chairperson:	Kirsi Heinonen	Secretary:	Jussi Tammisola
Members:	Eeva Fieandt		Juha Helenius
	Jussi Joensuu		Arja Kaiponen
	Outi Kostama		Juha Palonen
	Tuuli Pulkkinen		Marja Ruohonen-Lehto
	Mia Sahramaa		Irma Salovuori
	Alan Schulman		Mervi Seppänen
	Tero Tolonen		Kirsi Törmäkangas
	Erkki Vesanto		

Expert Work Group

The Ministry of Agriculture and Forestry appointed an Expert Work Group in February 2004 to prepare the recommendations for measures and instructions for enabling the coexistence of genetically modified crops and conventional and organic agricultural products in Finland.

The task of the Expert Work Group was to draw up a report on:

1) agronomical measures enabling coexistence. The study must be founded on scientific evidence on the likelihood of the admixture of genetically modified and other crops and sources of admixture.
2) economic impacts of coexistence and responsibilities. Coexistence measures must be functioning and cost-efficient. Measures may not cause unreasonable economic consequences to farmers or seed producers. The Work Group must also study the Finnish legislation on liability for damage and whether this provides sufficient and equal opportunities to the different parties to practise their trade.
3) regional measures which should be applied to crop species and types of production suited for the Finnish conditions (e.g. sowing seed production vs. other crop production). The regional aspects to be accounted for also include the share, number and type of genetically modified crops in the region, climate conditions, soil, topography, crop rotation and farm structure as well as the surrounding area, such as forests, uncultivated land and location of arable lands.
4) administrative decisions and changes in the legislation which may be needed as well as new control and inspection systems to be introduced.

The composition of the Expert Work Group**:**
Chairperson Kirsi Heinonen, Agricultural Counsellor, and secretary Jussi Tammisola, Senior Research Officer from the Department of Food and Health of the Ministry of Agriculture and Forestry; members (deputy members in brackets) Juha Palonen (Outi Kostama) from the Department of Agriculture and Tero Tolonen from the Department of Food and Health of the Ministry of Agriculture and Forestry, Erkki Vesanto (Tuuli Pulkkinen) from the Plant Production Inspection Centre, Alan Schulman (Mia Sahramaa) from the AgriFood Research Finland, Mervi Seppänen (Juha Helenius) from the University of Helsinki, Irma Salovuori (Jussi Joensuu) from the Ministry of Social Affairs and Health, Kirsi Törmäkangas (Marja Ruohonen-Lehto) from the Finnish Environment Institute, and Eeva Fieandt (Arja Kaiponen) from the National Food Agency.

The Work Group limited its work to cover the first part of the production chain to the stage when the farmer has stored the crop ("from field to bin").

The work of the Expert Work Group is to be completed by 30 December 2005.

Steering Work Group

The Expert Work Group is steered by a Steering Work Group, with extensive representation from various stakeholders, interest groups and NGOs. The task of the Steering Work Group is to give proposals for recommendations on measures and instructions for enabling the coexistence of genetically modified crops and conventional and organic agricultural products in Finland.

The task of the Steering Work Group was to draw up proposals for**:**

1) agronomical measures enabling coexistence;

2) regional measures which should be applied to certain crop species and types of production (e.g. seed production vs. other crop production). The regional aspects to be accounted for also include the share, number and type of genetically modified crops in the region, climate conditions, soil, topography, crop rotation and farm structure as well as the surrounding area, such as forests, uncultivated land and location of arable lands and
3) administrative decisions and changes in the legislation which may be needed as well as new control and inspection systems to be introduced.
4) The grounds for the liability for damage had to be examined.

The composition of the Steering Work Group**:**
Chairperson Matti Aho, Director-General and secretaries Kirsi Heinonen, Agricultural Counsellor and Jussi Tammisola, Senior Research Officer from the Department of Food and Health of the Ministry of Agriculture and Forestry; members (deputy members in brackets) Leena Hömmö from the Department of Agriculture of the Ministry of Agriculture and Forestry, Irma Salovuori from the Ministry of Social Affairs and Health (Jussi Joensuu), Kati Suihkonen from the Ministry of Finance (Seija Kivinen), Jyrki Pitkäjärvi from the Ministry of the Environment, Leena Mannonen from the Ministry of Trade and Industry (Anne Haikonen), Minna Oravuo from the Central Union of Agricultural Producers and Forest Owners (Markku Suojanen), Rikard Korkman from the Central Union of Swedish-Speaking Agricultural Producers in Finland "Svenska Lantbruksproducenternas Centralförbund", Pasi Lähdetie from the Finnish Food and Drink Industries' Federation, Sari Peltonen from the ProAgria Association of Rural Advisory Centres (Kaisa Tolonen), Kaarlo Kinnunen from the Swedish-speaking ProAgria Association of Rural Advisory Centres "Svenska lantbrukssällskapens förbund", Martti Kinnari from the Seed Traders Association (Tapio Lahti), Esa Partanen from the Nature League (Arja Peltomäki), Hannes Tuohiniitty from the Finnish Association for Nature Conservation (Liisa Kuusipalo), Matti Sarvas from the Advisory Board for Biotechnology (Reetta Kettunen), Mika Hyövelä from the Boreal Plant Breeding Ltd (Elina Tuomola), Saara Hassinen from the Finnish Bioindustries FIB (Kari Puukko).

The work of the Steering Work Group is to be completed by 30 December 2005.

1. BACKGROUND

The European Commission has issued a Recommendation[1] on guidelines for the development of national strategies and best practices to ensure the coexistence of genetically modified crops with conventional and organic farming (EU 2003b). According to the principles of the recommendation, farmers must be able to make a practical choice between conventional, organic and GM production. According to the Commission, the issue is also linked to consumer choice. To give the European consumers a real choice between foodstuffs coming from different production types, the traceability and labelling systems alone are not enough but agriculture must be capable of providing different types of goods using different types of production.

Coexistence is concerned with the ability of farmers to make a practical choice between conventional, organic and GM crop production in compliance with the legal obligations and/or purity standards. The aim is that the presence of GMOs would not normally exceed the threshold

[1] Commission Recommendation (2003/556/EC) of 23 July 2003.

values in cases where the product otherwise would not need to be labelled as containing GMOs.

It should be noted that we are concerned with varieties officially approved for cultivation in the EU, which have already passed the environmental impact assessments required by the gene technology legislation. In the recommendation the Commission emphasises that the legislation on coexistence should not deal with the environmental impacts of GM crops but they aim to solve the economic issues which may arise in the context of the coexistence of different types of production.

Coexistence of different production types is not new in agriculture. In seed production, for example, there is a great deal of experience of implementing farm management practices to ensure that the seed complies with the purity and varietal purity requirements.

One general principle in coexistence referred to in the Commission recommendation is that a farmer who introduces a new production type in a region[2] is responsible for implementing the farm management measures necessary to limit gene flow. However, successful coexistence calls for extensive cooperation between neighbouring farmers independent of who introduced the newest production type.

One of the most central issues is the outcrossing occurring between varieties and species. Various kinds of measures can be taken to reduce the resulting gene flow, but special attention should be directed at the crossing properties and biological compatibility of the species, mutual competition in pollination, and seed production. Natural barriers, such as woodlands and water bodies between open arable areas, are also important in reducing gene flows of species with no natural presence or easily crossing wild species of the same genus in the intervening territory.

Insects are the most significant pollinators of plants depending on external animal pollination. The pollen of such plans is heavy and sticky, while the pollen of wind-pollinating plants (e.g. cereals and grasses) is light and less sticky. The most important pollinating insects are bees and bumblebees. The flying radius of bees is large, which means that in favourable conditions they may pollinate plants quite far away from their hive. In general insects may cause random crossings over longer distances than wind. Crossing between cross-pollinating varieties is more common than between self-pollinating ones. This also applies to crossing between plant species. The likelihood that very strongly self-pollinating plants would cross with each other is very low, but the number of fully cross-pollinating or self-pollinating species is small. In most cases some kind of pollination takes place between species, but usually the crossing of species is extremely difficult or impossible as the pollination does not lead to fertilisation or viable seed is not produced due to genetic barriers to crossing.

Another important factor is the decrease in the purity of varieties due to mixing of seed or volunteers. Adventitious mixture can be reduced, for example, by using high-quality, certified seed. If a farm uses its own seed for sowing (FSS), this should be harvested from areas where the risk of mixing with material from a neighbouring farm is the lowest. Cleaning of sowing, harvesting and other field machinery and equipment can diminish the transport of seed between fields, and careful, well-planned harvesting reduces the amount of seed shattering on the ground. Proper after-treatment of arable lands and weed control reduce the number of volunteers and unnecessary gene flow in or from the plantation.

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[2] Commission Recommendation does not specify at which point a new production type is to be considered established in a region. The focus is on near future, which means that national work should focus on crops whose GM applications can first be expected to be introduced in the Member States.

These issues will be dealt with in further detail in Chapters 2 and 3. Where necessary the study will be taken to the level of species to be able to propose their necessary agronomical measures > the necessary agronomical measures for them as set down in the commission.

The work was founded on extensive review of scientific literature (see Chapter 5 References), and the Coexistence Report of the Advisory Board for Biotechnology completed in December 2004 (BTNK 2004) has also been utilised in drafting this mid-term report.

1. Finnish agriculture

The statistics describing the current state of Finnish agriculture are based on Agrifood Research Finland/ Economic Research 2004 (MTTL 2004), unless otherwise indicated.

The surface area of Finland is 33.8 million hectares, of which about 2.2 million hectares (6.5 per cent) is utilised agricultural area. The cultivated area (including set-aside land) totals 2,212,000 hectares. The cultivated area has grown by 89,800 hectares since 1996.

According to statistics of the Information Centre of the Ministry of Agriculture and Forestry, in 2004 the agricultural land was used as follows: cereal crops about 54 per cent, grasses about 30 per cent, set-aside about 9 per cent and other crops (potato, sugar beet, turnip rape and oilseed rape) about 8 per cent.

The cultivated area of turnip rape and oilseed rape was about 82,000 hectares (3.7 per cent of the utilised agricultural area) and that of potatoes about 29,000 hectares (1.3 per cent of the utilised agricultural area) (Information Centre TIKE 2004). In the past five years the area under cereals has grown by five per cent, while the area of grasses has decreased by six per cent.

In 2003 the number of Finnish farms with over one hectare which applied for agricultural support was 72,000. Between 1995 and 2003 the number of farms fell by 25 per cent: of the 95,562 farms in 1995 23,562 had quit by 2003.

Measured by the number of farms, the production structure of Finnish agriculture has changed considerably during the EU membership. The share of livestock farms has fallen and the share of crop farms has grown. In 2003 39 per cent of the farms that applied for support were livestock farms and about 57 per cent were crop farms or "other" farms.

As the number of farms has decreased, their average size has grown. Between 1995 and 2003 the average size of farms receiving support grew by 36 per cent from 22.8 hectares of arable land to 31.0 hectares. The cultivated area has mainly grown through leasing rather than purchases of additional land. In 2003 39 per cent of the total cultivated area of 2.23 million hectares was leased.

Finnish agriculture is almost exclusively based on family farms. Of the farms receiving support 88.6 per cent were owned by private persons and 10.5 per cent were owned by heirs, family companies and corporations. Cooperatives, limited companies and production rings owned 0.8 per cent of the farms and 0.1 per cent were owned by the State, municipalities, education establishments and parishes. The average age of farmers on farms receiving support is 49 years.

2. Organic agricultural production in Finland and the European Union

In the whole EU the area under organic production totalled about 4.3 million hectares in 2001, which is 3.4 per cent of the total arable area in the EU (Figure 1). The area under organic production grew rapidly all through the 1990s. Between 1993 and 2001 the average annual growth was 26 per cent (MMM 2005). Today the EU countries can be roughly divided into two categories: in some of them the organic production area continues to increase noticeably, while in others the increase has declined.

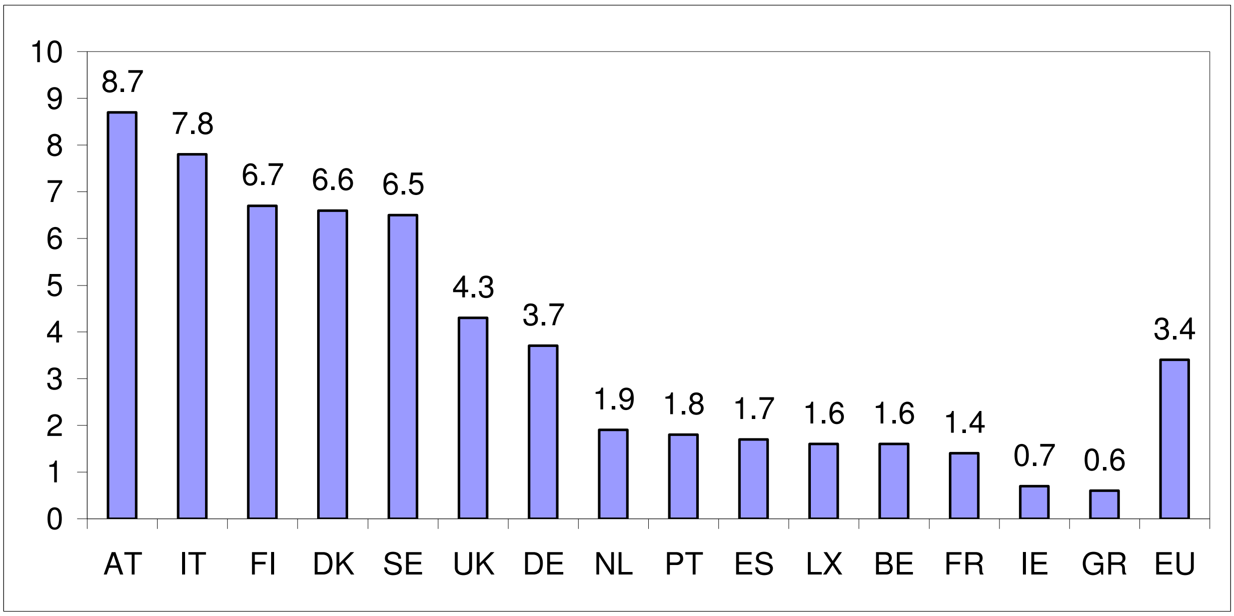

Figure 1. Organic agricultural production in EU Member States in 2001 as percentage of total arable area (Hamm & Gronefeld 2004).

In 2004 the arable land under organic production or conversion into this in Finland was about 169,000 hectares, which represented 7.6 of the total cultivated area. The number of organic farms was about 4,900. The growth in the organic area has slowed down in recent years because of the poor market situation of organic cereal and weakening of the relative profitability of the production, among other things.

Council Regulation on organic production (EEC) No 2092/91, amended by Council Regulation (EC) No 1804/99, prohibits the use of GMOs and their derivatives as foodstuffs, food ingredients, food additives, processing aids, feedingstuffs, compound feedingstuffs, feed materials, feed additives, processing aids for feedingstuffs, plant protection products, fertilisers, soil conditioners, seeds, vegetative reproductive material and livestock.

The Standing Committee on organic farming may decide on the threshold values for organic products. However, no threshold value has been set for the so-called adventitious presence of GM material in organic products. Thus, according to the Commission interpretation, so far the same rules apply to both organic products and other feeds and foodstuffs. No threshold values have yet been set for organically produced seed. (see Chapter 1.7 Statutes on GMOs and genetically modified products, *Seed production*).

Regional distribution of organic farms

The area under organic farming is the largest in Ostrobothnia, Pirkanmaa, Varsinais-Suomi and Uusimaa. The share of organic area in the total arable area is the highest in Kainuu, Åland, North-Karelia and Pirkanmaa (Figure 2, Table 1).

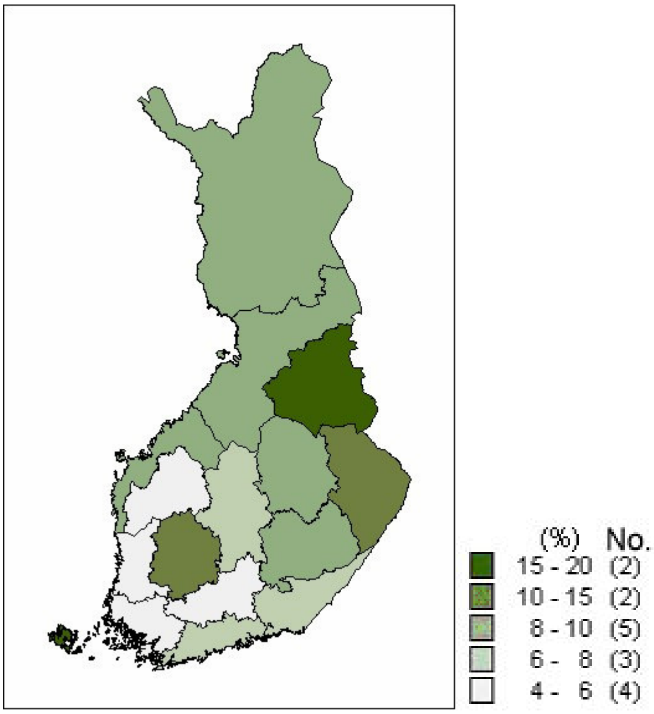

Figure 2. Share of organic farms in total arable area [%] (KTTK 2004). Chart**:** Jukka Lahtinen 2005.

Table 1. Regional distribution of organic farms, share of all farms, area under organic farming and share of total arable area in 2004. (KTTK 2004)

T&E Centre	Farms	Share of all farms [%]	Area [ha]	Share of total arable area [%]
01 Uusimaa	388	8.3	13 258	7.2
02 Varsinais-Suomi	398	5.0	16 161	5.6
03 Satakunta	234	4.5	8 553	5.6
04 Häme	209	4.0	7 500	4.0
05 Pirkanmaa	471	9.5	16 484	11.1
06 South-East Finland	274	5.9	10 555	7.6
07 South Savo	297	8.4	6 637	9.2
08 North Savo	405	7.8	13 721	9.8
09 North Karelia	330	10.8	11 220	13.2
10 Central Finland	233	6.1	6 077	6.6
11 South Ostrobothnia	361	4.4	11 429	4.8
12 Ostrobothnia	533	7.8	17 526	9.2
13 North Ostrobothnia	505	8.3	19 776	9.7
14 Kainuu	110	9.1	4 650	15.8
15 Lapland	84	4.1	3 409	8.2
20 Åland	107	16.3	2 046	15.5
Total	4939	6.9	160 021	7.6

Use of arable land

Bread cereals, peas, oilseed crops, potato and horticultural crops account for about 15 per cent of the organic production area. In the same way as in conventional farming, most of the area is used for the production of forage. In recent years there have been no major changes in the land use for organic production.

Table 2. Use of arable land in area approved for organic farming in 2002 (KTTK 2004)

	Cultivated area [ha]	Share[1] [%]
Bread cereals	14 909	11
Fodder cereals	39 247	29
Leguminous cereals	1 953	1.4
Oilseed crops	2 655	2
Potato	616	0.4
Vegetables grown in the open	303	0.2
Grass	52 972	39
Set-aside	20 182	15
Other crops	2 597	2
Total	135 434	100

[1] Share of the cultivation area of the crop of the total organic production area

3. Size of arable parcels in Finland

Greater size of the plantations reduces the proportional amount of admixture and gene flow between them (see Chapter 2.1 *Reducing unintended crossing*). The size of arable parcels may give some indications of the size of the plantations (Tables 3 and 4).

Table 3. Average size of base parcels[1] according to T&E Centres at the end of 2001 (Lahtinen 2005)

T&E Centre	Average size of base parcels [ha]
Uusimaa	3.23
Varsinais-Suomi	3.05
Satakunta	2.42
Häme	3.10
Pirkanmaa	2.16
South-East Finland	2.36
South Savo	1.84
North Savo	2.27
North Karelia	2.29
Central Finland	2.03
South Ostrobothnia	2.16
Ostrobothnia	2.05
North Ostrobothnia	2.41
Kainuu	1.80
Lapland	1.76
Åland	1.36
Finland in total	2.39

[1]Parcels with agricultural parcels in 2001 which have not been passivised and the land use type is arable land.

Table 4. Structure or arable lands in different regions based on sampling* results. (Arable lands of active farms in their own municipality covered by CAP payments.) (Ylikangas 2004)

Region	Average size [ha]		of parcels [%]	
	farm	parcel	< 2 ha	> 5 ha
South Savo	19.3	1.73	75.0	4.6
Ostrobothnia	22.3	1.89	67.2	6.5
Lapland	20.2	1.91	67.0	7.8
South Karelia	25.5	1.97	66.0	7.1
Kainuu	28.0	1.99	68.8	8.0
South Ostrobothnia	27.3	2.04	63.6	7.3
North Karelia	25.2	2.11	64.2	9.0
Central Finland	25.5	2.12	63.3	9.2
Pirkanmaa	29.0	2.27	63.2	11.0
Central Ostrobothnia	27.6	2.29	60.3	10.4
Satakunta	28.6	2.41	60.8	11.7
North Savo	27.1	2.46	58.1	12.1
North Ostrobothnia	34.7	2.75	54.6	15.8
Kymenlaakso	29.0	2.83	54.7	16.3
Päijät-Häme	33.0	2.93	55.1	16.9
Varsinais-Suomi	36.3	2.96	54.6	17.1
East Uusimaa	35.4	3.05	52.9	18.0
Kanta-Häme	33.6	3.21	51.4	20.0
Uusimaa	39.0	3.77	49.5	21.6

* Sample consisted of 2-4 municipalities from different regions from the Farm Register 2001-2003 of the Information Centre of the Ministry of Agriculture and Forestry TIKE.

However, parcel is used only as a unit for recording, and the real sizes of uniform plantations of a certain crop may be much larger or smaller. Base parcels consist of several agricultural parcels, which means that more than one crop may be cultivated on a single base parcel. On the other hand, the same crops or varieties may be grown on several neighbouring base parcels.

In Denmark the arable parcels are larger than in Finland, but the role of this from the perspective of mixing in the context of coexistence remains unclear. From the economic perspective increasing the parcel size was considered beneficial in Finland as well (Ylikangas 2004). If this led to an increase in the average size of uniform plantations of certain plant varieties, the proportional risk of admixture in the coexistence of different types of production could be smaller.

In many cases, however, increasing the parcel size is difficult, because a base parcel means a geographically uniform cultivation area delimited by, for example, the municipal boundary or boundary between support areas or a water body, main ditch, road or forest.

4. Farming conditions in Finland compared to Denmark

This report is based in part on the results of a report on coexistence in Denmark (DIAS 2003). This is why special features of Finland compared to Denmark have been described and taken into account as far as possible.

Differences in climate conditions (length of the growing season, severity of winter) influence, among other things, the selection of varieties and share of winter and spring cereals. Even a single factor such as rainfall in the autumn influences the over-wintering of fallen seed and thus the occurrence of volunteers on arable lands.

Unlike in Finland, there is a great deal of choice in cultivation in Denmark, because the varieties commonly cultivated in most parts of Europe usually succeed in Denmark as well. In Finland, for example, the winter varieties of many plants, such as oilseed rape, cannot be cultivated at all.

Denmark has a marine climate**:** windy, rainy and quite mild. Winters are clearly milder and the growing season is much longer than in Southern Finland, while in Finland the day is longer and there is more sunlight in June-July.

Table 5. Differences in the climate in Finland* and Denmark* with impacts on agriculture

	Southern Finland	Denmark
Average annual temperature [ºC]	3.6	7.9
Average daily maximum temperature in the hottest month[1]	21.0	19.3
Average daily minimum temperature in the coldest month[2]	-12.0	-1.8
Sunlight in June-July [h]	545	456
[% of the length of the day]	47.0	43.2
Length of the day from sunrise to sunset[3] [h]	18:59	17:17
Average wind speed in June-July [m/s]	3.4	5.1
Annual precipitation [mm]	608	727
Temperature sum of the growing season[4]	1100 - 1300	1350 - 1700

* Turku, Helsinki, Niinisalo, Jokioinen, Lappeenranta, Vaasa, Jyväskylä, Joensuu; in Denmark 15 weather stations across the country. The results are averages from 1961 to 1990 (WMO 1996)

[1] in Finland July, in Denmark August

[2] in Finland January, in Denmark February

[3] In Denmark on the average latitude, in Finland as average of Helsinki and Vaasa (Oja 2005)

[4] Sum of the temperatures exceeding 5°C of all days when this limit is exceeded across the growing season (= average temperature of the day minus 5°C) (Carter 1998, Skjelvåg 1998).

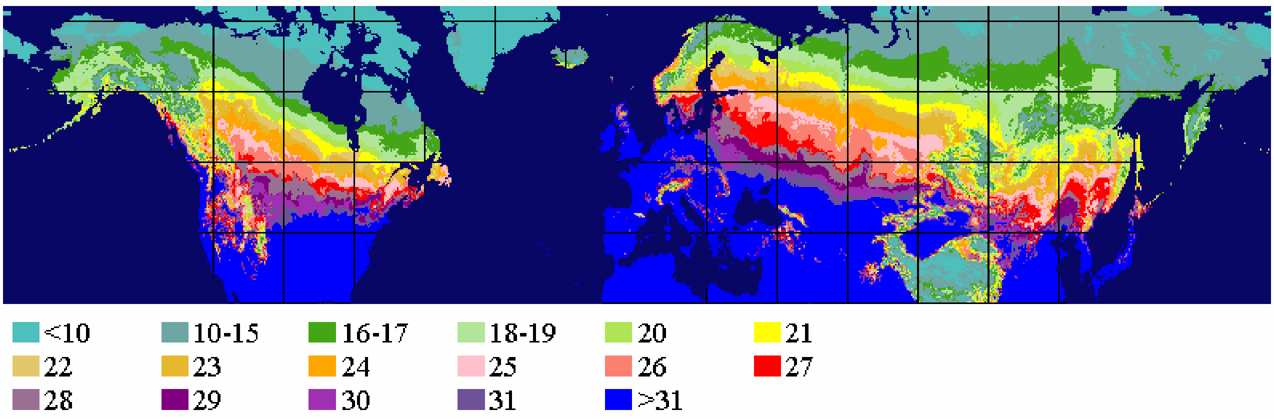

Figure 3. Length of the growing season [weeks] in the northern hemisphere.

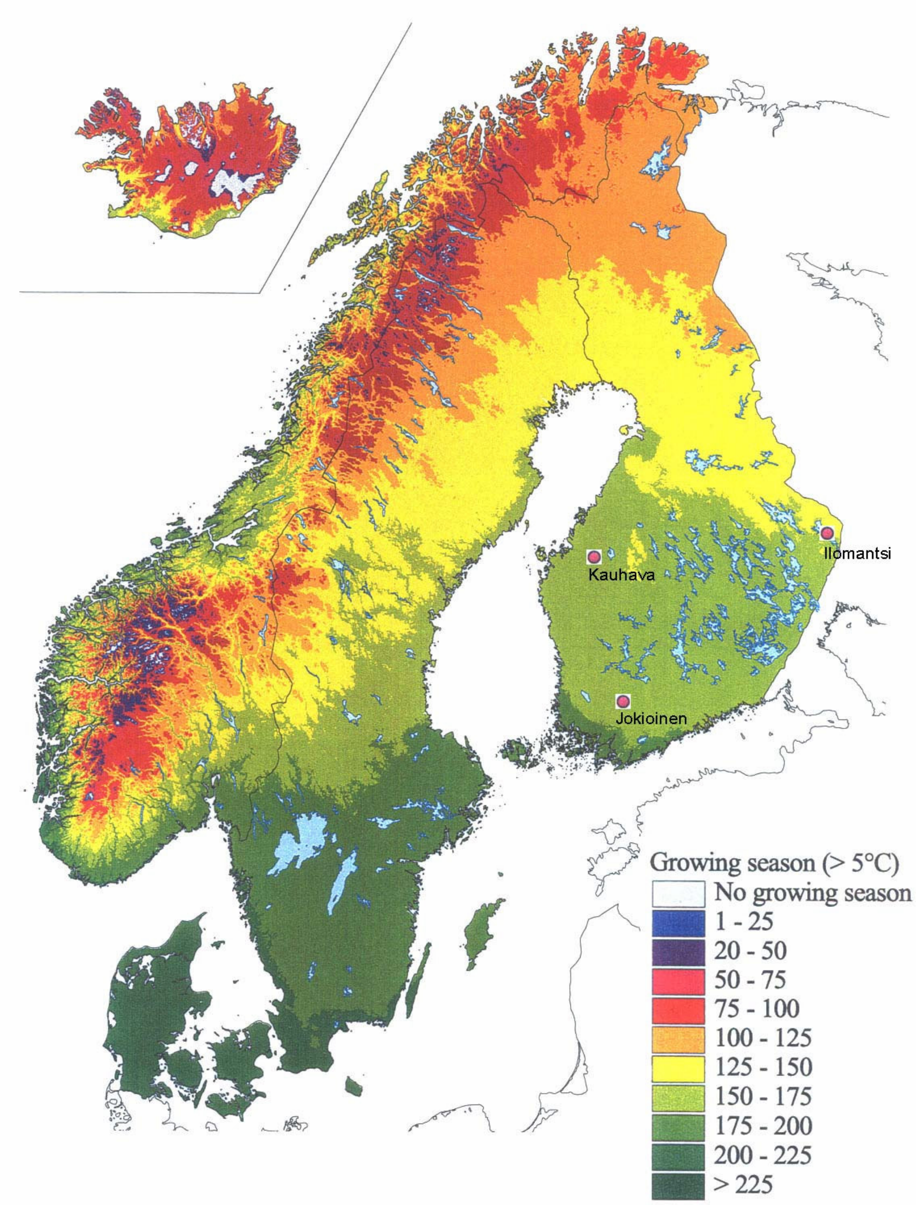

Figure 4. Average length of the growing season [days] (i.e. time when the average daily temperature exceeds 5°C) in the Nordic countries in 1961 - 90 (Tveito et al. 2001). The picture also shows the three locations selected for wind analysis in Finland (Jokioinen, Kauhava and Ilomantsi, see Figure 5).

Wind conditions in Southern Finland in early summer

Three locations, Jokioinen, Kauhava and Ilomantsi, were chosen to represent the farming areas in Southern Finland. The distribution of the wind direction and average speed in different directions in these locations in June-July from 1971 until 2000 has been presented as pie charts and wind roses (Figure 5). In the Finnish conditions there is relatively little variation in the wind direction and speed distributions during the flowering period of the crops.

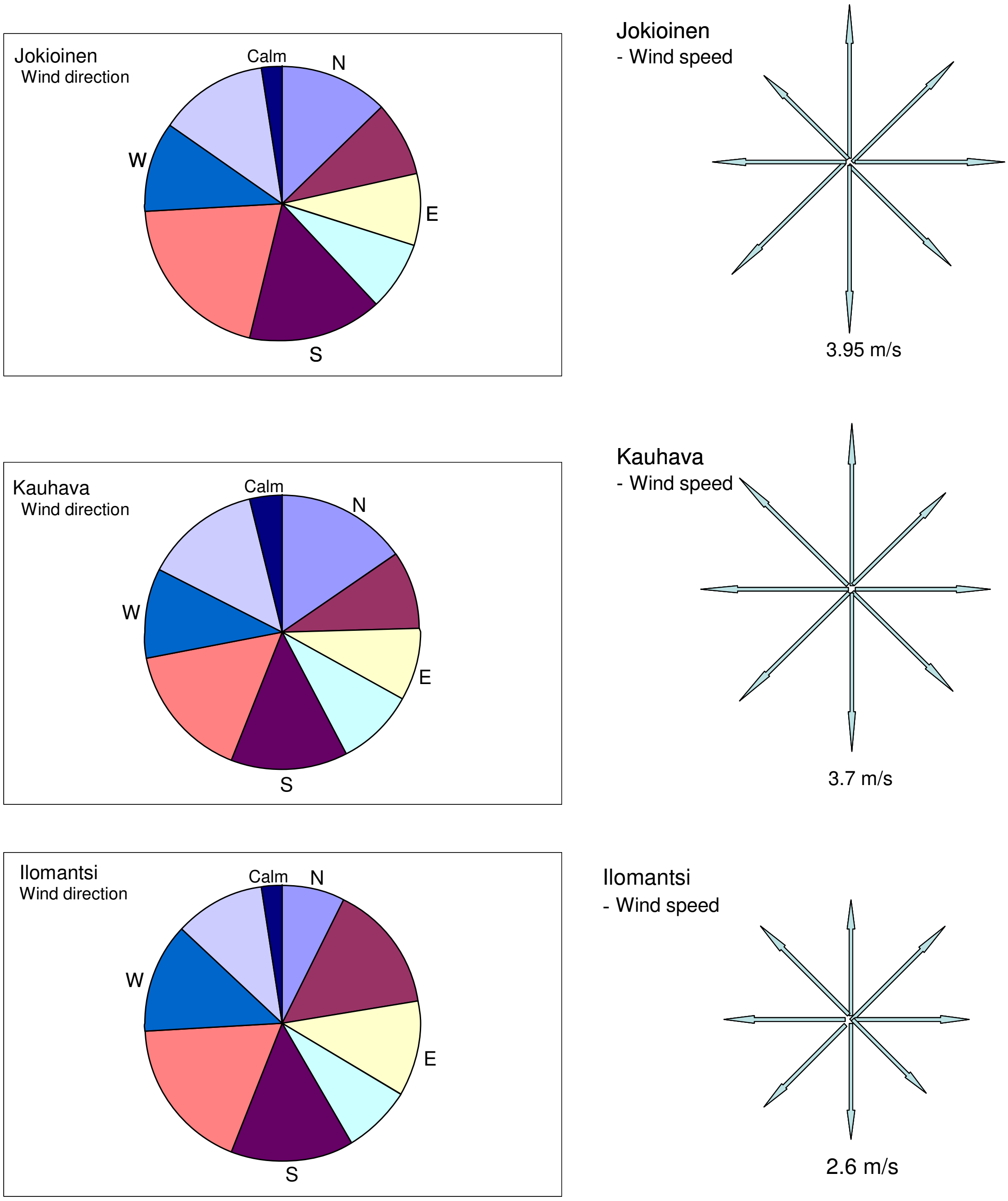

Figure 5. Wind direction and speed distributions in three locations in Southern Finland in June-July from 1971 until 2000 (Drebs et al. 2002). The point of the arrow shows the direction where the wind comes from and the length of the arrow indicates the speed of the wind blowing from this direction.

The marine wind phenomenon can be observed in a narrow strip along the coast: during the day the wind often blows towards the land (even if the wind turns during the day) and at night it blows towards the sea. The night wind is usually quieter and in summer the wind often stops for the night. The sea winds are weak, extending only a few tens of kilometres inland, and they seldom dominate over the winds of the current state of the weather.

5. Gene technology and genetically modified agricultural crops

Gene technology means molecular biology directed to genes (MMM 2003). It covers a set of new biological methods for analysing the genotype and changing it in detail according to human needs[3].

In traditional plant breeding gene technology methods may be utilised, for example, in the analysis of crossing progeny. According to the definition used in the EC legislation, we are dealing with a genetically modified organism when the genetic material has been altered in a way that does not occur naturally by mating and/or natural recombination[4]. This means that GM varieties are created e.g.when gene technology is used to fine tune the activity of the genes of the plant itself, silence harmful genes, or to introduce the desired gene in pure form[5] from a related plant species.

New information on the genotypes of living organisms and laws of inheritance has opened the way to more rapid modification of the genotypes of production animals in an increasingly controlled manner. However, the growing pace concerns only the biological stage when plant lines are developed from the breeding population into candidate varieties. Instead, the tests and studies required for the approval of varieties take even more time than before, because the legislation on varieties developed by means of the new technologies call for more extensive studies (Bradford et al. 2005).

One objective in the research on gene technology is to produce new kinds of products for the needs of consumers and industries. Research also ensures the safety of genetically modified products both to the humans and the environment.

In agriculture gene technology is expected to improve the productivity of plants and animals and their resistance to diseases and environmental stresses. New technology also provides tools for improving the nutritional quality of food and feed, for example, by reducing the amounts of indigenous harmful substances (OECD 2001–2005). Gene technology may be used to improve the nutrition content of food e.g. by altering the composition of fat acids or by increasing the vitamin content (Bouis 2003). One example of the international cooperation in this field is the rice rich in vitamin A, which may improve the resistance to infectious diseases and prevent small children from going blind in the developing countries, donated to the International Rice Research Institute (EU 1999, Paine et al. 2005). Genetically modified plants and animals may also be used for the production of medicines and vaccines (Rowlandson & Tackaberry 2003, Oksman-Caldentey & Inze 2004, Oksman-Caldentey & Saito 2005).

Development of plant breeding

The structure of genes is altered by natural mutations caused by cosmic background radiation, radioactive substances in the nature, viruses, genetically mutated chemicals, transposons and cell

[3] Gene technology is "a set of methods through which genes are isolated, analysed and transferred at the molecular level". (Tirri et al. 2001)

[4] The legal definition used in the EC rules (Directive 2001/18/EC) is based on lists and its is quite difficult to grasp (see Chapter 1.7. Statutes on GMOs, *Release of GMOs to the environment*). According to this definition, thousands of plant varieties developed by means of "conventional" mutation breeding are genetically modified (e.g. most of the modern short-stemmed cereal varieties, vegetable paprika and erucic acid-free turnip rape and oilseed rape. However, the varieties created through mutation breeding do not fall within the scope of Directive 2001/18/EC).

[5] Only the gene concerned is introduced in an isolated form, not accompanied by thousands of other genes of the species of the same genus, like in crossing.

malfunctions. This leads to genetic variation in the population, which in turn functions as the building material for evolution. Plant breeding is evolution directed by humans - the modification of cultivated plants' genetic material for human needs (OECD 2000). In order for breeders to succeed in their work the breeding material must contain enough genetic variation in the properties they wish to improve.

The development of crops through selective breeding started as long as 11,000 years ago. In this procedure the individuals with the most appropriate properties are selected and retained for further cultivation. In conventional breeding efforts are made to find new forms of genes (alleles) ready and waiting from the range of the random mutations available which would be more beneficial in view of the human uses than the mutations applied earlier. This method is sufficient in the early stages of breeding, but it becomes less efficient as the variation decreases. The ability to compile beneficial properties into one individual plant through crossing has been available for only 300 years (crossing breeding).

The foundations for understanding genetics were created by a monk called Gregor Mendel in Brno (in the present Republic of Slovakia). Selection breeding screens the natural stock of mutants in a plant population. However, this is often too narrow and useful gene forms are too rare to be picked out by the breeder. This is why in mutation breeding the plants are treated with chemicals causing mutations or types of radiation which break down the genome so that mutations area created a few orders of magnitude (say, 1,000 to 100,000 times) more frequently than in the nature. Mutation breeding is 60 years old, gene technology is 32 years old, and gene technology has been applied in plant breeding for 22 years.

As a result of breeding the plants are better suited for cultivation and to be used for human or animal nutrition. The yield level has grown up to 10 to 30-fold, half of which is attributed to breeding and half to better cultivation methods. The ears of the original wild maize teosint were as thick as one row of grains in the present maize and about half a finger long. The ear of wild barley broke easily and the grains fell to the ground. The wild potato was too poisonous to eat, while the wild carrot was thin, pale and woody. The erucic acid contained in natural turnip rape oil which is poisonous to mammals was removed through mutation breeding as late as in the 1960s.

Figure 6. How has the carrot developed.
The picture shows a bred and wild carrot and radish. Over a few thousands of years the roots of wild carrots were bred into thick, thin, short, bulky, white, yellow, red, deep purple and even black varieties. The orange[6] carotene carrot is a "novel food" from the 16th century, when breeders in Holland developed four orange varieties, from which today's carrots are derived.

Traditional mutations occur at random, and for each desired mutation there are always hundreds of thousands of undesired mutations. The objective in using gene technology is to create changes

[6] Colour of the Dutch royal family

through more carefully controlled methods. The desired form of a gene can be constructed separately outside the plant (by means of natural[7] enzymes intended for the modification of the genetic material). Beneficial forms of genes can often be found in taxonomically related plant species as well. By means of the modern biotechnology the completed gene can be transferred to the genotype of a plant in a pure form.

Adding a new gene form to a plant

When plants are bred by means of gene technology, the result differs from conventional breeding in that the original gene form of the plant cannot yet be replaced by the bred gene form, except in a few cases, but the desired gene form must be *added* to the genotype of the plant. This means that the old gene form usually functions alongside with the new one. In conventional breeding several forms of the same gene also often function simultaneously (heterozygotes, polyploids, gene families), but through crossing the original gene form of a plant can often be completely replaced by the new one (if this is what one wants to do).

Sometimes the new gene form can be substituted for the old gene form in the chromosome in plants as well. This succeeds when the gene form to be bred is taken to the cell as an RNA-DNA hybrid molecule (Hanin & Paszkowski 2003). However, so far this kind of regulated modification of a certain gene, i.e. ”gene-specific mutagenesis” or ”homological recombination” works in plants only in few exceptional cases and the method is not yet ready for general use. In microbes the modification of a gene on the level of a single DNA nucleotide has been used for a long time. It is hoped that progress in the application of this method to plants will be made in the near future, when we get more information on the natural genes regulating this hereditary phenomenon.[8]

Breeding issues which have given rise to discussion are dealt with in some further detail in Annex A.

Prior approval is required for genetically modified products

At present the utilisation of gene technology in the sectors governed by the Ministry of Agriculture and Forestry is one of the most strictly regulated activities. The revision of the central Community legislation on genetically modified products was completed during 2004. According to the Community provisions on gene technology, genetically modified organisms must pass a detailed approval procedure prior to the entry to the market, including the assessment of their health and environmental impacts on a case-by-case basis. Scientific safety assessment, precaution and ethical considerations are taken into account in decision-making and provisions on the necessary risk management measures are issued. The objective of the legislation is to ensure that the production chains of genetically modified products are safe for the humans, animals and the environment (Codex Alimentarius 2003a, b, Conner et al. 2003a, b, Cockburn et al. 2004).

Control of research and use

Genetically modified products approved for the market have been labelled, they are controlled and their use is monitored. Foodstuffs and feedingstuffs manufactured from genetically modified raw material are also labelled to show the use of gene technology. The Gene Technology Board

[7] These enzymes which modify the genetic material have usually been found in microbes, and they have then been further improved for laboratory use.
[8] According to the most recent studies, plants may possess a natural system of their own, through which they can transfer genetic information from other sources to their chromosomes (Lolle et al. 2005).

supervises all gene technology research in Finland. The control authorities referred to in the Gene Technology Act (377/1995, last amended by 847/2004) are the National Product Control Agency for Welfare and Health (STTV), Finnish Environment Institute (SYKE) and Plant Production Inspection Centre (KTTK).

The National Product Control Agency STTV maintains a register on gene technology and controls the contained use of genetically modified organisms. It also controls the deliberate release of genetically modified organisms to the environment as regards human health questions. The Finnish Environment Institute supervises the deliberate release in terms of the environmental questions and the Plant Production Inspection Centre in the agricultural and forestry sectors.

Controlled utilisation of gene technology

The Gene Technology Strategy and Action Plan of the Ministry of Agriculture and Forestry was adopted in autumn 2003 to ensure that the new gene technologies are used in a controlled, safe and ethically sustainable manner. It was based on the Strategy for Biotechnology and Genetic Engineering in Agriculture completed in 2000, which was further developed in a work group in 2001–2003. The Finnish scientific and non-government organisations were extensively involved in this work. The Strategy lays down the main principles for the use of gene technology in the natural resources sector (MMM 2003). Today most of these principles are already included in the revised EU legislation and national statutes.

The strategy is founded on the view that the different types of agricultural production must be viable, natural resources must be used in a sustainable way, the products must be safe and of high quality, and activities involving gene technology must be open and efficiently controlled. Uncontrolled release of genetically modified organisms to the nature and the possible ecological disadvantages this might cause must be prevented. The special characteristics of Finnish agriculture and nature must be taken into account in the application of gene technology. To ensure sufficient consumer information and possibility to make choices, the genetically modified organisms and products manufactured from these must be appropriately labelled. The production chains must be open and traceable to show the origin, production method, composition and quality of the products. Sufficient communication on gene technology issues must be ensured.

A EU strategy aimed at promoting research in biosciences and gene technology and the introduction of the useful applications has also been officially adopted in the Community (EU 2002, 2003a).

Cultivation

So far only a few properties bred by means of gene technology are in extensive use in cultivation. These include resistance to certain pests (cotton bollworm, European corn borer, corn rootworm, Colorado beetle) or herbicides (glyphosate, gluphosinate ammonium). Very few virus resistant plants are yet in use (papaya, melon), but many of them are being developed, and so are plant varieties resistant to fungal or bacterial diseases, such as blight resistant potatoes (Song et al. 2003) or fire blight resistant apples (Liu at al. 2001, Norelli et al. 2003). The new breeding properties could contribute to improving the food security in developing countries, but the public research sector has not yet invested sufficiently to their development and use in breeding (Gressel et al. 2004). The cultivation areas of genetically modified crops are growing by about 20 per cent per year (Figure 7, Table 6), and the share of the developing countries in the cultivation area has also been growing (Figures 7 and 8). GM crops are being raised by about 8.25 million farmers, of which about 90 per cent are small farmers in the developing countries (James 2004).

Table 6. Share of GM crops in the world area under the most significant GM crops in 2004 (James 2004).

Species	Cultivation area of the species in the world [Mha]	Area under GM varieties [Mha]	Share in total area of the species 2004	Share in total area of the species 2003
Soya	86	48.2	56 %	55 %
Cotton	32	9.0	28 %	21 %
Oilseed rape	23	4.4	19 %	16 %
Maize	140	19.3	14 %	11 %

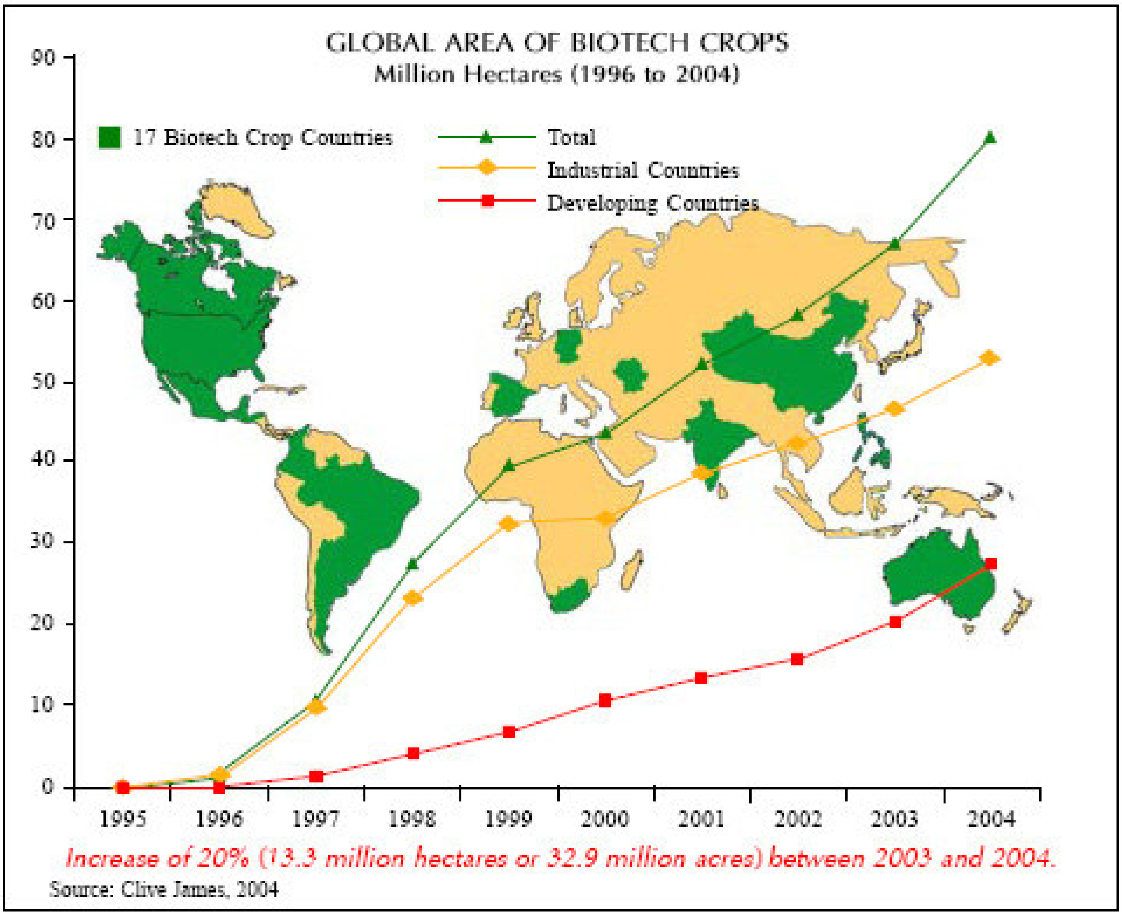

Figure 7. Development of the area under GM crops world-wide (James 2004).

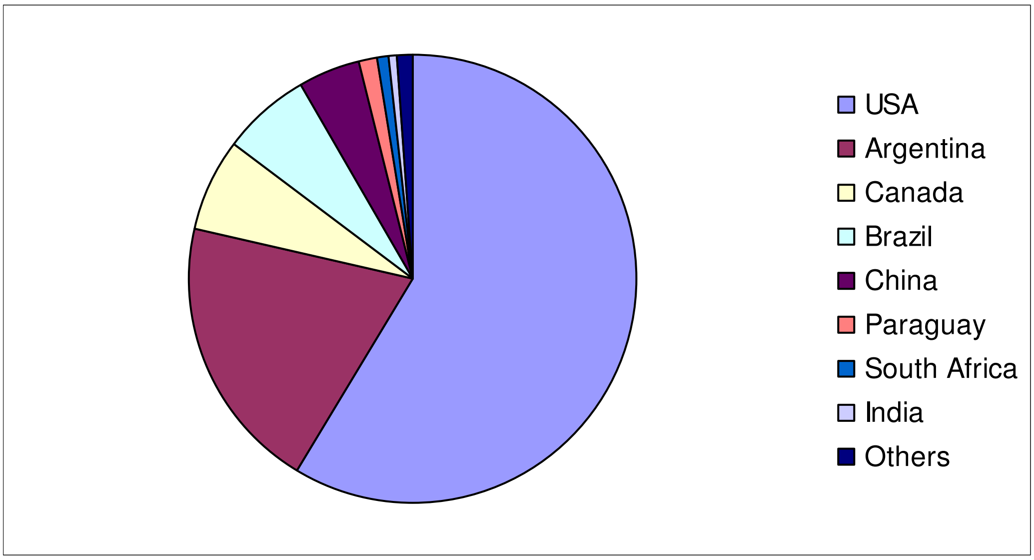

Figure 8. Top countries in the cultivation of GM crops (share of the total area under GM varieties world-wide) in 2004. GM varieties were cultivated in 17 countries. (James 2004)

In the EU genetically modified maize, soya and oilseed rape products have been approved for the market to be used as either food or feed (see Chapter 1.7. Statutes on GMOs and genetically modified products, *Approval of genetically modified products in the* EU). The genetically modified crops approved for cultivation in the EU are usually not suitable for cultivation in Finland without further plant breeding (MMM 2004).
The small share of the EU in the statistics is partly due to the fact that between 1998 and 2003 no new GMOs were approved for marketing because of the revision of the legislation.

Industrial potatoes could be the first GM varieties to be cultivated in Finland. Sweden has an application concerning the approval of so-called amylopectine potato for cultivation pending in the EU. In this potato the starch consists mainly of amylopectine (the production of amylose fraction has been extinguished). This potato could also be cultivated in Finland. In Finland Boreal Plant Breeding is developing genetically modified starch potato for the coating of fine paper. The objective is to develop a potato variety suited to the Finnish conditions where the starch content could be raised from the current 17 per cent to 20-21 per cent, which improves the productivity of starch production. The study is now at the field test stage and the variety could enter the market around 2010. Genetically modified beets or oilseed rape could also be introduced to cultivation in Finland if the EU gives the permission for this, but it is uncertain whether varieties suited to the Finnish conditions would be available. The production of a commercial GM variety for the cultivation of sugar beet in Finland would take 2 to 5 years.

6. Transport of pollen, fertilisation and gene flow

When different varieties of the same plant species are cultivated side by side, there is usually natural gene flow between them, especially through pollen. Part of the crop seed is formed as a result of fertilisation by pollen which comes from another plantation. The share of such seed depends, among other things, on the distance between the plantations and the pollination system of the plant (whether the plant is a self-pollinating or cross-pollinating one). In order to reach the objectives set for coexistence, gene flow via pollen must be estimated quantitatively.

Decisions on isolation distances to be applied in breeding and seed production to achieve the degree of varietal purity required for sowing seed have been made on the basis of long-term experience in plant breeding.

In most plant species the seed is produced through sexual reproduction, i.e. as a result of pollination and fertilisation. In certain plant groups, such as citrus fruit and many wild grasses, seed may often (or mainly) be produced asexually (apomictically), which means that the seed grows into genetic copies of the mother plant.

In Finnish crops either the wind or insects transport the pollen from one flower to another. Wind-pollinating plants include cereals, fodder grasses and beets, and partly turnip rape and oilseed rape, while many plant species with conspicuous flowers, such as berry and fruit plants, carrot, sunflower, and partly turnip rape, oilseed rape and potato, are insect-pollinating ones. The last one, however, lacks nectar and thus does not attract pollinating insects.

The transportation of pollen decreases rapidly as the distance from the source plant or plot increases. In addition, only part of the transported pollen participates in the fertilisation, which means that the fertilisation frequency decreases even more as the distance becomes longer.

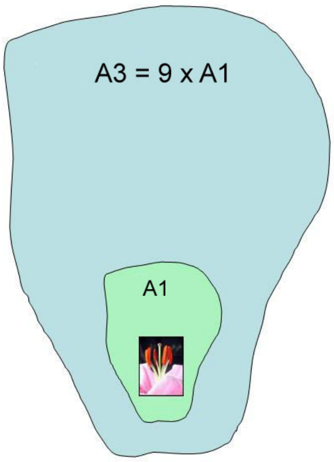

Figure 9. When the diameter of the distribution area grows three-fold, the average content of the pollen originating from the plant decreases to one-ninth per area unit (i.e. in proportion to "the square of the diameter")**.**

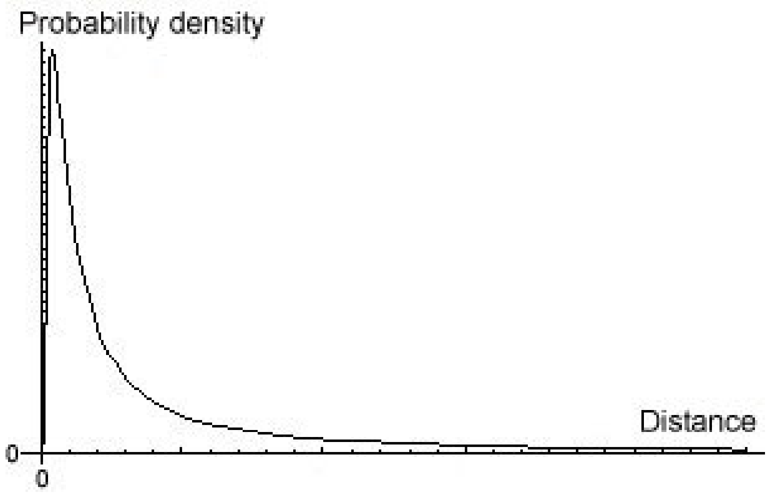

Figure 10. An example of a leptokurtic i.e. "high peak" frequency distribution. The peak is high, which means that most of the probability mass is strictly concentrated. The tails are low, i.e. there is little probability mass. Figure**:** Anna Kuparinen 2005.

The reduction can be described using the geometry of equally shaped figures (Figure 9). If the pollen leaving the source flower spread evenly to the surrounding area, the average content of the pollen would decrease in proportion to the increase in the distribution area. Thus, if the diameter of the distribution area grows ten-fold, the average content of the pollen from the flower in the area decreases to a hundredth part.

In reality pollen is not distributed evenly over the area but decreases much more rapidly in accordance with the negative-exponential or so-called leptokurtic model (Figure 10). In this kind of distribution model with a "high peak" most of the pollen stays close to the source flower or leaves the pollination process along the way. Only a very small share of the pollen is transported over longer distances, but in the "tails" of the distribution the decrease also occurs more slowly.

The small share of pollen left in the tail (long-distance transportation) is not very significant for coexistence, because quantitatively it causes little admixture. Relatively short distances are in the key position in terms of staying below the threshold values laid down in the Community legislation.

What has been described above represents the statistical main rule. However, pollen may occasionally spread in very small quantities further away, especially if whirlwinds lift it higher and the direction of the wind does not change during the flowering season.

The fertilisation capacity of pollen decreases as it is transported in the nature. Factors that may weaken the capacity include ultraviolet radiation, drought and excessive humidity. Depending on the species, this reduces the success of pollen transported over longer distances in the competition on fertilisation with fresh pollen from nearby plants.

When reaching its destination the small amount of pollen transported over a longer distance is faced with strong competition with quantitatively overwhelming (and more viable) pollen mass or cloud produced by the recipient plant population. In the cross-breeding creeping bentgrass the competition by local pollen reduced the share of seed produced by long-distance pollen to a hundredth part compared to a situation in which the local pollen had been eliminated through test arrangements (Watrud et al. 2004). In insect-pollinating oilseed rape the share of seed produced by long-distance pollen fell to less than a tenth when measured in normal, pollen-producing recipient plants (instead of test plants with sterile stamens) (Ramsay et al. 2003). The advantage is even clearer in self-breeding plants with closed flowering type, where the pollen of the plant itself often comes loose before the bud opens, and pollination has usually been done before the flowers dehisce.

For these reasons, among others, the gene flow has in reality proven much smaller than could be deducted from the primary observations on the transport of pollen (Figure 12, Tonsor 1985). This is why the strength of the gene flow is now measured from the real fertilisation results, i.e. by recording the frequency of occurrence of long-distance genes in the seed produced by the recipient test pants (Ritala et al. 2002).

Insect pollination

In insect pollination the pollen is transported in the hair of the pollinator to the stigma of the recipient plant. The structure of the flower is usually adapted to the way a certain pollinator acts. Bees are the most significant pollinators of cultivated plants, but sometimes flies may also be of some importance.

The pollination result depends on the strength of the bee communities, distance from the hive to the plant stands and location of the hives, time when the communities are moved and steering of the bees to the stands. The larger the bee community is the greater number of field bees it has. Stronger communities also fly in cooler weather than the weak ones.

Bumblebees fly out for pollination also in cool conditions, markedly cooler than bees do, but they change the plant species quite easily even during one pollination trip, which may weaken the fertilisation result.

Bees are more loyal to certain flowers than bumblebees and they often stick to one, well-flowering plant species at a time. Bees may visit plantations which are several kilometres away when there is a shortage of nutrition, but in favourable conditions very few of them fly further than 1,000 metres from the hive. When the distance from the hive grows, the number of bees per area unit decreases. This means that the pollination result is the poorer the further away the bee communities are from the plantation. The best result is achieved when the hives are located in the plantation and the plants are less than 100 metres away from the bee community (Hämäläinen et al. 1983).

The position of the European Commission is that pollen is an unintended impurity in the honey and the amount is less than 0.5 per cent. The amount of the possible alien GM pollen present in the pollen is so small that no labelling may be required under any provision. Pollen is not an ingredient in the honey, because honey is a single food, which means that no separate approval for this kind of honey can be required.

Bees comb pollen from their hair into pollen baskets on their legs, where the pollen is transported to the hive to be used as nutrition, i.e. it does not take part in fertilisation. Part of the pollen falls on the ground or wears off during the visits in flowers (Figure 11). The fertilisation capacity of the pollen falls along with the time and flight, which weakens the fertilisation result accordingly.

Where necessary, the transportation of alien pollen from the neighbouring plantation can be reduced by means of buffer rows on the field borders.

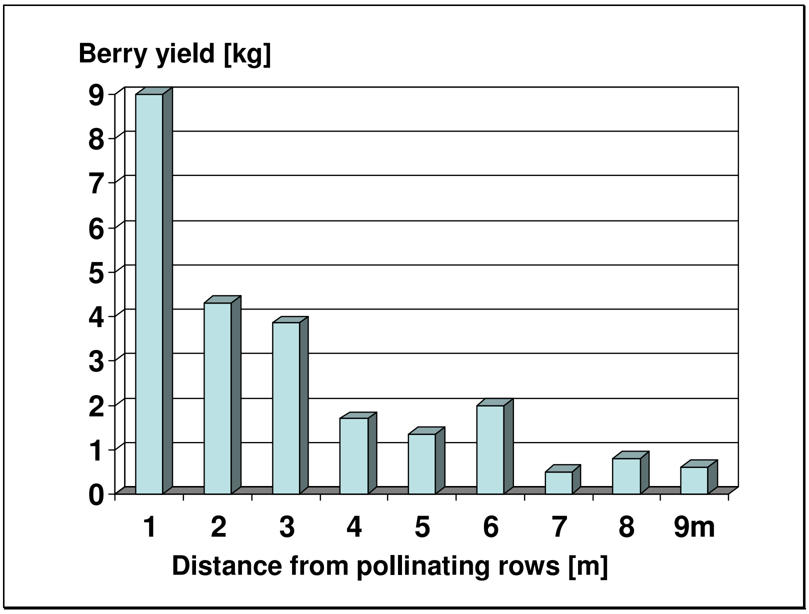

Figure 11. The yield of a self-sterile insect pollinating plant (arctic bramble) decreases rapidly when the distance from the pollinating rows increases (Ryynänen 1973). In self-fertile species the gene flow would remain smaller because their fertilisation is dominated by pollen from the stand itself.

Wind pollination

The spread of pollen depends on both the external conditions in the district and the properties of the plants. The wind speeds in Finland (especially in the inland) are clearly smaller than in Denmark or England.[9] In Finland the woodland areas also often restrict the transport of pollen from one field to another.

Part of the pollen of wind pollinating plants falls to the ground or gets stuck in the plants. The pollen of maize, for example, is heavy and most of it falls to the ground within the radius of a few metres from the source plant, while the pollen of bentgrass may spread in proportionally larger quantities over longer distances as well (Watrud et al. 2004).

Table 7. Size of pollen particles in grasses. (Nilsson et al. 1977, Lewis et al. 1983, Faegri & Iversen 1989)

	Largest diameter of a pollen particle [µm]
Bentgrass	22
Meadow foxtail	25 - 34
Orchard grass	30 - 38
Italian ryegrass	30 - 42
Timothy	30
Oats	48 - 54
Barley	40 - 48
Rye	47 - 65
Wheat	45 - 60
Maize	80 - 122

However, the flight properties of pollen are not in direct proportion to the size of pollen particles, but they depend more on the density of the particles.

The different flowering time of, for example, turnip rape and oilseed rape or the winter and spring varieties of the same plant species can minimize or prevent the transport of genes between them.

Self-breeding reduces the gene flow very strongly (Figure 12). On the contrary, cross-breeding male-sterile plant line can only be fertilised by pollen of another plant line, which increases the gene flow. The latter situation may arise in the production of sowing seed of hybrid varieties.

[9] This reduces the average intensity of gene flow through pollen in Finland.

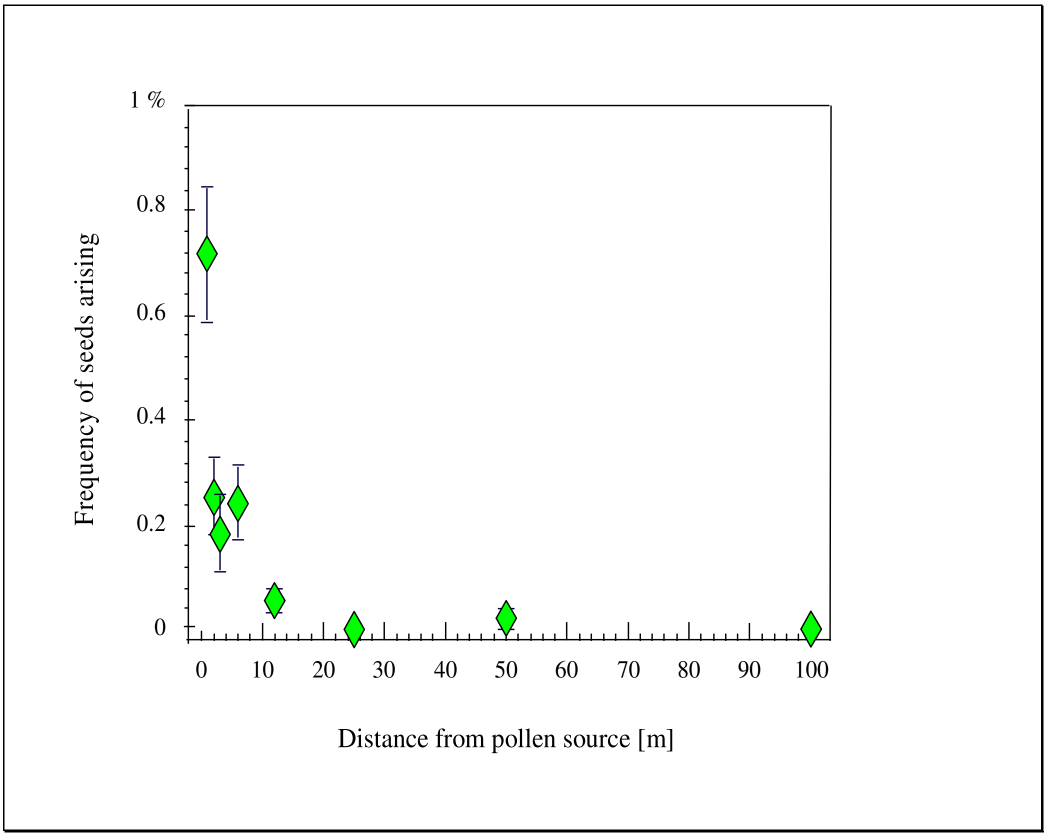

Figure 12. In barley there is very little gene flow, even if the recipient in the test is an open-flowering and male-sterile test barley (Ritala et al. 2002).
In the cultivation of conventional barley the gene flow from one field to another is 10 to 100 times less frequent, because the recipient plant is ordinary barley, which has fertile stamens and is of the "closed flowering"-type. In this kind of barley only 2 to 10 per cent of the seed is usually produced as a result of cross pollination (Hammer 1975, 1977, Ritala et al. 2002, Jacot et al. 2004). Pollen originating in the recipient field has an advantage in timing and volume, which means that it easily supersedes pollen transported from elsewhere in the competition on fertilisation (Watrud et al. 2004).

7. Statutes on GMOs and genetically modified products

Provisions on the use of genetic modification in research, laboratories, industrial plants, cultivation, and various kinds of products on the market are given in several statutes of the European Community.

Release of genetically modified organisms to the environment

Directive 2001/18/EC[10] concerns the deliberate release of GMOs[11] to the environment. Part B of the Directive deals with small-scale research and development tests (field tests), where the decision-making is for the most part national. Part C of the Directive concerns placing of GMOs on the market as such or in products, and here the decisions are made on the Community level. According to part C, a product may be rejected in commercial cultivation only if it has been found to pose a risk to human health or the environment.

After a product has been approved, it may be used and released in the whole Community territory. According to the safeguard clause in Article 23 of the Directive, the use of an approved product

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[10] Directive 2001/18/EC of the European Parliament and of the Council of 12 March 2001 on the deliberate release to the environment of genetically modified organisms and repealing Council Directive 90/220/EEC - Commission Declaration [OJ L 106, 17/04/2001]

[11] The legal definitions relating to the topic are mainly given through various kinds of lists and exception (which are not justified on the grounds of scientific risk assessment).

Article 2 Definitions. For the purposes of this Directive**:** 1) 'organism' means any biological entity capable of replication or of transferring genetic material; 2) 'genetically modified organism (GMO)' means an organism, with the exception of human beings, in which genetic material has been altered in a way that does not occur naturally by mating and/or natural recombination. Within the terms of this definition:

a) genetic modification occurs at least through the use of the techniques listed in Annex I A, part 1;

b) the techniques listed in Annex I A, part 2, are not considered to result in genetic modification;

Article 3 Exemptions. 1. This Directive shall not apply to organisms obtained through the techniques of genetic modification listed in Annex I B.

ANNEX I A, PART 1. Techniques of genetic modification referred to in Article 2(2)(a) are *inter alia*:

1) recombinant nucleic acid techniques involving the formation of new combinations of genetic material by the insertion of nucleic acid molecules produced by whatever means outside an organism, into any virus, bacterial plasmid or other vector system and their incorporation into a host organism in which they do not naturally occur but in which they are capable of continued propagation;

2) techniques involving the direct introduction into an organism of heritable material prepared outside the organism including micro-injection, macro-injection and micro-encapsulation;

3) Cell fusion (including protoplast fusion) or hybridisation techniques where live cells with new combinations of heritable genetic material are formed through the fusion of two or more cells by means of methods that do not occur naturally.

ANNEX I A, PART 2. Techniques referred to in Article 2(2)(b) which are not considered to result in genetic modification, on condition that they do not involve the use of recombinant nucleic acid molecules or genetically modified organisms made by techniques/methods other than those excluded by Annex I B:

1) in vitro fertilisation,

2) natural processes such as: conjugation, transduction, transformation,

3) polyploidy induction.

ANNEX I, B. Techniques/methods of genetic modification yielding organisms to be excluded from the Directive, on the condition that they do not the use of recombinant nucleic acid molecules or genetically modified organisms other than those produced by one or more of the techniques/methods listed below are:

1) mutagenesis,

2) cell fusion (including protoplast fusion) of plant cells or organisms which can exchange genetic material through traditional breeding methods.

may be provisionally restricted or prohibited in a certain Member State if there is new or additional information indicating that it constitutes a risk to human health or the environment.

In Finland the provisions laid down in the Directive have been implemented in the national legislation through amendment 847/2004 to the Gene Technology Act 377/1995, which entered into force on 15 September 2004.

Genetically modified food and feed, labelling and traceability

The Community legislative acts concerning GM food and feed are**:**
- Regulation on genetically modified food and feed (EC No 1829/2003)[12], and
- Regulation concerning the traceability and labelling of genetically modified organisms and the traceability of food and feed products produced from genetically modified organisms (EC No 1830/2003)[13].

These regulations have been applied as of 18 April 2004.

The purpose of Regulation 1829/2003 of the European Parliament and of the Council is to ensure (for the part of GM foods and feeds) a high level of protection of human life and health, animal health and welfare, the environment as well as consumer protection while ensuring the effective functioning of the internal market. The Regulation lays down the Community procedures for granting authorisation to genetically modified food and feed and issues the rules for the control and labelling of GM food and feed.

According to the Regulation, products, consisting of, containing or produced from genetically modified organisms (in this case food and feed) must be clearly labelled. Based on Regulation 1830/2000, GM products must be traceable in all stages of the food chain. This is considered important to give the users of the products the freedom of choice and win their confidence in the products.

The earlier rule was that foodstuffs containing genetically modified organisms or produced from these had to be labelled if modified DNA or proteins were present in the products. After the revision the labelling obligation was extended a) to concern both feeds and feed and food additives b) to the obligation to label all foods and feeds with ingredients derived from GMOs - independent of whether gene technology has influenced the properties of these ingredients or composition of the product (Table 8).

According to the current legislation, for example, oil produced from genetically modified oilseed rape must be labelled, even if its chemical composition does not differ from the conventional one and no indications of modification would be shown in analyses. However, the labelling obligation does not concern fermentation products manufactured by means of genetically modified microbes, such as additives, flavourings or vitamins, provided that the genetically modified microbe is not present in the product (Table 8).

To ensure uniform practices in different Member States, decisions on detailed interpretations are

[12] Regulation (EC) No 1829/2003 of the European Parliament and of the Council of 22 September 2003 on genetically modified food and feed (Text with EEA relevance) [OJ L 268, 18/10/2003]
[13] Regulation (EC) No 1830/2003 of European Parliament and of the Council, of 22 September 2003 concerning the traceability and labelling of genetically modified organisms and the traceability of food and feed products produced from genetically modified organisms and amending Directive 2001/18/EC [OJ L 268, 18/10/2003]

searched for in the Standing Committee on the Food Chain and Animal Health, section Genetically Modified Food and Feed and Environmental Risk . Table 8 shows some examples of how the labelling obligation is being interpreted today.

Regulation 1829/2003 also defines the limits for unintended presence of GMOs, i.e. labelling threshold values. If these are exceeded, the products must be labelled as containing GM material. The threshold value is 0.9 per cent for ingredients approved for marketing in the Community and 0.5 per cent for ingredients which have not been approved to the Community market but whichhave passed the scientific safety assessment in the EU. The new rules require that feed must be labelled based on the same principles as those applying to food. At least for the time being these threshold values also apply to organic production.

Table 8. Examples of the labelling of GM food and feed.[a]

Product	**Example**	**Labelled before**	**Labelled now**
GM crop	Chicory	Yes	Yes
GM seed	Kernel of maize	Yes	Yes
GM foodstuff	Maize, soybean sprout, tomato	Yes	Yes
Product produced from GMO	Maize flour[b]	Yes	Yes
Products produced from GMO	Maize oil, soya oil, rapeseed oil[c]	No	Yes
Product produced from GMO	Glucose syrup made from maize starch[c]	No	Yes
Foodstuffs produced by means of GM enzyme	Juice clarified by means of pectinase[d]	No	No
Foodstuffs derived from animals fed by GM feed	Eggs, meat, milk[e]	No	No
Additives produced from GMO	Purified lecithin made from GM soya present in chocolate[c]	No[f]	Yes
GM feed	Maize	No[f]	Yes
Feed produced from GMO	Maize gluten feed, soy flour	No	Yes
Fermentation product produced by means of GMO	Vitamin B2	No	No[g]

[a] Examples are GM food and feeds which have not been approved to the market in the EU.
[b] Product contains modified DNA and protein.
[c] Product contains no modified DNA or protein.
[d] Processing aids used only in the manufacturing process of food and feed do not fall within the definition of food and feed and thus they do not fall within the scope of Regulation (EC) No 1829/2003/EC.
[e] Foods and feeds obtained from animals fed by GM food or medicated using GM medicinal products do not fall within the scope of the Regulation, either.
[f] Earlier statutes did not concern additives or feedingstuffs
[g] The meeting of the GM section of the Standing Committee on the Food Chain and Animal Health of 24 September 2004 approved a Commission interpretation, according to which fermentation products produced by means of genetically modified micro-organisms which is not present in the final product are not included in the scope of Regulation 1829/2003. Such fermentation products include additives, aromas and vitamins.[14]

[14] Requirements laid down in the Regulation concerning notification and package labelling do not apply to these fermentation products. However, the GM microbe must be cultivated in contained circumstances. Further information: http://www.elintarvikevirasto.fi/.

According to Regulation 1830/2003[15] concerning the traceability and labelling of genetically modified organisms, products containing GMOs must be labelled and their movement in the production and distribution chain must be controlled. The operators must also transmit information on the GM ingredients contained in the product when it moves forward in the production chain, as well as keep such information for five years. The most important objectives of Regulation 1830/2003 are that products containing GM ingredients are properly labelled, the labelling can be controlled and the information can be verified, the possible impacts of the products can be monitored and, where necessary, a certain product can be removed in a targeted way from the market.

Approval of genetically modified products in the EU[16]

Between 1998 and 2003 no new genetically modified organisms were approved for the market in the EU. During this so-called moratorium the Community legislation was developed, for example, by revising the Directive concerning the release of genetically modified organisms to the environment (2001/18/EC)[17] and by creating rules for the approval, labelling and traceability of genetically modified food and feed (Regulations 1829/2003 and 1830/2003).

The principle of a "one door" is applied to the assessment and application procedure for GMOs and genetically modified food and feed. This means that only one application is needed for obtaining the authorisation for deliberate release of a GMO in accordance with the conditions laid down in Directive 2001/18/EC and introduction into market of a GMO to be used as food and/or feed as laid down in Regulation (EC) No 1829/2003.[18]

According to these procedures, marketing authorisation for food or feed containing genetically modified organisms or ingredients derived from these may be applied for food or feed use only (in the case of import), as well as for cultivation in the EU (if this is also the intention). The authorisation can be applied for from the same competent authority with a single application. If the product is intended for cultivation, Regulation 1829/2003 calls for the environmental risk assessment resembling the one laid down in Directive 2001/18/EC. The assessment must also be carried out when a product intended for food or feed use contains live genetically modified organisms capable of reproducing, such as germinable seed.

When assessing an application concerning a GM organism which can be used as both food and feed the authorisation should be granted for both uses or neither. The applicant must attach a plan on monitoring after the placing of the product on the market to the application. The authorised products are entered into a public EU register of GM food and feed. Usually the authorisation is granted for ten years and it may be renewed for ten years at a time.

Summary record of the meeting**:**
http://europa.eu.int/comm/food/committees/regulatory/scfcah/modif_genet/summary03_en.pdf

[15] Regulation (EC) No 1830/2003 of European Parliament and of the Council, of 22 September 2003 concerning the traceability and labelling of genetically modified organisms and the traceability of food and feed products produced from genetically modified organisms and amending Directive 2001/18/EC [OJ L 268, 18/10/2003]

[16] http://europa.eu.int/comm/food/food/biotechnology/gmfood/legisl_en.htm

[17] Directive 2001/18/EC of the European Parliament and of the Council of 12 March 2001 on the deliberate release into the environment of genetically modified organisms and repealing Council Directive 90/220/EEC [OJ L 106, 17/04/2001]

[18] Report on the approval procedure, see MEMO/04/102

So far altogether 18 genetically modified organisms have been authorised in the EU for different purposes, such as farming, import, processing, feed and food, under the provisions on the deliberate release of GMOs to the environment (Directive 2001/18/EC, earlier Directive 90/220/EC or Regulation (EC) No 258/1997 concerning novel foods).

Altogether 17 products derived from genetically modified organisms may be marketed in the EU as foodstuffs.[19] These include

• one genetically modified type of soya and maize authorised under Directive 90/220/EEC before the entry into force of the Regulation concerning novel foods and novel food ingredients

• processed foodstuffs derived from e.g. seven varieties of oilseed rape and four varieties of maize as well as seed oil of two varieties of cotton

• Bt11 sugar maize. The European Commission authorised its placing on the market as an imported product for food use on 19 May 2004 (the authorisation application concerning the cultivation of Bt11maize is still being processed)[20]

• NK603 maize. The European Commission authorised its placing on the market as foodstuff and food ingredient on 26 October 2004.[21]

Genetically modified products authorised earlier may still be marketed, but the operators had to submit information referred to in Article 8 of Regulation 1829/2003 to the Commission within six months from the entry into force of the Regulation.[22] These GM products are also entered to the public register, and the ten-year time limit starting from the date when they were first placed on the market applies to them as well.[23]

Summaries of the notifications submitted for the authorisation procedure under Directive 2001/18/EC are published on the Internet.[24] By October 2004 the number of notifications under section C (”Placing of GMOs on the market as or in products”) was 28, 29 applications under Regulation 1829/2003 had been submitted to the Commission[25,26], and 10 new applications had been submitted to the EFSA for assessment.

The European Commission authorised the placing on the market of genetically modified NK603 maize as feed on 19 July 2004. The authorisation concerns the import and processing of maize for only feed or industrial purposes.

However, import of NK603 maize may not be started until the maize has also been authorised for food use, because the authorisation for genetically modified organisms which are likely to be used as both food and feed must be granted for both uses or neither.[27]

On 9 September 2004 17 varieties derived from genetically modified maize (MON810) were approved to the EU list of varieties. The MON810 maize was authorised under Directive

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[19] http://europa.eu.int/comm/food/food/biotechnology/authorisation/list_author_gmo_en.pdf
[20] http://europa.eu.int/comm/food/food/biotechnology/authorisation/258-97-ec_authorised_en.pdf
[21] IP/04/957
[22] Information on existing products submitted to the Commission (products referred to in Article 8 and 20 of Regulation 1829/2003) http://europa.eu.int/comm/food/food/biotechnology/gmfood/notifications_existing_products.pdf
See also http://europa.eu.int/comm/food/food/biotechnology/gmfood/notification_en.htm
[23] IP/03/1056
[24] “Deliberate releases and placing on the EU market of Genetically Modified Organisms (GMOs)” http://gmoinfo.jrc.it/
[25] Summary record of the meeting of the GM section of the Standing Committee on the Food Chain and Animal Health of 24 September 2004 http://europa.eu.int/comm/food/committees/regulatory/modif_genet/summary240904_en.pdf
[26] See http://europa.eu.int/comm/food/food/biotechnology/gmfood/index_en.htm
[27] IP/04/957

90/220/EEC already in 1998. After the decision, sowing seed could be marketed in all Member States. Before this these were included in the variety lists of only Spain and France.[28]

Seed production

The drafting of Community legislation on the threshold values for seed is under way. According to the proposal, a plant variety where the amount of genetically modified seed present as impurity exceeds the content laid down by the variety-specific threshold value may not be marketed as seed for sowing in the Community.

The establishment of the threshold values has not yet been completed, but the Commission has proposed the values 0.3, 0.5 and 0.7 per cent, depending on the species. The value would depend, among other things, on the reproduction strategy of the species.

Factors to be taken into account when selecting the threshold values for seed include the likelihood of gene flow through cross-pollination, volunteers and seed accumulated in the soil (soil seed bank). The threshold values for seed should be such that in most cases the content of unintended GM material in products from non-GM plantations does not exceed the threshold value of 0.9 per cent laid down in the EU provisions, which would trigger the labelling obligation for the product.

National legislation on sowing seed (mainly in Finnish):

- Seed Trade Act 728/2000
- Decrees of the Ministry of Agriculture and Forestry concerning
    - trade in the seed of cereal crops 109/00, amended by 33/03
    - trade in the seed of grass and fodder crops 110/00, amended by 32/03
    - trade in the seed of oil and fibre crops 111/00, amended by 28/03 and 6/04
    - trade in seed potato 112/00, amended by 22/01, 30/03 and 69/04
    - trade in seed of vegetable crops 113/00, amended by 27/03
    - trade in seed of beet 114/00, amended by 34/03
    - variety list of plant varieties 51/04
    - sowing seed mixtures 116/00
    - seed trade in local varieties of cereal, grass and fodder crops 117/00, amended by 31/03
    - carrying out plantation inspections 118/00, amended by 29/03
    - control of seed trade 119/00
    - sampling supervised by an authority in seed production 44/03, amended by 48/04
- Act on Preventing Wild Oat 185/2002
- Decrees of the Ministry of Agriculture and Forestry concerning
    - preventing wild oat 326/2002
    - compensating for costs incurred in preventing wild oat 32/02
    - wild oat in seed production 43/02, amended by 23/03
- Act on Plant Variety Rights 789/1992, amended by 721/1995, 238/1999 and 651/2000 (also in English)

[28] IP/04/1803

Organic production

The minimum requirements for organic production to be applied in all Member States are laid down in Council Regulation (EEC) No 2092/91.[29] The Regulation has been supplemented by Regulation 1804/1999.[30] Community legislation prohibits the use of genetically modified organisms and products derived from these in organic production (except for veterinary medicines). Today the products are labelled in accordance with the relevant legislation (see *Genetically modified food and feed, labelling and traceability*).

National legislation on organic production (mainly in Finnish):

- Act on Implementation of the Common Agricultural Policy 1100/1994 (also in English), amended by 273/2003
    - Decree of the Ministry of Trade and Industry concerning the use of additives and other similar substances in foodstuffs derived from animals marketed as organic products 773/2000
    - Decree of the Ministry of Agriculture and Forestry concerning the organisation of the control of organic agricultural products, foodstuffs and alcoholic beverages 346/2000, amended by 127/2001, 712/2003 and 897/2003
    - Decree of the Ministry of Agriculture and Forestry concerning organic livestock production 74/00, amended by 39/2003
    - Decree of the Ministry of Agriculture and Forestry concerning propagating material used in organic production 1271/2003

Obligations of the Cartagena Protocol on Biosafety

The objective of the Cartagena Protocol on Biosafety adopted by the parties to the Convention of Biological Diversity (CBD 1992) is to protect biological diversity and its sustainable use in accordance with the precautionary approach against the adverse effects of the transfer, handling and use of living modified organisms especially in transboundary movements, taking also into account risks to human health. Community legislation implementing the provisions of the Protocol (in particular, the so-called Export Regulation EC No 1946/2003[31]) has introduced a common system of notification and information to ensure an adequate level of safety in the movements of living genetically modified organisms between the European Community and third countries.

The Protocol entered into force in Finland in October 2004.[32] The national focal point referred to in the Protocol is the Ministry of the Environment, and the Gene Technology Board is designated as the competent national authority for the Protocol in the Gene Technology Act.

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[29] Council Regulation (EEC) No 2092/91 of 24 June 1991 on organic production of agricultural products and indications referring thereto on agricultural products and foodstuffs

[30] Council Regulation (EC) No 1804/1999 of 19 July 1999 supplementing Regulation (EEC) No 2092/91 on organic production of agricultural products and indications referring thereto on agricultural products and foodstuffs to include livestock production

[31] Regulation (EC) No 1946/2003 of the European Parliament and of the Council of 15 July 2003 on transboundary movements of genetically modified organisms (Text with EEA relevance) http://europa.eu.int/eur-lex/pri/fi/oj/dat/2003/l_287/l_28720031105fi00010010.pdf

[32] http://europa.eu.int/scadplus/leg/fi/lvb/l28119.htm

2. GENERAL AGRONOMICAL MEASURES

1. Tillage, sowing and harvesting

Good agricultural practice

Compliance with the good agricultural practice demands that the land is tilled and fertilised in an appropriate manner and sowing is carried out so that even germination is possible. The species and varieties must be suitable for the region. Both the cultivation region and size of the seed must be taken into account in determining the quantity of seed to be sown. The parcels must be in such condition that a marketable crop can be harvested from them. This includes appropriate plant protection, which may be realised through crop rotation or mechanically, biologically or chemically. Wild oat must be prevented as well. Appropriate fertilisation means that that balanced intake of nutrients by the plants is ensured in cultivation. The crop must be harvested or the land must be grazed in an appropriate manner (MMM 2001, Muhos 2004, Verso 2004).

Tillage of land to reduce the soil seed bank

The species composition and abundance of the seed sprouting on the land and weed seed in the soil (soil seed bank) reflects the cultivation history of the land. The soil seed bank consists mainly of weed species which have adapted to the cultivation system. Tillage influences the sprouting of seed and seed production as well as the depth in which the seed is located in the soil. Ploughing turns the new seed deep into the soil while lifting old seed on the surface. With no or reduced tilling there is less soil turnover and this does not go as deep, which means that a larger soil seed bank may accumulate in the soil surface. In unploughed land the seed also stays closer to the surface where germination is easier, and efficient weed prevention may reduce the amount of seed considerably in a few years. Variations in the temperature also destroy seeds left close to the surface. It has been estimated that the yield, soil properties and weed stand would gain a new balance when the same tillage practice has been applied for 4 to 10 years.

The amount of sprouting seed does not depend on the quantity of the seed in the soil alone. Various factors, such as seed dormancy, lack of light, soil temperature and excessive moisture or drought, metabolites and reduced oxygen content may prevent germination, depending on the species.

The germination capacity of seeds varies considerably between species, but some seeds may survive in the soil for years. Factors influencing this include the soil type and tillage method. Seeds maintain their germination capacity the longer the deeper they have been sown. 90 per cent of the seed lose their germination capacity within six months from the harvesting, but the others retained their capacity for years. According to studies, 95 per cent of the seed did not retain their germination capacity for more than 20 months when reduced tillage and delayed ploughing were used. When regular ploughing was carried out immediately after harvesting, the seed retained their germination capacity twice as long (DIAS 2003).

The soil seed banks of oats, wheat, maize, rye and onion usually disappear from the soil in a year, while the soil seed banks of barley and perennial ryegrass may survive one to four years. In favourable conditions the seeds of oilseed crops and soil seed banks of clover and potato may survive in the soil for several years. However, the germination capacity decreases over the years, which makes the soil seed bank less and less significant in practice. For example, tubers of potatoes retain their germinability in practice for less than one year even in carefully controlled laboratory conditions. As a rule small seed retain their germination capacity in the soil longer and spread more easily e.g. in the wind than bigger seed. The accumulation of the soil seed bank also depends on the variety (DIAS 2003).

The following factors should be taken into account to reduce the soil seed bank.

- Seed is destroyed or germination capacity is lost the best on the soil surface. In Finland seed do not overwinter very well or they are eaten by birds. Various kinds of pests also influence the survival and health of seed. Plants resulting from germination in the autumn can be destroyed chemically or mechanically. The cultivation of autumn cereals increases the soil seed bank because the land must be tilled immediately after harvesting
- Deep ploughing influences the seed dormancy and the seed retain their germination capacity longer. The period of dormancy and germination capacity of the soil seed bank disappear when the seed are on the surface.
- Climate, soil moisture and temperature influence the duration of dormancy and survival of seed. The period of dormancy is shorter in warm conditions and/or moist soil.
- Soil seed bank can be reduced through crop rotation so that, for example, another species, bred by conventional means, is cultivated after the genetically modified species. The result is the best when grasses and dicotyledonous plants rotate with each other and efficient, selective pesticides are used when possible. In seed production, efforts are made to prevent the admixture of species and varieties through restrictions on the preceding crop in the rotation.

Reducing the number of volunteers

Volunteers refer to tubers and roots which survive in the soil over the winter and begin to grow and develop new tubers and roots in the following spring. According to experiences of the Sugar Beet Research Centre, in the Finnish conditions the ground frost destroys the volunteers. In the case of potatoes the problem is more difficult to solve (see 3.4. Sugar beet and 3.5. Potato).

The problems relating to volunteers can largely be solved through restrictions on the preceding crop in the rotation and appropriate timing of tillage.

Treatment of headlands and border zones

The headlands and border zones have two different roles in plant production. On the one hand, they increase the problems due to diseases, pests and weeds, the cultivated area is smaller and their management is more difficult and expensive, but, on the other hand, they reduce erosion and the movement of nutrients and pesticides outside the arable land areas. They also serve as habitats to natural enemies of pests and allow the occurrence of diversified flora and fauna. At present one of the conditions for environmental support is that headlands and border zones are covered with perennial vegetation.

Birds and other animals, insects, wind, currents of air and machines transport seed, grains and pollen from one arable area to another and to headlands and border zones. The weather conditions during the sowing and harvesting period, such as the strength and direction of the wind, influence the formation of the soil seed bank. According to the conditions for environmental support, the headlands and border zones should not be ploughed so that most of the seed disappears during the winter. Careful cleaning of the machinery before moving from a plantation of a genetically modified crop to other plantations prevents the spreading and admixture of seed.

Determining the sowing time

The maturing of the crop can be influenced through the selection of species and varieties. When cultivating genetically modified varieties, the growth period and pollination time must be taken into account to prevent cross-breeding. If genetically modified and conventional varieties of the same species are cultivated in the same area, involuntary pollination between the varieties can be prevented by making sure that the growth periods of the varieties are different.

For cereals this succeeds quite well, because their pollination time is short. Oilseed rape starts flowering about a week later than turnip rape, but flowering may last as long as 3 to 4 weeks, which means that their flowering may overlap. Winter turnip rape would make it easier to separate the flowering periods. However, it is difficult to breed winter turnip rape varieties that would succeed in the Finnish conditions. So far only small amounts of two varieties of winter turnip rape have been cultivated in Finland.

Only the spring varieties of barley and oats are cultivated in Finland. Instead, both spring and autumn varieties of wheat suited to the Finnish conditions are available. In the case of rye there are only autumn varieties, except for one new domestic spring variety. Because of the early sowing time of winter cereals the plants grow quite a lot in the autumn, which increases the pest risk. Rye has been found to suffer from early sowing less than winter wheat. The growth of plants from seed which has fallen on the ground is prevented through control treatment in the autumn.

In addition to the selected species and varieties, the sowing time depends on various other factors, such as the soil type, drainage system and weather conditions. Because of the unfavourable weather conditions and short optimal sowing season, sowing cannot often be done at the best possible time in Finland. In clay soil the optimal sowing period may be only 3 to 5 days. Early sowing increases the risk of crust formation in silt and clay soil and the slow warming of the land influences the quality and quantity of the final crop. The beginning of May is the best sowing season for spring cereals and oilseed crops, while winter wheat is usually sown in late August or early September. The end of August is the optimal sowing period for rye in Southern Finland, while in the north it is somewhat earlier.

The time of potato planting is determined according to the soil temperature and type as well as the variety. On average the best time is around mid-May. In the case of sugar beet only early sowing done in April produces a good yield. In potatoes and sugar beets unintended pollination between species does not cause any problems, because the growing period is too short to allow the seed to mature (further information on this is needed). Instead, volunteers may cause admixture between varieties.

Cleaning machinery, implements and combine harvesters

Seed spread easily through machinery and implements. Even if thorough cleaning of machinery is a difficult and time-consuming task, it must be done especially when equipment is transferred to parcels planted with other species or varieties. This is even more important if equipment moves across neighbouring fields or other land areas.

The cleaning of machinery and implements is not yet included in the definition of good agricultural practice, which is a condition for receiving certain payments. When genetically modified crops are being introduced to cultivation, the definition of good agricultural practice needs to be revised by adding the requirement concerning the cleaning of machinery and implements. In contract harvesting this will not be without problems.

Reducing unintended crossing

The intensity of the gene flow coming to an arable parcel depends a great deal on its size and shape (Tables 3 and 4). If the cultivation area is large, most of the pollination takes place within the area. Instead, if a small area is cultivated next to a larger one with another variety of the same plant, a larger share of the seed in the small area may originate from pollen which comes from the larger areas. Namely, the marginal zone facing to the adjacent plantations constitutes a proportionally larger share of the small area. The effect is even greater if the area is narrow and the other variety grows along its long side.

To prevent unintended gene flow from one variety to another, the cultivation areas of each variety should be as large, uniform and square (i.e. not narrow) as possible.

Crossing between varieties also depends quite strongly on the size of the pollination source and distance to it. This applies especially to beets and maize.

The isolation distance is a central factor in reducing unintended crossing. The content of the spreading pollen decreases at first very rapidly as the distance grows. However, very small quantities may be spread over long distances depending on the speed and direction of the wind and air temperature. Of this pollen only a fraction may lead to fertilisation and seed formation, because the content of local pollen on the recipient spot is great and it has a head-start in fertilisation, especially in self-pollinating species. The fertilisation capacity of the pollen often weakens during transport as well.

Reducing threshing and harvesting loss

The purpose of threshing is to detach the grains from the ear, panicle or other flowerage as gently as possible but efficiently enough to avoid threshing loss. In order for the grain to be detached from the ear, the external pressure directed to it must be greater than the one attaching it to the ear. How easily the grain is detached is partly a property of the species or variety, but in part it depends on the conditions during the growing season, as well as e.g. the location of the grain in the ear. Grains located in the middle of the ear are more tightly attached than those on the top. The force needed to detach the grain is the smallest when the ear is fully ripe.

The best way of reducing the soil seed bank and volunteers is to cut down the threshing and harvesting loss. Threshing loss can be minimised by adjusting the combine harvester and correct driving speed. The threshing loss depends a great deal on the ripeness of the grains. If harvesting is carried out too late (especially for oilseed rape) grains fall on the ground already before harvesting. Harvesting losses of potato and sugar beet also depend on the adjusting the harvesting machine and driving speed.

2. Transport, drying and storing of the crop

Seed may spread to the surrounding area when the crop is transported from the arable land to the drying plant or farm or intermediate storage. This may take place especially if the trailer is not covered. Seed may also spread during the other handling, including the handling of straw. However, the basic principle must be that the crop of a genetically modified variety must always and in all conditions be traceable. The requirements concerning threshold values also apply to admixture of varieties.

The best and, in fact, only way of preventing the spreading of seed to the environment and admixture is by thorough cleaning of the storage facilities and drying equipment between varieties. This should be done especially if the harvested crop includes at least one genetically modified variety. Special care is also needed in the storage of genetically modified sowing seed which is not sown in the next season as well as genetically modified crop left in the stores so that no admixture with conventional sowing seed takes place.

3. Exchange of information between neighbours

The right to information among neighbours must also be solved. Farmers cultivating the neighbouring parcels have the right to know what is cultivated on each parcel and which production type is being used (cf. right to information from the Rural Business Register and notification obligation under the Gene Technology Act).

According to the guidelines given in Commission Recommendation (EU 2003b), farmers who introduce a new production type[33] in a region must take the other farmers into account in GM issues so that priority is given to the choices of the other farmers, whether these concern the selection of species or varieties, crop rotation or sowing time. Farmers who plan to introduce newer production techniques should inform the neighbouring farmers about their intention in writing well before spring, and those adhering to older techniques must also give their reply well before the sowing is started. Those introducing new technologies must adapt to the demands of the established farmers, provided that the requirements can be considered reasonable in terms of running the farm. The procedures must be clear and the possibility of intentional harm or mischief must be excluded.

4. Training

According to the Commission Recommendation, Member States should encourage voluntary or mandatory training courses and extension programmes for farmers to raise awareness on coexistence among farmers and other parties. Member States should also offer technical information on the implementation of coexistence measures. Appropriate measures might include training of staff specialised in coexistence issues for advisory organisations who could then advise farmers in measures relating to coexistence.

A handbook needs to be drawn up on the matter, including a general explanation of coexistence and recommendations, instructions and provisions for cultivation measures. It should provide a thorough account of the consequences to a farmer, for example, from the cultivation of genetically modified species. Farmers also need information on the obligations relating to coexistence, including the requirements concerning certain measures and liability rules. In addition to traditional training courses and various kinds of publications, training and information can be provided through the Internet.

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[33] This refers to type of production which has not been used in the region before. Thus it may just as well mean organic or conventional production or cultivation of a genetically modified variety.

5. Machine cooperation

There are many ways of realising machine cooperation. Neighbourly help is an informal form of cooperation founded on good personal relations. This has not always been planned or agreed in advance. Neighbourly help may include lending of machines or carrying out the work with or without machines or as machine chains. There are no written contracts and the activity is in every respect quite free and flexible.

Many farmers have designed a joint work chain with a neighbour in cases were creating a functioning and efficient work chain alone is not feasible (e.g. harrowing and sowing). Joint work chains are the most common form of machine cooperation. They differ from neighbourly help in that the work is planned in advance and farmers are responsible to each other for the performance, as well as dependent on each other's labour input. The machines used in a joint work chain may be jointly owned or owned by one of the partners, or each partner may also own one machine used in the chain.

A contractor offers machine work for pay so that in this case both the machine and its user are hired to carry out the work. Contracting has increased rapidly, in part because the growth in the farm size increases the amount of work. A contractor may be an independent entrepreneur, but often they are part-time farmers.

Farmers quite seldom conclude a written contract on machine cooperation, and often there is not even a detailed oral agreement. However, when cultivating genetically modified crops, machine cooperation must be based on a written contract, because the responsibilities and procedures must be written down in detail. The cleaning of machinery and implements is particularly important in joint use. The contract must also include instructions on the use of machinery and implements and their cleaning when moving from one farm or parcel to another or when changing the species or variety. Joint use should not be applied at all when cultivating species which cross easily or if the conditions in other respects are particularly difficult in terms of coexistence. No detailed instructions on the joint use of machinery and implements have yet been drafted for advisory purposes, but there is a growing need for these as genetically modified crops are being introduced to cultivation. The right to information among neighbours needs to be settled as well. Farmers cultivating the neighbouring parcels have the right to know what is cultivated on each parcel and which production type is being used (cf. right to information from the Rural Business Register and notification obligation under the Gene Technology Act).

6. Seed production

In seed production coexistence depends largely on whether practical threshold values for seed can be agreed on a uniform basis in the EU and nationally. Certain farming practices which may not be very different from those in conventional seed production need to be taken into account. However, very detailed definition of a good agricultural practice that would be the same on different farms and in different conditions through acts and other statutes is not always possible, but solutions to problems also need to be found on a case-by-case basis

Seed production

Seed production aims at an abundant, equally-sized, healthy and well germinating grain, seed and tuber crop. The selection of the location is important for the formation of an even plant stand of appropriate density so that the development, maturing and ripening of the stand takes place evenly and it can be harvested at the same time. The quality of the parcel used for seed production must be good and the cultivation properties must be of even quality. The soil type, depth of the top soil, bottom soil and the humidity conditions must also be as even as possible. Seed grain must be threshed with special care. Legislation provides certain special requirements for the cultivation of seed (preceding crops in rotation, special distances, etc.), and enterprises making seed production contracts have additional requirements of their own concerning e.g. the use of pesticides.

Certified seed

Certified seed refers to officially certified seed lot placed on the market where the package is officially sealed and accompanied by an official label. Official label is issued after the seed lot has passed field inspection and inspection of an official sample from the prepared seed lot controlling that the seed lot is correctly named, variety pure and of fair marketable quality and fulfils the quality requirements (germination capacity, humidity, litter content, freedom from diseases, etc.). The feasibility of coexistence depends a great deal on the level of the seed certification measures.

The certified seed classes are pre-basic seed, basic seed and certified seed. The class of certified seed is determined according to the descending of the seed, varietal purity of the lot and other quality characteristics. Quality requirements have been set for each seed class according to species. The seed class is given on the official label in the sales package. The official label also shows whether the variety is genetically modified.

Certified seed can be marketed freely in the EU territory and no new certification is needed in trade from one Member State to another. The principle is that only certified seed of varieties included in the national and/or EU variety lists may be marketed. Genetically modified varieties must be labelled.

Farm saved seed (FSS)

Farms may also use seed they produce themselves. When propagating seed by themselves, farmers' consciously take the responsibility for its properties and quality. Farmers should verify the quality and consistency of the seed.

Organically produced propagating material

Propagating material used in organic production (e.g. seed, seedlings and plantlets) must be organically produced whenever such material is available. The Plant Production Inspection Centre publishes an annual list of varieties of which there is a sufficient amount of organically produced material available.

The Plant Production Inspection Centre estimates that for the majority of plant species there is enough organically produced propagating material on the species level, but the range of varieties is insufficient for the part of varieties suited to the northern conditions. In 2005 there will be a serious shortage organic seed potato and some shortage of organic pea and meadow fescue seed. The estimate is based on amounts of seed certified between 1 July 2003 and 30 June 2004. In 2003 and 2004 organic seed has been produced on about 1,900 hectares.

3. PROPOSALS FOR SPECIES-SPECIFIC AGRONOMICAL MEASURES

1. Barley, wheat and oats

Background

Barley (*Hordeum vulgare*), wheat (*Triticum aestivum*) and oats (*Avena sativa*) are strongly self-fertilizing plants, whose pollination takes place through the wind. Most of the modern species are of the closed-flowering type, while only 2 to 10 per cent of the seed is produced by cross-pollination (Hammer 1975, 1977, Ritala et al. 2002, Jacot et al. 2004).

The total annual cultivation area of barley is about 565,000 hectares, and three quarters of the crop is used as feed. The cultivation area of organic barley is 1.5 per cent of the total area under barley. The cultivation area of wheat is about 225,000 hectares, and about a quarter of the crop is used as feed. Organic wheat is cultivated on about 4 per cent of the area under wheat. The total area under oats is about 370,000 hectares, four-fifths of the crop is used as feed and the share of organic oats is 6.4 per cent (TIKE 2004, KTTK 2004).

Only spring varieties of barley and oats are cultivated in Finland, while 18 per cent of the wheat area is under winter wheat.

Barley and oats can be cultivated in northern Finland as well, but the commercial cultivation of wheat is mainly located in the southern parts of the country.

Cultivation practices

Crop rotation

Crop rotation has not been widely used in cereal farming after the decrease in the number of livestock farms in the main cereal cultivation areas in southern Finland. Turnip rape and oilseed rape could be suitable intermediate crops for cereals (every fifth or sixth year), provided that the weed problems could be kept better under control. Cereal volunteers are quite easy to control among dicotyledonous intermediate crops, which means that after the rotation it is easier to shift from genetically modified cereal to a non-GM variety of the same plant.

Seed production

Only 30 per cent of the barley seed, 20 per cent of wheat seed and 30 per cent of oat seed used in Finland is certified seed.

<u>Requirements for a seed plantation of self-pollinating cereals (barley, wheat, oats)</u>

The requirements for the first generation of certified seed are described below. The requirements are based on the national legislation on seed production (see Chapter 1.7, *Seed* production), and their realisation is controlled by the Plant Production Inspection Centre KTTK. A seed lot produced by the conventional method may contain no more than 0.5 per cent of GM material, and the working figure for the threshold value for organic production used in this report is 0.1 per cent (the threshold values are decided on the Community level).

- On the plantation (farm) there may be no other plantations of the variety in seed production from which a ripe seed crop is harvested. Regarding self-pollinating species there may be no seed plantations of varieties belonging to the same group of varieties on the same plantation (farm).
- Restrictions on preceding crops in rotation. In the production of certified seed one year must have elapsed from the last time when a different variety of the same plant species or the same variety whose varietal purity is not known was cultivated on the plantation.
- Isolation distances. In most cases the prescribed isolation distances to crops with which undesired crossing might occur must be complied with in seed plantations. However, no isolation distances are required for self-pollinating cereals.
- Properties of the crops.
  With respect to varietal purity, the variety of the crops must be identifiable and the varietal purity must be at least 99.7 per cent.
  Only a slight incidence of diseases which may reduce the use value of sowing seed is allowed.
  The purity of the plantation must be cared for by removing all alien species and varieties during the growing period. A seed plantation may be rejected if the abundance of harmful crops or weeds is too high. The crop of a seed plantation is rejected if any wild oat is found in the plantation.
- Quality requirements for seed.
  With respect to varietal purity it is required that the variety of the seed must be sufficiently identifiable and the purity must be at least 99.7 per cent.
  Germination percentage must be at least 85 per cent of the pure seed and purity must be at least 98 per cent of the seed weight. Seed humidity may not exceed 16 per cent. There may be no more than 10 seeds of other plant species in 500 g of seed and the incidence of diseases which reduce the usability of the seed must be low.

Related species

In Finland there are no established occurrences of wild hay species with which the cultivated barley could cross. Of the wild barley species there are some random occurrences (mainly in ports) of mouse barley (*H. murinum*) and fox-tail barley (*H. jubatum*). In tests carried out in Finland it was impossible to cross barley with the wild species (Ritala et al. 2002). The few random occurrences are usually far away from the cultivation areas, except that today fox-tail barley is also grown as an ornamental plant in gardens. In practice wheat does not cross with the domestic grass species, while oat crosses only weakly with wild oat. It has been provided by law that wild oat must be destroyed in plantations. In the cultivation of cereal sowing seed this is an absolute requirement and seed lots which contain wild oat must be destroyed. This is why wild oat is not a significant transmission route of genes to the sowing seed of oats.

Dispersion routes

Shedding

When cereals are harvested some seed always sheds on the field, and in principle these may create volunteers among the next year's crop. However, cereal seed seldom retains its germination capacity for more than a year. In the Finnish conditions cereals cannot run wild and develop into permanent runaway or wild populations.

Seed shed by winter wheat is better capable of germinating and surviving as sprouts over the winter, which means that they may occur more easily as volunteers in the following year. Various measures can be taken to prevent this, such as changing the plant species/variety and control of the germinated plants by tilling the land after germination late in the autumn or before sowing in the following spring.

Pollination

In self-fertilizing plants of the closed-flowering type pollination often takes place already before the flowers dehisce, which means that the pollen of the plant itself has a strong head start. In these varieties cross-pollination is even rarer than in varieties of more open-flowering type, in which alien pollen may enter the flowers after they open. The majority of the modern varieties are of the closed-flowering type. Efforts have been made to develop hybrid barley from the more open-flowering varieties but the results have been modest - in practice sufficient cross-pollination has not been achieved.

In self-fertilizing cereals the significance of the transport of pollen and cross-pollination is small. Their amounts follow the customary, so-called leptocurtic pattern. At first the amount decreases very rapidly as the distance grows, but very small quantities may be transported further away. However, long-distance transportation produces very little impurity on the level of seed, because the pollen created on the recipient field has not only a high quantitative superiority, but it also has a head start in the pollination in terms of the distance and timing. These well-known results were confirmed in Finnish gene flow studies on genetically modified barley (Ritala et al. 2002).

According to the Danish model the share of genetically modified material can be kept within the required limits in seed production through the regular seed production procedures (DIAS 2003). Experiences in seed production show that in self-fertilizing cereals the gene flow from one field to another is so small that in practice no isolation distances are needed.

The amount of genetically modified material which may be transported to the field as a result of cross-pollination also decreases rapidly when we move from the field margin towards the centre. Maximum purity can be achieved through a protective row of at least 0.5 metres along the field margin which is in the direction of the GM plantation.

Dispersion of seed

Soil seed bank

The grains of spring cereals left on the surface become moist in the autumn rains and they are destroyed during the winter. Cereal seed seldom retains its growing capacity for more than a year. Grains shed in dry conditions which are ploughed deep in the dry soil may be an exception to this: in principle a portion of these may retain their germination capacity in the soil seed bank (as long as four years in the Danish conditions). However, such dry conditions are highly exceptional in the autumn period in Finland.

In the cultivation experiments of genetically modified barley in Finland the occurrence of volunteers in the following year was very low, and even the grains sown intentionally to the field in connection with harvesting did not produce them. Thus volunteers can be prevented by avoiding heavy ploughing of the land immediately after harvesting especially if the autumn is dry (Ritala et al. 2002).

Dispersion of seed between field parcels

Combine harvesters and sowing machines may transport seed from one field to another. This can be prevented by cleaning the machines thoroughly before moving them.

Dispersion of seed during transportation and storage

Genetically modified and other grains must be kept separated on the farms during transportation and storage, especially if the farm uses farm saved seed for sowing.

Dispersion of seed in seed lots

The share of genetically modified material in the seed lots has great impacts on the total amount of genetically modified material in the whole crop. Farms using farm saved seed must take account of the fact that as a result of volunteers genetically modified material may be mixed with seed harvested from the parcel in the following years.

Recommendations for measures for cereal production other than sowing seed production (threshold value 0.9 per cent, working figure for organic production 0.1 per cent; assumed share of genetically modified production[34] no more than 30 per cent of the total cultivation area of barley, wheat and oats)

The conventional or organic cultivation of the same species after genetically modified barley, wheat or oats is possible when the following measures are taken

- weed control to prevent the growth of volunteers (instruction)
- appropriate soil preparation sufficiently late in the autumn (instruction)
- crop rotation => same cereal species is cultivated no less than two years, in organic farming three years, after a genetically modified variety (provision).

Both genetically modified barley, wheat or oat and conventional or organic cereal of the same species can be cultivated in the same area so that the share of genetically modified material in the latter parcels remains below the threshold values when

- harvesting is differentiated between the different production types (instruction)
- preferably large cultivation areas which are square in shape are used (instruction)
- if a GM plantation is very close to another plantation, a buffer strip of at least 0.5 metres is left along the field margin which is on the side of the GM plantation (provision)
- the machines are cleaned thoroughly (instruction)
- certified sowing seed is used (provision)
- there is an agreement on cooperation between neighbours (provision)
- control measures are sufficient and appropriately targeted (provision).

[34] Assumed values are not recommendations but only working figures (scenarios) applied when assessing the necessary measures.

2. Rye

Background

Rye (*Secale cereale*) is a cross-fertilizing species whose pollination takes place via the wind. Pollen particles are classified as large (over 40 µm) (Table 7).

The annual cultivation area of rye in Finland is about 30,000 hectares. Less than one per cent of the crop is used as feed. The area under organic rye is about 6,400 ha, which represents 21 per cent of the total rye area and 12.5 per cent of the rye crop (KTTK 2004, Cooperation Group for the Cereal Sector VYR 2004).

Spring rye is only cultivated on about five per cent of the total rye area (on 11 per cent in organic cultivation), while the rest is under winter rye. Commercial rye cultivation area extends to Northern Ostrobothnia. A small share of the winter rye varieties are hybrid varieties.

In the global perspective rye is not among the most significant crops, and so far no genetically modified rye varieties have been bred.

Cultivation practices

Crop rotation

Winter rye is often sown after some other cereal (e.g. early barley) has been harvested or after fallow, a parcel is seldom sown with rye in consecutive years.

Seed cultivation

In Finland about 30 per cent of the rye seed used for sowing is certified seed.

<u>Requirements for a seed plantation of rye (1st generation certified seed, assumed threshold value 0.3 per cent)</u>

- Only one variety of rye may be cultivated on one plantation (farm).
- Restrictions on preceding crops in rotation. In the production of certified seed one year must have elapsed from the time when a different variety of rye or the same variety whose varietal purity is not known was cultivated on the plantation.
- Isolation distances. On seed plantations isolation distances of 250 metres (500 metres in the case of hybrid seed) to plants with which undesired crossing may take place must be complied with.
- Properties of the crop stands.
  With respect to varietal purity, the stands must be of identifiable and pure variety. The number of types which clearly differ from the cultivated variety may not be more than $1/10m^2$.
  Only a slight incidence of diseases which may reduce the use value of sowing seed is allowed.
  The requirements relating to plant diseases, purity of the plantation and wild oat are the same as for self-pollinating cereals.

- Quality requirements for seed.
  With respect to varietal purity it is required that the variety of the seed must be sufficiently identifiable and pure (so that the varietal purity requirements for the crop stand will be fulfilled). There may be no more than 10 seeds of other plant species in 500 g of seed. The requirements relating to germination, purity, seed humidity and plant health are the same as for self-pollinating cereals.

Related species

There are no wild hay species capable of crossing with rye in Finland.

Dispersion routes

Shedding

When rye is harvested some seed always sheds on the field, and in principle these may create volunteers among the next year's crop. However, in the soil rye seed normally retains its germination capacity for less than a year. In Finland rye also cannot run wild and develop into permanent runaway or wild populations.

Various measures can be taken to prevent volunteers, such as changing the plant species/variety and control of the germinated plants by tilling the land after germination late in the autumn or before sowing early in the following spring.

Pollination

Rye seed is created as a result of cross-pollination which takes place through the wind. Pollen flies over long distances and pollination may take place quite far away, which is reflected in the special isolation distances to be applied in seed production.

In southern Finland winter rye usually flowers between 10 and 20 June and the flowering of spring rye starts in the beginning of July. This can be utilised to reduce the gene flow between genetically modified and other rye varieties.

In patches with poor vegetation the flowering of winter rye may also take place later, which means that there is a slight possibility of overlapping flowering periods and some crossing may take place. However, the possible hybrids are not too well adapted to either cultivation method, but most of them will be eliminated.

The selection pressure against crossed individuals is very strong. If seeds of the winter varieties are sown as spring cereals, they do not flower or they flower too late (so that the seed does not ripen before harvesting). If spring varieties are sown in the autumn, the seedlings are often not sufficiently adapted to sustain the winter conditions.

The winter and spring varieties differ from each other with respect to the genes regulating both the so-called vernalisation and resistance to cold. To flower early enough the winter varieties call for long exposure to cold, which they get when they are sown and they germinate in the autumn and the seedlings (tips of the shoots) experience the cold winter season. The spring varieties do not need any cold treatment.

Vernalisation is regulated by at least three genes, which also interact with each other, while the resistance to cold is influenced by several genes (Pugsley 1971, Hömmö 1994a, b, Trevaskis et al. 2003, Yan et al. 2004). Hybrids of winter and spring varieties can be used for breeding of varieties of the intermediary type in mild climate, but they could not adapt to harsh conditions prevailing in Finland (Braun & Sãulescu 2002).

In Finland the woodlands between plantations constitute efficient barriers to the transport of pollen. High plants or conventional rye as buffer zones on the margin of non-GM rye plantation can also be used as buffer zones.

Rye was not included in the ESGEMO study (see *Gene flow from oilseed rape to turnip rape*), which means that its gene flow from one field to another in the Finnish conditions should be studied by modern population genetic methods to ensure the functioning of the traditional isolation distances.

Dispersion of seed

Soil seed bank

The grains of spring cereals left on the surface become moist in the autumn rains and they are destroyed during winter. Cereal seed seldom retains its growing capacity for more than a year. In principle grains which end up in the oxygen-free state as a result of ploughing may retain their germination capacity longer than one year in the soil seed bank, which means that rye may appear as a volunteer on the plantation. However, these are easy to identify and eliminate in crop rotation.

Dispersion of seed between field parcels

Combine harvesters and sowing machines may spread seeds from one field to another. This can be prevented by cleaning the machines thoroughly before moving them.

Dispersion of seed during transportation and storage

Genetically modified and other grains must be kept separated on the farms during transportation and storage, especially if the farm uses its own sowing seed.

Dispersion of seed in seed lots

The share of genetically modified material in the seed lot has great impacts on the total amount of genetically modified material in the whole crop. Farms using farm saved seed must take account of the fact that as a result of volunteers genetically modified material may be mixed with seed harvested from the parcel in the following years.

Recommendations for measures for cereal production other than seed production (threshold value 0.9 per cent, working figure for organic production 0.1 per cent; assumed share of genetically modified production[35] no more than 20 per cent of the total cultivation area of rye)

[35] Assumed values are not recommendations but only working figures (scenarios) applied when assessing the necessary measures.

The conventional or organic cultivation of rye after genetically modified rye is possible when the following measures are taken

- weed control to prevent the growth of volunteers (instruction)
- appropriate soil preparation sufficiently late (instruction)
- crop rotation => rye is cultivated no less than two years, in organic farming three years, after genetically modified rye (provision).

Both genetically modified rye and conventional or organic rye can be cultivated in the same area so that the share of genetically modified material in the latter parcels remains below the threshold values when

- isolation distances are complied with => 300m, 500m for hybrids, 600m in organic production (provision)
- preferably large cultivation areas which are square in shape are used (instruction)
- harvesting is differentiated between the different production types (instruction)
- the machines are cleaned thoroughly (instruction)
- certified sowing seed is used (provision)
- there is an agreement on cooperation between neighbours (provision)
- control measures are sufficient and appropriately targeted (provision).

Further precautionary measures which may be used

- rye varieties flowering at different times (spring vs. winter rye) (instruction)
- cultivation of high plants as a buffer zone on the side of the GM plantation; conventional rye whose crop is harvested separately may also be used as a border zone (provision)

3. Turnip rape and oilseed rape

Background

Turnip rape *(Brassica rapa)* is fully cross-fertilizing, while oilseed rape *(Brassica napus)* is self-pollinating, but cross-fertilization is possible with a likelihood of about 30 per cent. Pollination may take place via the wind or insects. Mixtures of plants with sterile and fertile stamens are used in the sowing seed production of hybrid varieties (ratio 80/20).

Turnip rape seed contains about 40 per cent of oil and 20 per cent of protein. The composition of the oil is of high nutritional quality, while turnip rape is also a valuable protein crop. Rapeseed oil can also be used for lubricants and fixing agents in plant protection substances. Its use as fuel has also been tested (Hyytiäinen et al. 1999).

The annual total cultivation area of turnip rape and rape varies from 70,000 to 80,000 hectares (of which a few thousand hectares under rape), which is about five per cent of the total cultivated area in Finland. In recent years the turnip rape area has grown by about 10,000 hectares as the quotas for oilseed crops are no longer applied in the EU. The feasibility of turnip rape production is also dependent on the availability of efficient pesticides. The area under organic turnip rape is about 3.5 per cent of the total rape area. In 2003 the area under organic rape was 2,800 ha.

The growth period of turnip rape is 101 to 104 days (Kangas et al. 2003) and it is mainly cultivated south of the Lappeenranta - Tampere - Vaasa -line. The growth period of oilseed rape is about 10 days longer and it can be cultivated only in southern Finland. In 1991-2001 the average yield of turnip rape and oilseed rape was 1,516 kg/ha (MMM/TIKE).

Cultivation practices

Crop rotation

Turnip rape and oilseed rape can well be used as preceding crops in rotation for cereals (barley, spring wheat), but they can also appear as weeds because their seed may germinate from the soil for years after their cultivation. The seed of oilseed rape also sheds very easily. Because of diseases oilseed crops should be cultivated in the same location only every five years.

Seed production

In Finland almost all of the turnip rape and oilseed rape seed used for sowing is certified seed. However, the share of farm saved seed is increasing.

<u>Requirements for a seed plantation of turnip rape and oilseed rape (certified sowing seed, assumed threshold value 0.3 per cent)</u>

- A farm which has a sowing seed plantation of a certain turnip rape or oilseed rape variety may not have any other plantation from which a ripe seed crop is harvested of this variety. In seed production of turnip rape only one variety may be cultivated on each farm.
- Restrictions on preceding crops in rotation. In the production of certified seed five years must have elapsed from the time when a different variety of the same species or the same variety whose varietal purity is not known was cultivated on the plantation
- Isolation distances. On seed plantations isolation distances of 200 metres (300 metres in the case of hybrid seed) to plant stands with which undesired crossing may take place must be complied with.
- Properties of the crop stands.
  With respect to varietal purity, the crops must be of identifiable and pure variety. In hybrid varieties the variety purity must be at least 90 per cent and when using a male-sterile crossing parent the degree of male-sterility must be at least 98 per cent. In non-hybrid varieties the varietal purity must be at least 99.7 per cent if the variety is intended for uses other than feed and 99 per cent if the variety is intended for feed use only.
- The requirements relating to plant diseases, purity and weeds are the same as for cereals, except that the occurrence of wild oat is not a cause for rejection.
- Quality requirements for seed. The requirements for varietal purity are the same as those for plant stands. The requirements for germination capacity, purity and plant health are the same as those for cereals. The seed humidity may not exceed 10 per cent and no more than 0.3 per cent of seeds of other plant species are allowed.

Related species

In Europe there are several wild species related to oilseed rape with which it can be crossed artificially. However, in the northern conditions significant crossing takes places only with wild turnip rape. Crossing with wild radish and wild mustard is less frequent and these hybrids are hardly ever capable of producing subsequent backcrossing progeny, nor have they transferred oilseed rape genes to the genome of wild radish or wild mustard (Chevre et al. 2004).

In the nature some gene flow always takes place between related species. From the perspective of coexistence, what is significant is the strength of this gene flow: a) whether the crossing is so strong and b) whether the abundance of the crossable related species on the plantation or environment is such that significant gene flow (in terms of the threshold values) from the variety of the crop concerned or from a field to another may appear. This is seldom the case, and the gene flow within a cultivated crop is in any case much stronger than gene flow through and intermediary agent, i.e. another species.

There are also a number of cultivated crops related to oilseed rape with which it may cross, such as rutabaga, mustard and turnip rape. There has been no commercial cultivation of mustard in Finland since 2004 and the area under rutabaga is only 460 ha. Instead, the crossing between turnip rape and oilseed rape is a greater problem due to their larger cultivation areas.

Gene flow from GM rape to turnip rape

Genetically modified varieties of turnip rape have not been introduced to cultivation anywhere in the world, which means that modified genes may be transported to organic turnip rape mainly from GM oilseed rape. Oilseed rape is a tetraploid species while turnip rape is diploid. Their hybrid is triploid in term of the number of chromosomes, which means that it is quite sterile. Very little seed is produced and the plants which may grow from these have highly mixed sets of chromosomes and their viability is weak - only a couple of percentages of these survive in field conditions.

Turnip rape is cultivated very little on the global scale, which means that there are no research results available on its gene flow in the same way as for oilseed rape. Gene flow from oilseed rape to turnip rape on the neighbouring field is being studied by the Agrifood Research Finland MTT in the ESGEMO programme of the Academy of Finland. The objective of the study is to develop a low-priced, sensitive and reliable DNA tool for turnip rape (*Brassica rapa*), oilseed rape (*Brassica napus*) and potato (*Solanum tuberosum*) for the observation of gene flow and GM admixture, to use this tool for analysing the gene flow via pollen and volunteers in the research data, model the gene flow and risk of admixture on the basis of the collected research data, and to use the research data and models to draw up recommendations for coexistence in the Finnish climate and cultivation conditions.

The research plan is founded on risk studies published earlier, but these studies have been carried out in more southern conditions. Research data indicating gene flow occurring in the Finnish agro-ecosystems are used to draw up cultivation recommendations which aim to minimise the risk of adventitious GM admixture. The project produces new information on the risks of gene flow from genetically modified plants in the northern conditions, develops DNA markers to observe the gene flow and draws up cultivation recommendations to minimise GM admixture.

Gene flow between oilseed rape and wild turnip rape

Wild turnip rape is the original, natural form of turnip rape which occurs in Finland as a common weed. Like most wild plants it is self-sterile (this property has often been removed when breeding crops for cultivation). If there are some isolated wild turnip rapes in an oilseed rape field, it is very unlikely that they will get any pollen capable of fertilising them from other wild turnip rapes. In such conditions oilseed rape pollen may function as a replacement and fertilise some of the wild turnip rape flowers - provided that there is some overlap in their flowering periods. Even if wild turnip rape develops more quickly, some of the flowering periods may overlap in England, and based on crossing results in Denmark as well (Norris et al. 2004, Jörgensen et al. 2004).

Hybrids of oilseed rape and wild turnip rape are as sterile as hybrids of oilseed rape and turnip rape (see above). However, if wild turnip rape is relatively abundant on the field for several years, a small share of the hybrids (oilseed rape x wild turnip rape or oilseed rape x turnip rape) may succeed in backcrossing with wild turnip rape. In Danish studies this was observed on one former organic field, but not in conventional farming where weed control was properly taken care of (Jörgensen et al. 2004). In studies made in the other parts of the world very little crossing has been observed from oilseed rape to wild turnip rape outside the plantation. In England the share of crossed individuals close to an oilseed rape field varied between 0.4 and 1.5 per cent (Scott & Wilkinson 1998).

If crossing and backcrossing constituted a regular chain, oilseed rape genes might eventually be transferred to wild turnip rape. It should be noted, however, that in organic production the herbicide resistance gene cannot become enriched, because in an organic field this property gives the plants no selection advantage.

Gene flow between turnip rape and wild turnip rape

Wild turnip rape crosses easily with turnip rape because they belong to the same species and their chromosome number is the same. Based on the above-mentioned Danish study (Jörgensen et al. 2004) it has been supposed that in cases where there are serious weed problems this might compromise genetic purity especially in the cultivation and seed production of organic turnip rape.

If there were significant gene flow from wild turnip rape to turnip rape in practice, in principle adverse traits removed in breeding, such as erucid acid and glucosinolates, might return to turnip rape. However, no indications of this have been observed in the quality control of oil.

There is no research information from Finland on the overlaps between the flowering periods of wild turnip rape and turnip rape. Turnip rape is very little cultivated anywhere else, which means that there are no foreign studies available, either. However, as we are concerned with the same species, their developmental rhythm should be quite similar.

Unlike in England and Denmark only spring varieties of oilseed crops (turnip rape and oilseed rape) are cultivated in Finland. Their development lags behind the wild turnip rape seedlings originating from seed which germinated in the autumn. However, part of the wild turnip rape seed may germinate in the spring and the development of these seedlings is likely to be on the same pace with turnip rape. Furthermore, the flowering period of wild turnip rape is long so that some overlap with the flowering of turnip rape is likely.

The control of wild turnip rape on turnip rape and oilseed rape plantations is difficult. Because the plants are closely related, any pesticides that would be efficient for wild turnip rape would be harmful for the cultivated crops as well. Hence, pesticides used on turnip rape fields (napropamid and trifluralin) are no too effective on wild turnip rape. A herbicide resistant variety would facilitate the control of closely related weed species. However, there are already effective substances for preventing wild turnip rape from cereal plantations in the intermediate years of the crop rotation.

In organic production the control of wild turnip rape is even poorer. The control of wild turnip rape on the plantation and use of certified seed is particularly important in the cultivation of organic turnip rape and especially in the coexistence with genetically modified varieties.

Dispersion routes

Shedding

After the cultivation of turnip rape and oilseed rape these often occur as weeds in cereal plantations. However, they are highly sensitive to herbicides used in cereal cultivation, which means that volunteers can be quite efficiently controlled through carefully and correctly timed chemical control, except in organic farming. Measures should also be taken to prevent shedding during harvesting. Shedding cannot be completely avoided, because the turnip rape and oilseed rape seeds are very small. Some seed shed on the ground already before harvesting, some is shed from the combine harvester.

Pollination

The success of the pollination of turnip rape and oilseed rape depends on the variety and climate and other conditions influencing the spreading of pollen, such as wind. Because turnip rape is a fully cross-pollinating species, its variety properties are not significant in terms of pollination. Crossing of the same oilseed rape variety varies a great deal depending on the air temperature, strength and direction of the wind, and size and topography of the field. Cross pollination may occur if the different varieties flower at the same time. In Finland the turnip rape varieties flower at about the same time, while oilseed rape flowers somewhat later. It should also be born in mind that even if most of the pollination takes place in arable areas, small amounts of seed may spread to ditches, roadsides and surroundings of farm buildings and germinate there.

The nectar of oilseed plants attracts pollinating insects. In most cases the insects search for nectar over distances of a few hundred metres, but in some cases honey bees may fly even a few kilometres from their hive.

Gene flow between plants via pollination varies a great deal, depending on

- size difference between the pollen donor plant and the recipient plant
- natural differences between the plant which produces the pollen and the recipient plant, their fertility, varietal purity and flowering time
- gene flow from volunteers, i.e. restricting the number of volunteers
- various kinds of environmental conditions, e.g. direction and strength of the wind, air temperature
- size and location of the field
- variety and whether the plant is a cross-pollinating or self-pollinating one
- isolation distances.

The size and shape of the field influences the gene flow. The broader the field parcel is the smaller is the relative gene flow directed to it, while the impact is the greatest on narrow and long field parcels. According to the model developed in Denmark, the share of genetically modified material can be kept under 0.3 per cent with 95 per cent certainty even on small parcels if the distance between the parcels is 200m (Damgaard & Kjellsson 2003).

In Great Britain the pollination between large oilseed rape fields is likely to stay below 0.1 per cent (Ramsay et al. 2003). A donor field of seven hectares was capable of pollinating less than 5 per cent of the seed germs of a small recipient row located 10 metres away even if this competing source consisted of only 10 plant individuals. Thus even in such disproportionate circumstances over 95 per cent of the seed is created through short-distance pollination (from less than 10m away). In usual oilseed rape fields the plants are completely surrounded by close neighbours and 99 per cent of the seed is created through short-distance pollination.

Dispersion of seed

Soil seed bank

During harvesting some of the seed sheds to the ground. The amount of seed lost depends on the species, variety and the local conditions. Usually the loss varies from 5 to 10, but it may be as high as 50 per cent. Volunteers may cross with each other and the source of pollination may get mixed with the new crops and new plants.

Soil seed banks of oilseed crops are common in cultivated field parcels and they may stay in the soil for very long, even 10 to 12 years. The average number of seeds of oilseed crops found per square metre is 100 (DIAS 2003).

The formation of the soil seed bank can be prevented and its size can be reduced through crop rotation and soil preparation. The soil seed bank increases if the field is ploughed immediately after harvesting. The seeds are preserved in the soil material where they start dormancy, during which they may retain their germination capacity for a long time. The normal seed dormancy of oilseed plants is weak if the seeds stay on the soil surface in moist conditions after harvesting. Transition into dormancy can be prevented by postponing the soil preparation until late in the autumn or early spring. Soil seed bank can also be reduced by means of weed control spraying together with appropriately timed soil preparation.

Dispersion of seed between field parcels

Seed is an important, random, means of dispersion for plants through which the plants may spread to new locations in the following growing periods. The seed of oilseed plants spread easily especially during harvesting.

It is estimated that the gene flow through natural dispersion of seed (via the wind or animals) is smaller than the spreading of genes through pollination. Machines may spread seed from one field to another. The best way of preventing this is to clean the machines thoroughly before moving them. However, it is impossible to prevent completely the spread of especially the very small turnip rape and oilseed rape seeds along with the machines.

Dispersion of seed during transportation and storage

The seed of turnip rape and oilseed rape are small and round, and they shed easily during transportation between fields and to the stores. Dispersion can be reduced by being careful in transportation and through proper cleaning, but it cannot be prevented completely.

Dispersion of seed in seed lots

The share of genetically modified material in the seed lot has great impacts on the total amount of genetically modified material in the whole crop. On farms using farm saved sowing seed volunteers and weed seeds may increase the share of genetically modified material in the harvested seed crop. Certified sowing seed should be used to prevent the admixture of varieties.

Recommendations for measures for production other than sowing seed production (threshold value 0.9 per cent, working figure for organic production 0.1 per cent; assumed share of genetically modified production[36] no more than 15 per cent of the total cultivation area of turnip rape and oilseed rape)

The conventional or organic cultivation of turnip rape or oilseed rape after genetically modified turnip rape or oilseed rape is possible when the following measures are taken

- weed control to prevent the growth of volunteers (instruction)
- appropriate soil preparation sufficiently late in the autumn (instruction)
- crop rotation => turnip rape and oilseed rape is cultivated after no less than eight years, in organic farming no less than 12 years after genetically modified varieties (provision).

Both genetically modified and conventional or organic turnip rape and oilseed rape can be cultivated in the same area so that the share of genetically modified material in the latter parcels remains below the threshold values when

- isolation distances are long enough[37] => 200m, 300m for hybrids, 400m in organic production (provision)
- harvesting is differentiated between the different production types (instruction)
- large field parcels which are square in shape are used (instruction)
- the machines are cleaned thoroughly and the crop is transported in seedtight containers (instruction)
- certified sowing seed is used (provision)
- there is an agreement on cooperation between neighbours (provision)
- control measures are sufficient and appropriately targeted (provision).

4. Sugar beet

Background

Sugar beet *(Beta vulgaris)* is a cross-pollinating plant. Its cultivation area is about 30,000 ha, which represents a little less than 2 per cent of the total crop production area in Finland. The production is based on contracts. Most of the production is located close to the Salo and Säkylä sugar processing plants in Varsinais-Suomi and Satakunta, but sugar is also produced in South Häme and South Savo. The average production area per farm is about 13 ha.

Sugar beet should be sown early in the spring, in April, if possible and harvested as late as possible in the autumn. The average annual yield of sugar beet is about 35 tonnes/ha, which yields about 6,000 kg of sugar per hectare.

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[36] Assumed values are not recommendations but only working figures (scenarios) applied when assessing the necessary measures.

[37] The recommended isolation distances will be revised when the studies of the ESGEMO Research Programme of the Academy of Finland concerning the gene flow from oilseed rape to turnip rape in the Finnish conditions have been completed.

Cultivation practices

Sugar beet is a highly demanding crop. Success in cultivation depends on several growth parameters. Suitable soil types are fine sand and gyttja clay. Sugar beet parcels must be properly drained. Three-year crop rotation is recommended to maintain the soil structure and prevent weeds and pests.

Sugar beet is a biennial plant which produces flowers in the second year. Because the plant does not usually overwinter in Finland, it produces no seed. However, the wild beet produces seed already in the first year and may cross with sugar beet in the European sowing seed production areas.

Because of the use of low-quality sowing seed the hybrid variety, weed beet, has become quite common in many sugar beet production regions in Europe. Weed beet cannot be used for sugar production. Because it flowers in the first year, it produces seed which is capable of a long dormancy period and which thus accumulates in the soil seed bank.

In regions where weed beet is not yet established its spread can be prevented by using high-quality sowing seed which is as free as possible from hybrids. The safest production system for sowing seed is to use a tetraploid strain of pollinators and diploid strain of recipients, which produces a triploid beet variety.

However, in certain regions of Europe weed beet is already so abundant that the cultivation of sugar beet is no longer possible. Because of the close similarity to sugar beet weed beet cannot be controlled by means of the traditional methods for beet production. Instead, in the cultivation of herbicide-resistant genetically modified sugar beet varieties weed beet would not be a problem, because herbicides could be used to prevent weed beet and their seed bank could be reduced over the years (Dijk 2004, Soukup & Holec 2004).

The harvesting losses may be as high as 20 per cent. The losses can be dropped to a few percentages through correct adjustment and careful use of the lifting machine. Sugar beets may be left on the ground in several phases during the harvesting from tens to thousands of kilos depending on e.g. the lifting depth and condition of the plough share.

Dispersion routes

In sugar beets the leaf rosette appears in the first year and the flowers and seeds in the second. However, some individuals may flower in the first year if they have been exposed to cold. Wild beets are problematic in terms of coexistence, because they provide favourable dispersion routes and may cross with sugar beets. Sugar beet may also cross with fodder beet or red beet.

Instead, volunteers are not a significant problem because in the normal Finnish winter conditions beets left on the ground or which fall during transport rot.

Pollen of the cross-fertilizing sugar beet is mainly transported via the wind, but insects may also act as pollinators. Along with the wind the pollen may travel over long distances, up to five kilometres, but the pollen content and fertilization frequency fall as the distance grows.

Sowing seed of sugar beet is not produced in Finland. Sugar beet production is based on contracts. The processor delivers sowing seed whose varietal purity, purity and other quality have been analysed to the farmer. Sugar beet should flower only in the second year, i.e. only on sowing seed plantations, but some flower stems may also appear in the first year when cultivating sugar beets for harvesting. These should be removed to prevent crossings between species.

Recommendations for measures for sugar beet production other than sowing seed production (threshold value 0.9 per cent, working figure for organic production 0.1 per cent; assumed share of genetically modified production[38] no more than 30 per cent of the total cultivation area of sugar beets)

To prevent the spread of genetically modified material the following measured are needed

- weeding of flowering beets and control of wild beets (instruction)
- thorough cleaning of the sowing machines, especially if in joint use (instruction)
- efficient soil preparation also in the spring to destroy possible volunteers (instruction)
- crop rotation where every second year a crop other than sugar beet or other variety of the beet *(Beta vulgaris)*[39] is cultivated (provision)
- control measures are sufficient and appropriately targeted (provision).

5. Potato

Background

Potatoes are produced to be sold fresh and for food industry, starch production and seed (Table 9). The area under conventional potato production is about 30,000 ha and the average yield is 26.2 tonnes/ha. Organic production represents about 2 per cent of potato production and the average yield is 12.9 tonnes/ha.

Commercial potato production is located in the coastal regions, where the soil types are suitable for potato. Most of the cultivation for food or starch industry takes place close to the processing plants utilising the potato raw material in Ostrobothnia and Satakunta. The propagation and cultivation of the high grade seed potato is concentrated to North Ostrobothnia, where virus diseases spread especially by insects occur hardly at all. The origin of the seed potato used in the cultivation for home use is often unknown.

Table 9. Production volume and cultivation area of potatoes for different uses in 2002 (sources**:** MMM/TIKE; publications of KTTK B2 Organic production 2/2003).

	conventional production		organic production	
	[t]	[ha]	[t]	[ha]
fresh potato	289 000	11 300	-	362
food industry	126 300	4 200	-	-
starch potato	264 000	8 800	-	28
seed potato etc.	100 800	5 400	-	13
other	-	-	-	214
total	780 100	29 800	7 950	616

'-' denotes missing data

[38] Assumed values are not recommendations but only working figures (scenarios) applied when assessing the necessary measures.
[39] The purpose of this is to minimise the possibilities of GM beets to flower and cross with wild or weed beets or other variety of beet (see Dispersion routes).

Potato differs from other crops in that, in addition to the commercial production, it is cultivated widely in home gardens. When cultivating for home use the left-over food potato whose origin is not known is often used as seed. Commercial potato production is largely based on production contracts.

Food industry and starch potato industry purchase their raw material mainly from contract producers to ensure that the high quality requirements are fulfilled. Contract production often includes very strict requirements for the varieties to be used as well as detailed cultivation instructions, advice during the growing season and monitoring of certain cultivation measures. Instead, the cultivation of potatoes to be sold fresh is less frequently regulated by contract but it is based on informal contacts between the producers and trade. However, some retail chains have concluded production contracts or started packaging operations to ensure the quality.

Approval to the national list of varieties is no longer a condition for certification, but all varieties approved in Europe are also approved for cultivation in Finland. However, the importers of new varieties want to test their properties in the Finnish conditions before the varieties are spread more widely. Potato differs from other crops in that varieties bred in other parts of Europe can be utilised in Finland. Pre-germination of seed potatoes shortens the growing period and, with certain restrictions, makes it possible to cultivate varieties requiring longer growing periods or bred for the more southern conditions in Finland.

Thus, most of the potato breeding takes place elsewhere in Europe, mainly in the Netherlands. With few exceptions the new potato varieties entered to the variety lists are of foreign origin, while Finnish seed potato companies and potato processing plants purchase the rights to represent the European varieties in Finland. In practice this very likely means that the genetically modified potato varieties that are becoming common in the other parts of Europe will mainly be introduced to cultivation in Finland through the representatives of the varieties. However, field tests are carried out on test lines of starch potato bred in Finland where the starch content has been raised through genetic modification.

Cultivation practices

Crop rotation

Potato cultivation calls for sufficient crop rotation. On farms specialised in potato production the area under potatoes is often too large relative to the total area, partly because the farm may only have potato cultivation machinery. In potato monoculture the pest risk increases rapidly and the soil structure weakens. It is recommended that potato should be cultivated on only about half of the arable area of the farm, which would make it possible to follow five-year crop rotation cycles where potato would be cultivated for two and intermediate crops for three years. Suitable intermediate crops are cereals, annual or biennial grass or leguminous plants.

Seed production

In commercial cultivation the share of certified seed potato is about 45 per cent.

Requirements for seed potato production (certified seed potato, assumed threshold value 0.3 per cent)

- Other potato may be produced simultaneously on a plantation producing certified seed potato provided that the other potato plantations have been established using at least certified seed potato and a field inspection is carried out. The other potato must be of a different variety than the seed potato.
- Restrictions on preceding crops in rotation.
  A plantation producing seed potato may not be located on a parcel on which potato has been cultivated, stored or handled during the past two years. Seed potato may be produced on the same parcel in two successive growing periods provided that**:**
  a) the cultivated variety is the same in both years, and b) the quality grade of the potato cultivated in the second year is not higher than the grade entitled by the incidence of fungal and bacterial diseases detected in the field inspection in the first year.
- Requirements concerning pests and soil-transmitted viruses, mechanical or physiological damage, and amount of soil and other impurities in the seed.
- Varietal purity shall be at least 99.5 per cent.

Related species

Gene flow from potato to related species is very unlikely in Finland. Species that are closely related to potato in Finland are black nightshade (*Solanum nigrum*) and climbing nightshade (*S. dulcamara*). The possibility of crossing potato with black or climbing nightshade has been studied by doing the pollination between the species by hand. Crossing has not succeeded and no seed has been produced (Eijlander & Stiekema 1994). This means that the spread of modified potato genes in Finland seems almost impossible.

Dispersion routes

Pollination

Potato is propagated asexually through tubers. In potatoes very little spread of pollen takes place because the flowers do not produce any nectar which would attract pollinating insects. Studies made in other countries have shown that no pollen is spread from a plantation of genetically modified potato varieties to other potatoes cultivated at a distance of at least 20 metres (Tynan et al. 1990, McPartlan & Dale 1994, Connor & Dale 1996).

In seed potato production in Finland very little admixture between varieties has occurred (0.02 per cent of the 300,000 tubers studied). The bulk of these few cases were found on such parcels, which were situated at less than 3 m distance from a parcel planted with another potato variety (Tuomisto 2005). The great majority of this admixture was likely to have been caused by relocation of tubers during harvesting.

The spread of pollen or tubers to unmodified potato varieties can be prevented by means of sufficient isolation zones. Since most of the current potato varieties are male- or female-sterile, crossing between varieties is very unlikely. If needed, unintentional crossing of a GM variety to another parcel can be prevented completely by breeding the variety to be male-sterile.

Volunteers

Potato cannot escape and form permanent runaway or wild populations in Finland. However, tubers may be left in the soil during harvesting. These may overwinter quite readily for the next spring and grow into potato plants whose tubers may mix in the potato yield in the autumn.

According to the potato harvesting study of the Work Efficiency Institute TTS and MTT Agricultural Engineering Research VAKOLA towards the end of the 1980s, as much as 1000 kg per hectare of potatoes may be left to the field. Assuming that the average size of tubers is about 30 grams, the number of potatoes left on a hectare of land is almost 35,000. If the volunteer plants growing from these in the next summer are not removed, they may produce new tubers and through these a new potato generation. This cycle may be repeated up to four years in sequence in Finnish conditions. The volunteers can be controlled by applying an appropriate crop rotation.

Admixture of varieties caused by volunteer potatoes may be a problem for coexistence if different varieties are cultivated on the same field in successive years. The risk is reduced by the restrictions on the varieties to be cultivated in different years. If a genetically modified potato variety is followed by a conventional variety, there must be at least one year between their cultivation when the area must be under cereals, oilseed or fibre crops or grass. The requirements for crop rotation must also be taken into account to avoid the admixture of varieties.

To prevent volunteers, measures should be taken to ensure that potatoes left on the ground during harvesting do not retain their germination capacity over the winter. In a cultivation system study of the Potato Research Institute in 2001, four potatoes per square metre were found from land ploughed in the autumn, while no potatoes were found from land which was only cultivated in the autumn and ploughed in the spring.

The best way of preventing volunteers is to postpone ploughing until the spring. If the land is not ploughed in the autumn the potatoes left in the surface layers do not get buried deeper and remain susceptible to repeated freezing and melting during the winter. Potatoes left buried in the land can be better exposed to frost which destroys them if the soil surface is harrowed after harvesting to the depth of 5 to 7cm. Repeating the harrowing after a few frosty nights ensures that the volunteer potatoes are destroyed. Volunteers can also be prevented by means of the restrictions on preceding crops in rotation.

Admixture of genetically modified and other potatoes may take place mainly when potato lots get mixed during transport and storage or due to the non-traceability of the seed used in home gardens. Genetically modified varieties can be cultivated in contract production and for the needs of the food and starch industry without any risk of admixture, but in the cultivation for household use the risk of mixing genetically modified and other potato varieties is evident.

Admixture of potato lots during transport and storage has been low in Finland (Tuomisto 2005). GM varieties can be produced without significant mixing problems in contract production for the needs of food and starch potato industry.

Gene flow in potato cultivation in the Finnish conditions is studied at the MTT Agrifood Research Finland as part of the ESGEMO programme of the Academy of Finland (cf. *Gene flow from oilseed rape to turnip rape*). The overwintering and growth potential of volunteer potatoes is studied in different conditions. To minimise unintended admixture of genetically modified and other potatoes, recommendations are drawn up on the basis of the research information on the gene flow produced in Finnish agro-ecosystems.

Recommendations for measures for potato production other than seed potato production (threshold value 0.9 per cent, working figure for organic production 0.1 per cent; assumed share of genetically modified production[40] no more than 50 per cent of the total cultivation area of potato)

To prevent the spread of genetically modified material

- when using farm saved seed potato (see 2.6), this must be grown in a parcel where no genetically modified potato has been produced, if seed potato completely free from GM material is wanted. In organic production adventitious presence of GM material can best be prevented by using only organic seed potatoes (instruction)
- machines must be cleaned thoroughly, especially if in joint use and in regions where genetically modified potatoes are cultivated (instruction)
- isolation distances[41] must be defined => 5-10 m (provision)
- volunteers must be collected and destroyed (instruction)
- land must be prepared after harvesting (e.g. by light harrowing) so that tubers left in the soil are lifted to the surface (provision)
- tubers set aside in preparation and sorting must be handled in an appropriate manner to prevent the admixture of varieties
- non-modified potato may not be cultivated on the parcel until after at least two years from the cultivation of genetically modified potato[41] and in such cases certified seed potato must be used (provision)
- control measures must be sufficient and appropriately targeted (provision).

6. Grasses

Background

The cultivation of grasses started in Finland only about one hundred years ago, even if some early efforts were made already at the turn of the 18th and 19th centuries. Thus the properties of most grasses are similar to the wild grass plants, which are cross-pollinating plants. The most significant grass species in Finland are timothy, meadow fescue, cocksfoot, tall fescue, rye-grass, smooth meadow grass and red clover.

Grasses are cultivated on about 30 per cent (657,000 ha) of the arable area in Finland, of which 8.6 per cent (57,000 ha) was under organic production in 2003. In recent years grass seed has been produced on 8,000 to 11,000 hectares (11,300 ha in 2003 and about 8,000 ha in 2004). In 2003 the area used for the production of dry hay was about 101,000 hectares. Grasses are also used in golf courses and lawns. In 2003 the production of grass seed totalled about 6,000 tonnes and 1,600 tonnes were imported (KTTK 2003). The import statistics of the Seed Inspection Department of the Plant Production Inspection Centre KTTK do not show all seed traded on the single market.

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[40] Assumed values are not recommendation but only working figures (scenarios) applied when assessing the necessary measures.

[41] The provision will be revised when the results of the ESGEMO Research Programme concerning the gene flow in potato via sexual propagation and volunteers in Finland are available (see above).

The first genetically modified grasses that could be introduced to Finland are the GM varieties of perennial rye grass (*Lolium perenne* L.) and "rye-fescue" (*Festulolium*), but so far no product applications concerning these have been submitted within the EU.

Cultivation practices

Crop rotation and volunteers

In grass cultivation the best method for preventing volunteers is crop rotation regardless of whether the volunteers derive from the crop of the production year or the soil seed bank. Spring cereals, oilseed plants, sugar beet and potato are appropriate crops to be cultivated after grasses. Grasses occurring as weeds are easy to control by pesticide treatments, except for leguminous plants. In organic production weeds can be prevented only mechanically.

Seed cultivation

In Finland 80 per cent of the grass seed used for cultivation is certified seed.

<u>Requirements for sowing seed plantation of grasses (certified seed)</u>

- There may be no plantations of the variety cultivated for sowing seed from which a ripe crop is harvested on the farm.
- Restrictions on preceding crops in rotation. In the production of certified seed two years in the case of hay plants and three years in the case of leguminous grasses must have elapsed from the time when a different variety of the same plant species or the same variety whose varietal purity is not known was cultivated on the plantation.
- Isolation distance to plants with which undesired crossing may take place is 200 metres if the size of the plantation is less than 2 hectares and 100 metres if the size of the plantation is over 2 hectares.
- Properties of the crop stands.
  The crop stand must be of an identifiable and pure variety. In sowing seed production the maximum number of types which clearly differ from the cultivated variety is $1/m^2$, for smooth meadow grass $4\text{-}6/m^2$.
- Quality requirements for seed.
  With respect to varietal purity it is required that the variety of the seed must be sufficiently identifiable and pure. Depending on the species, the germination requirement is 70 - 85 per cent, purity requirement is 75 - 98 per cent, and the share of seed of other species may be 3.1 - 4.1 per cent of the weight. Moisture may be no more than 14 per cent and only small amounts of pests which may affect the usability of the seed are allowed.

Related species

Wild species of grasses are abundant in all environments, also along ditches and in forests. Our most important grasses (timothy, meadow fescue, cocksfoot, tall fescue, rye-grass, smooth meadow-grass and red clover) are ancient incomers. Only tall fescue and some of the subspecies of the polymorphic smooth meadow-grass[42] may be "original" species in some parts of Finland; i.e. they have arrived here (after the Ice Age) by themselves, not aided by human influence.

Dispersion routes

Pollination

Grasses flower partly or fully in both sowing seed and dry hay production. Grasses are cross-pollinating plants, and hay pollen is transported by the wind. At a distance of a hundred metres from the field about a tenth of the pollen may still be left. Information would be needed on the survival of the pollen of different species.

Flowering must be prevented in the cultivation of genetically modified grass feed. In feed production the vegetation is cut two or three times during the growing period well before flowering. However, there may be early sprouts which may flower even if the vegetation is cut before the inflorescences appear in most of the plants, which is why there is a risk of spreading genetically modified material to the environment in grass feed production as well. In some cases too wet conditions, for example, may prevent the cutting of the vegetation and flowering takes place. Certain isolation distances should be required in feed production as well. Pollen production could be prevented by utilising e.g. male-sterility. Gene flow from a genetically modified plant can be dramatically reduced by linking a gene causing at least partial sterility to the useful gene to be bred (Slavov et al. 2004). Other genetic mechanisms for the prevention of spreading have also been developed or are being studied at present.

If a bred gene introduced plant properties which do not improve the ecological adaptation of the plant in the nature or as weed, the ecological impacts of the gene may be minimal. Such properties include high protein or vitamin content or better feed quality of the seed (Lu et al. 2004).

In most cases a property bred into a plant does not become common in wild populations unless it is beneficial for the plant in natural conditions. One example of such non-adaptive properties is slow growth bred (by means of gene technology) into bent grass used in golf courses. The property improves the quality of the golf grass and reduces the need for management work and environmental burden. If this property were transferred to the environment by crossing with wild hay plants, as a negative property for the plants it would be rapidly removed through natural selection. This is why the wild hays would have hardly any role in the transfer of such a property outside the plantation or to other plantations (Dijk 2004, Pilson et al. 2004).

A neutral property may become common poorly by accident only in very small population. In terms of coexistence, however, a small wild population cannot function as a significant transmitter of the gene flow between plantations, especially if the plant species is not the same.

Shedding

Usually the ripening of the grass seed is uneven and the mature seed sheds very easily. As yet there is little research information available on the preservation of grass seed in the field. After grass seed production, a plant species which cannot cross with the grass species concerned should be cultivated on the parcel. Admixture may also be caused by birds and other animals, which may transport seed and pieces of inflorescences over long distances.

[42] According to the broad taxonomic definition. Nowadays smooth meadow-grass is subdivided into several separate species.

Transportation of genetically modified grass feed and vegetative propagation from pieces of straw which fall on the ground is a risk factor only in the case of genetically modified reed canary grass, which may be bred in the future. Other grass species do not seem to be capable of such aggressive vegetative growth from only pieces of straw.

Timothy and meadow fescue

The most common grass species in Finland is timothy. For a long time its cultivation used to be based on wild local populations, but today bred varieties are being used. Another significant grass species is meadow fescue. In 2003 2,594 tonnes of timothy seed was certified (50 tonnes in organic production) and 0.35 tonnes was imported. The amount of meadow fescue seed certified in Finland was 454 tonnes (8 tonnes in organic production) and 26.5 tonnes were imported (KTTK 2003).

Grasses are mostly fertilised by pollen produced nearby (DIAS 2003) and the quantitative significance of pollen transported over longer distances is one to two degrees of magnitude (10 to 100 times) smaller. This means that efforts should mainly be targeted to the closest individual plants when preventing unintended genetic admixture.

Special attention should be directed at the control of volunteers and weed individuals of the species concerned in crop rotation to prevent the gene flow from these to a non-modified variety which may be cultivated on the parcel later on, as well as the accumulation of seed which retain their germination capacity in the soil seed bank. The spread of weed grasses to the plantation from field margins can be prevented by leaving an uncultivated strip of the width of the machine along the field margin.

Timothy seed retained their germination capacity longer than the other hay species in tests where they were placed at the depth of about 25 centimetres and the soil was not turned after this (DIAS 2003).

Seed shed on the ground should be allowed to stay on the surface for as long as possible so that as many of them as possible will germinate or be destroyed before the soil preparation. Ploughing should be done as late as possible in the autumn or, when possible, it should be postponed until the following spring.

Red clover

The most significant leguminous grass in Finland is red clover. In 2003 62 tonnes of red clover seed was certified (24 tonnes in organic production) and 38 tonnes was imported (KTTK 2003).

Red clover is a highly self-sterile plant, which means that it requires cross-pollination. Bees and bumble bees function as pollinators. In clovers gene flow is much smaller than the transport of pollen because (due to hormonal reasons) the creation of seed requires quite a large amount of pollen which can only be accumulated as a result of the visits of several pollinating insects. Studies have also shown that in most cases the fertilising pollen comes from very near, i.e. from the flower of the clover where the insect last visited (DIAS 2003).

In experiments made in Denmark the germination capacity of seed fell to less than one per cent when the seed was kept in the ploughing layer undisturbed for three years. In other parts of the world the seed has been reported to survive for much longer time. One reason for this may be the so-called hard seed, which apparently may assume a state of deeper dormancy. A great part of the seed may be of this type if the conditions during the maturation period are hot and dry, while in Denmark the share of hard red clover seed was only 6.7 per cent (DIAS 2003).

To minimise the admixture which may continue for a long time through the seed bank the volunteers of reed clover must be carefully controlled at all stages of the crop rotation if genetically modified red clover has been cultivated on the plantation. This is particularly important in the production of certified seed.

Recommendations for measure for grass production other than seed production (threshold value 0.9 per cent, working figure for organic production 0.1 per cent; assumed share of genetically modified production[43] no more than 10 per cent of the total cultivation area of grasses)

Dispersion of the pollen of grasses can be restricted but not completely prevented by means of

- sufficient, species-specific isolation distances => 200m (provision)
- cutting the vegetation before flowering (instruction)
- crop rotation, at least 3-year interval in the cultivation (provision)
- ploughing late in the autumn or in the spring when most of the seed have germinated (instruction)
- efficient weed control (provision)
- an uncultivated strip of the width of the machine along the field margin (provision)
- sufficient and appropriately targeted control measures (provision).

4. LEGISLATIVE NEEDS

The recommended measures concerning coexistence include both instructions and binding regulations. Very likely there is a need to prepare a completely new act which will define the general objectives and principles of coexistence as well as the responsibilities and sanctions. Provisions on the use of sowing seed, isolation distances, buffer strips, crop rotation, cooperation between neighbouring farms and control measures would be issued by lower-level statutes. Instructions on the destroying of volunteers, weed control, harvesting, cleaning and maintenance of machinery, soil preparation, and size and shape of the field parcels used would have the status of recommendations.

Legislative measures and proposals concerning these are dealt with in further detail [in Finnish] in the final report[44] of the work group completed in December 2005.

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[43] Assumed values are not recommendations but only working figures (scenarios), applied when assessing the necessary measures.

[44] Enabling the coexistence of genetically modified crops and conventional and organic farming in Finland. Final report [in Finnish]. Ministry of Agriculture and Forestry, Helsinki, Finland, 7 Dec. 2005. http://www.mmm.fi/julkaisut/tyoryhmamuistiot/2005/trm2005_16.pdf

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Annex A. Technical and biological topics in breeding

In agriculture and farming practices of the European Union coexistence is understood to mean that conventional and organic agriculture and agriculture utilising genetically modified organisms are of equal standing and the products can be successfully differentiated in the way required by the labelling rules.

The work on coexistence is concerned with products which have been proven safe for humans, animals and the environment. The questions involved concern mainly the arrangement of agricultural practices to ensure the differentiation between the types of production and organisation of the financial responsibility in case admixture should take place to such an extent that it would lead to economic losses to the producers.

However, the use of genetically modified crops in production involves various other issues besides the organisation of coexistence. There is a wide discussion on these questions, especially the environmental and health impacts of genetically modified plants. Annex A deals with the technical and biological questions of plant breeding and the related gene technology.

Location of gene in the genome

The nature changes the location of genes in the chromosomes by means of classical chromosome mutations (inversion, deletion, duplication, translocation). This phenomenon has been known since the 1920s and it causes no problems in plant breeding. The gene may function better or worse in the new location, but poor outcomes will disappear as a result of natural selection or selection by the breeder. In traditional plant breeding the location of a gene in the chromosome was seldom known. By means of the modern gene mapping programmes it is possible to find out at least the approximate location of many genes, which also benefits the traditional plant breeding work.

In the **early gene technology** the chromosomal attachment point of a gene transferred to a cell could not be determined in advance, but the transferred gene could attach to a random location in the plant's chromosome. This means that a gene could end up in an area where its functioning weakens. The nearby genes may also influence each others' regulation, which can be prevented by placing empty DNA thread at the ends of the gene as isolating material. In principle the attaching gene may also end up in the location of another gene and shut it down. However, this seldom takes place in cultivated crops (e.g. barley, wheat, maize, leguminous plants), because only about five per cent of their chromosomes are coding regions (with the exception of rice, whose genome is very small and half of the DNA is genes). Still, there are thousands of locations in the chromosome where the modified gene functions well. Usually a sufficient number of "successful hits" is found by producing some tens of genetically modified plant strains, of which only the best ones are selected for further study. The realised attachment point of the gene can be verified later on by means of gene technology and unsuitable plant strains can be discarded.

Mutations which shut down genes are quite common in the nature. In most cases the shutting down of genes makes the plant less successful and the strain disappears by itself or in the breeder's selection. However, if the mutation shuts down an adverse gene, it can be used in breeding.

Modern gene technology develops methods for determining the attachment point of a transgene in the chromosome in advance in certain situations[45]. It is possible to transfer an "attachment sequence" of the length of a few DNA bases to which the gene can be attached to the plant in advance. A large number of different plant lines where the attachment sequence is in a different site will be developed in advance. Laboratory studies of these plant strains show which of the sites are the most favourable in terms of the functioning of the genes. Finally the gene is transferred to the site in the plant's chromosome which according to the studies is known to be the most favourable (Ow 2004). The gene can also be cut off from the chromosome afterwards or other useful genes can be added next to it.

In the near future the possible undesirable impacts of the attachment point of transgenes can also be avoided in plants by assembling the transgenes into a small "minichromosome" (Perez et al. 2004, Preuss 2004). This is particularly useful when several genes are transferred to the plant at the same time. The functional parts of the minichromosome (tips or telomeres and the centromere which moves the chromosome) derive from the plant itself. No other genes except the gene forms to be bred into the plant are located to the arms of the chromosome. Then the finished minichromosome is inserted to the cell by means of the normal gene transfer techniques (Preuss 2004). Bred minichromosomes have proven highly stable in plants, because plants accept changes in the chromosome count much more readily than animals.

Stability of the functioning of genes

When applying gene technology a gene transferred to a plant may become silenced in several initial plant lines.. Often this happens in situations where there are several copies of the transgene itself or closely related genes in the plant's genome. A plant silences genes by attaching methyl groups which function as kinds of sordini to their DNA bases. No gene products (proteins) are created from strongly methylated genes in the cell. It should be noted that normally a significant share of the plant's genes are silenced either permanently or temporarily. The plants can afford this, because often their whole set of genes is repeated several times in their cells (crossing and polyploidy are highly common in the evolution of plants). Many of these multiple genes may originate from different plant species. The properties of an indivudual plant depend on which of the genes influencing the property are functioning.

The possible silencing of the functioning of a transgene does not concern the other genes in the genome. "The problem of silent lines" can be dealt with through the usual breeding methods by producing in the first stage extra strains in the tests from which the best ones are selected for further breeding (Tammisola 2004b) and by monitoring the stability of the strains for several generations. It should be noted that the problems caused by DNA methylation also concern traditional crossing breeding. In crossings with distant relatives or wild species the DNA methylation may be released and reorganised, which means that the plant may change in unpredictable ways: latent adverse genes may start functioning and important useful genes may be silenced. However, genetic modification is a basic condition for breeding and such secondary changes may also be useful for the breeder.

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[45] These so-called targeting techniques cannot take advantage of the traditional gene technological method of adding a useful gene to a ready elite species without altering the other gene combination of the variety used in traditional gene technology. So far these are suited only for situations where the useful gene is added to a breeding population which functions as the starting point for the forthcoming breeding work.

Depending on the method used, more than one copy of the gene to be bred may attach to the plant's genome. When the variety is propagated sexually later on, these copies may become separated from each other in the creation of gametes. Thus there may be variation in the number of copies of the gene and possibly in the level at which the gene is manifested between the progeny strains. This is why today molecular biological analyses are carried out to ensure that there is only one copy of the gene in the breeding strain[46].

Auxiliary genes in selection

Auxiliary genes are often used in gene transfer for finding and enriching cells where the transfer has succeeded among the cells and plant tissues. A genetically modified cell can be made visible through some staining technique or the auxiliary gene may improve the tolerance of the cell against a treatment or chemical that normally would be harmful to a plant cell. When breeding a variety with the aim of making it tolerant to herbicides, the tolerance gene to be bred functions by itself as this kind of selection marker. In **the early gene technology** the auxiliary gene was often present in the final variety, where it was no longer of any use. On the contrary, the gene prevents the utilisation of the same selection method for introducing further useful properties to the plant later on. In **modern gene technology** the auxiliary gene is usually not present in the final variety. Various methods have been developed for this purpose (Hare & Chua 2002). When the gene to be bred and the auxiliary gene are inserted to the cell at the same time but separately (for example, in two different plasmids), they may attach to different loci in the genome. In such cases they can be separated from each other later by means of usual crossings. In some recent methods the attached auxiliary gene can be cut off from the genome of the plant strain later on by means of suitable enzymes (Ow 2004).

Antimicrobial resistance is a property which is often used in selection. Antibiotics used internally in the treatment of illnesses usually destroy bacteria but do not damage higher organisms (i.e. eukaryotic ones, such as animals, plants and fungi). However, certain antibiotics affect the plant cells as well, which means that they can be used for selection in plants. (Often such antibiotics cannot be used internally for treating diseases, because they cause serious side effects). In theory the bacteria may - albeit quite seldom - include genes present in the plant in their genome. This is significant in terms of the time scale of evolution. Because bacteria which belong to different species are sometimes capable of switching genes with each other, there has been some concern that antimicrobial resistance genes may be transported to intestinal or pathogen bacteria through this.

When considering the risk we should bear in mind that the resistance genes to be used in plant biotechnology derive from soil bacteria, where they are widely spread and highly common (Flavell et al. 1992, Smalla et al. 2000, Summers 2002, APUA 2004). People consume large quantities of these in, for example, fresh food products (Levy 1998). Another important source are intestinal bacteria of domestic animals and humans, which often contain forms which are resistant to antibiotics. Each cell of a genetically modified plant contains the antimicrobial resistance gene so that extensive cultivation of the plant increases the number of antimicrobial resistance genes in food and the environment, which may increase the likelihood of the transfer. According to recent studies, however, the possibility that genes would be transferred from genetically modified crops to the soil is minimal (NERC 2005). Furthermore, the resistance genes transfer from one bacterium to another must more easily than from plant DNA to a bacterium. Based on quantitative risk assessments, the bacteria obtain resistance genes directly from each other many orders of magnitude (say, millions of

[46] On the other hand, when the aim is to silence an adverse gene, several copies of the silencing gene form may be deliberately bred into the plant.

times) more easily than from genetically modified plants (Redenbaugh et al. 1993, Chambers et al. 2001, Shoemaker et al. 2001).

The transfer of functioning genes to bacteria can be prevented by means of the structure of the transgenes, because in higher organisms the structure of the gene differs from bacterial genes. In the human genome the genes are in pieces (exons) which are separated from each other by uncoded sequences (introns). Instead, bacterial genes are contiguous (i.e. without introns), which means that bacterial cells cannot take advantage of the genes of higher organisms. In bacteria the functioning of resistance genes used in selection in plant breeding can be prevented by breaking the structure of the gene by several introns.

To maximise safety, according to the current EU legislation[47], the varieties placed on the market may not contain auxiliary genes capable of coding resistance to antibiotics that are significant for the treatment of diseases.

Controllability in breeding

Gene technology makes it possible to avoid the great randomness which is a problem in traditional breeding based on selection and crossing, where a significant share of the achievements of the earlier breeding work is lost when improving the variety. This is a serious problem especially in asexually propagated cross- fertilising plant species (berries, fruits, potato, etc.), whose varieties have often been found as a result of extensive crossing and selection work and whose genotype cannot be reconstructed after crosses. In self-fertilising species, however, this usually succeeds by means of 10 to 20 generations of back-crossing.

Gene technology has the advantage that the beneficial properties of the existing variety can be retained and further improvement can be targeted to certain specific properties. This is possible because a) no undesired genes are transported along with the transgene and b) the trait is inserted to the vegetative tissue of the variety and the plant does not have to go through the sexual propagation process (where the unique combination of the plant's properties falls apart).

The amount of work needed in **traditional mutation breeding** is great. Mutations are highly infrequent and random, which means that large numbers of progeny need to be examined. For each desired change there are hundreds of thousands of undesired genetic changes. In practice random mutations are incapable of producing the desired mutant if, for example, we wish to alter two or three different DNA bases in different parts of the gene.

Gene technology aims to reduce the amount of work in breeding. As a result of the better accuracy in the mutations the amount of progeny material to be analysed is smaller. When the desired gene form (or the DNA sequence to be modified) can be constructed in advance and then inserted to the plant, it is in most cases necessary to produce only some tens of test strains.[48] By means of the gene regulation site the gene can also be steered to function in the desired part or cell tissue of the plant.

It has been suggested that the attachment of a transgene to a plant's genotype may trigger uncontrolled phenomena, such as silencing or activating of existing genes. However, it should be

[47] Directive 2001/18/EC
[48] However, if we aim to breed an existing gene in its present location in the plant by means of so-called targeted mutagenesis (see 1.5 Gene technology and genetically modified agricultural crops, *Adding a new gene form to a plant*) large numbers of progeny need to be screened because the frequency of mutations is still low.

born in mind that **traditional breeding** may in fact trigger even more extensive chaotic phenomena, like silence functioning genes or reveal hidden genes (see above). Crosses with distant relatives may also cause mutations by triggering the plant's jumping genes, transposons. Such phenomena increase the genetic variation of the breeding material, which is the basic condition for breeding. However, if the aim is only to improve a certain property in an established variety, this kind of uncontrolled variation may cause breeding to regress to an unnecessarily primitive initial level (Tammisola 2004b).

It has been known for a long time that, besides the primary impacts, the genes also have other **"unexpected" impacts** (Mendel 1866). In plant breeding certain unexpected interactions (e.g. epistasis, specific combination ability SCA, heterosis, hybrid varieties) have been taken advantage of in the same way as the additive effects (Simmonds 1979). Individuals in whose progeny such genetic interactions have been proven the most favourable in crossing tests have been selected as crossing parents.

An extensive research programme of the EU (ENTRANSFOOD, 2000 - 2003) concludes the following: "Crop genomes are constantly changing through a broad range of natural and man-mediated mechanisms. Uncertainty associated with food safety of GM crops is no greater than uncertainty associated with conventionally bred crops. Unintended effects that alter the composition of food crops are as likely to occur through natural recombination and mutagenesis approaches used in plant breeding as through genetic modification." "Safety considerations for foods derived from GM crops are fundamentally the same as those for conventional foods." (Cockburn et al. 2004).

Most recent studies have shown that, when properties are inserted to a plant by means of gene technology, the impacts on the general level of manifestation of genes in the plant may be smaller than in traditional breeding (NERC 2005).

The bred property is biologically significant

There are two approaches to the regulation of GM crops. One of these is founded on properties and risks, and it rests on the view often presented in the scientific community that the potential ecological and nutritional impacts of agricultural crops depend on the properties bred into them, not on the methods applied in plant breeding (EUCARPIA[49] 1989, EMBO 2000, OECD 2000, SOT[50] 2002, ICSU[51] 2003, NRC[52] 2004, Conner et al. 2003a, b, Cockburn et al. 2004, Bradford et al. 2005). The other approach is founded on technology. The first approach is applied in Canada, where provisions concerning plant breeding apply to all plants to which new properties have been bred to a significant extent (Plants with Novel Traits) independent of the breeding method. The approach followed in the EC legislation is technology-oriented. The difference between the two approaches can be illustrated by the fact that in Canada the legislation also covers the herbicide tolerant sunflower developed by traditional breeding and imidazolinone tolerant oilseed rape, to which the technology-oriented EC regulations do not apply.

[49] European Association for Research on Plant Breeding (EUCARPIA)
[50] Society of Toxicology
[51] International Council for Science is the umbrella organisation of 103 national science academies and 27 international associations of science.
[52] American Council of Science

Ecology

According to the EU rules[53], the environmental impacts of a genetically modified plant must always be studied before the plant can be approved for cultivation. The cultivation of genetically modified crops must be monitored to observe the potential environmental impacts (Lohtander-Buckbee et al. 2004).

The ecological impacts of a plant depend on its properties (Conner et al. 2003a, b, NAAEC 2004). In general impacts may only appear if the plant succeeds in a certain environment and, possibly, is capable of spreading. The spreading of agricultural crops is restricted by the fact that many of them or the forms used in farming were originally exotic plants which would not survive in the conditions where the cultivation takes place. Such plants cultivated in Finland today are potato, cereals, cucumber, pea, tomato, certain cultivated berries (except currants) and many fruit trees. Breeding weakens the possibilities of agricultural crops to survive in the nature, because in most cases the alteration of plant's properties to meet the human interests takes place at the cost of the ecological adaptability of the plant. Maize no longer survives without human assistance and tomato has not been capable of developing wild populations in Europe during the 200 years when it has been cultivated here.

On the other hand, spreading may also take place via the gene flow between agricultural crops and wild plants. In practice, however, the bred properties have not established themselves permanently to the nature, because the plant species only adopt properties that are beneficial for them in the prevailing conditions. Adverse properties are discarded in natural selection. If there are no **wild species** which may cross with the agricultural crops, the genes of the latter cannot transfer to wild plants. This applies to the majority of the important food crops in Finland and, for example, to maize in Europe. (Turnip rape and oilseed rape are an exception because there are wild or weed-like related species among the European crucifers). Genetically modified plants do not spread their genes more efficiently than the traditional crops unless efforts have been made to influence this particular property. However, genetic modification can be used to develop varieties[54] that may significantly reduce the natural gene flow from agricultural crops to wild plants (Kuvshinov et al. 2001).

Ecologically insignificant breeding properties (Regal 1994, Conner et al. 2003a, b) are properties which weaken the adaptability of the plant in natural conditions. This is the case with many of the most common breeding properties. Almost all changes which improve the nutritional value, usability or product quality of the plant (from the human perspective), such as protein breeding or shutting down adverse genes (e.g. erucid acid in turnip rape and potato alkaloids), are harmful for the plant itself.

In both traditional breeding and gene technology applications efforts have been made to improve the **resistance of plants** to environmental stresses. Resistance breeding has been carried out for centuries by introducing resistance to diseases and tolerance to the conditions to the farming areas from exotic sources - genetic resources which have never before occurred in the regions concerned. Resistance breeding does not usually convert the agricultural crop into a wild plant or weed. If, for example, we succeed in breeding cold resistance to potatoes, they will not take over the Finnish meadows and heaths, because their survival in the nature is also restricted by a number of other factors, such as competition and herbivores. However, potatoes with higher cold resistance could

[53] Directive 2001/18/EC and Regulation (EC) No. 1829/2003.
[54] So-called GURT technologies

overwinter better in the fields, in the same way as potatoes in Central Europe. This should be taken into account in the cultivation recommendations to avoid additional admixture (due to volunteers) between the varieties.

Disease resistance genes transferred to agricultural crops could also improve their competitiveness in the nature. Disease resistance has been bred into agricultural crops by means of both traditional breeding methods and gene technology. For example, **blight resistant potato** has been bred by using gene technology to transfer the resistance gene from a wild potato species to established potato varieties (Fig. A.1.), so that the adverse properties of wild potato were not transported to the cultivated potatoes.[55] Such transfer is not possible in traditional breeding, because these potato species do not cross with each other. This GM potato is resistant to all known blight races (Song et al. 2003). The advantage of this kind of general blight resistance is that, as experiences have shown, it breaks more slowly as a result of the evolution of the pathogen than the resistance to a specific blight race. In the cultivation of blight resistant potatoes the yield losses and need for pesticides are smaller (Gianessi et al. 2002, 2003). Organic producers could also benefit from the use of blight resistant varieties, because the risk of spreading the disease from other plantations to the fields used for organic production would be smaller.

Fig. A.1. Blight resistant potato. Established popular potato varieties can be *a posteriori* bred into blight resistant ones (on the right) by means of gene technology. Photo**:** University of Wisconsin.

Gene technology has also been used to breed plants for **resistance to insect pests**. Such plants have been considered to represent the kind of "pointwise control" which is ideal for the environment because the control only affects the pest that eats the plant. In other control methods (spraying, parasites, etc.) the negative impacts are also exercised on the other surrounding organisms (Bigler et al. 2002).

However, it has also been suggested that pest resistance may be harmful to insects other than the targeted ones. The pollen of corn borer resistant Bt maize was found to weaken the viability of the monarch larvae in preliminary laboratory tests, where pollen and parts of the stamens of Bt maize

[55] Combination of whole sets of genes of different potato varieties e.g. by means of crossing should be avoided because new alkaloids may be formed in the hybrids (Laurila et al. 1996, Oksman-Caldentey & Inze 2004).

were fed to the larvae. However, in the nature monarch larvae do not feed on maize but on the poisonous milkweed[56], which grows on dry meadows and as weed on fields. In the laboratory test the idea was that maize pollen may end up on the leaves of milkweed growing on the field. However, extensive ecological studies showed that the cultivation of corn borer resistant maize had no negative impacts on the insects living on the field (except for the pests concerned) but, on the contrary, they benefited from this as the use of the less accurately targeted prevention methods decreased[57] (Saxena & Stotzky 2001, Head et al. 2002, Bigler et al. 2002, Motavalli et al. 2004, Romeis et al. 2004, Candolfi et al. 2004). Monarchs also benefit from this (Fig. A.2., Sears et al. 2001). The most recent varieties where the control protein which affects the larvae is not formed in the pollen are the most favourable in terms of the butterflies. Earlier one variety in whose pollen this protein was present was used in commercial cultivation (with a 2 per cent share), but this variety is no longer used.

According to studies, the cultivation of corn borer resistant maize (30–40 per cent of the maize area in the USA) seems to have led to a permanent reduction in the oversized European corn borer populations and yield losses in the cultivation areas. ECB resistant maize has also been found to contain less mycotoxins than regular maize (Munkvold et al. 1999, Magg et al. 2002, Clements et al. 2003, Papst et al. 2005). Moulds growing on ears eaten by larvae produce mycotoxins which cause kidney and liver damages and cancer (CFSAN 2001) as well as developmental disorders and nervous damages (Marasas et al. 2004).

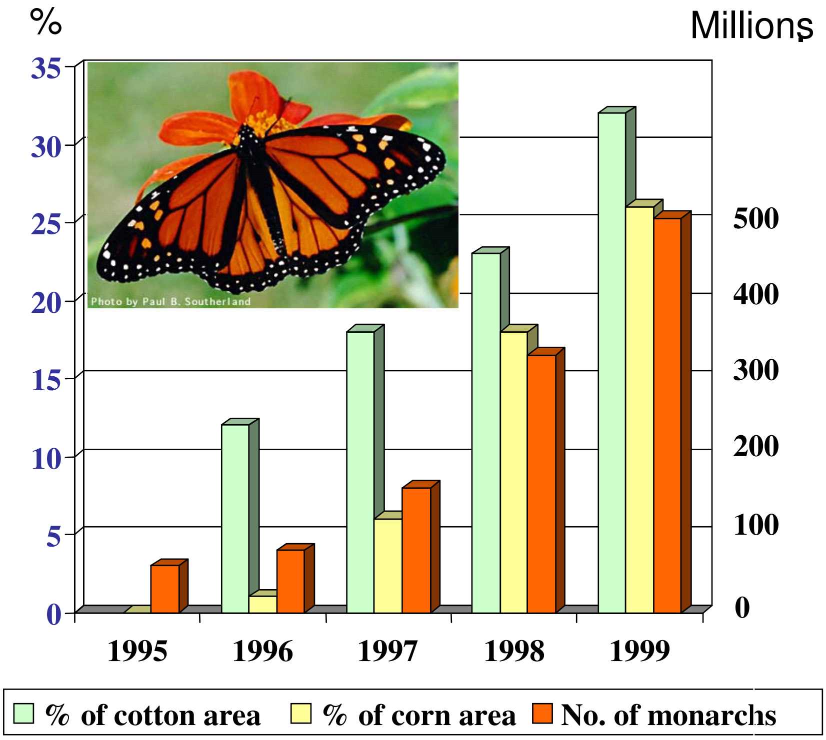

Fig. A.2. Cultivation areas of insect-resistant cotton[1] and corn[2] and the number of monarchs[3] in the USA in 1996 - 1999.
[1]USDA (1995-2000); [2]Carpenter & Gianessi (2001); [3] The monarch population grew to a record high level during the research period, Monarch Watch (2000).

[56] Monarch larvae are immune to the milkweed poison, but they themselves become toxic as they feed on the plant, which protects them against their enemies.
[57] Sprayings, spreading of parasites, ploughing

The most significant environmental benefits have been observed in the cultivation of insect resistant **Bt cotton**. Of the agricultural crops traditional cotton requires the highest amounts of pesticides. Pest resistant varieties survive with fewer pesticide sprayings[58], which reduces the harmful impacts on farmers' health (Maumbe & Swinton 2003, Hossain et al. 2004) and improves the state of the environment. Biological diversity has increased considerably in the plantations of insect resistant varieties and their surroundings (Head et al. 2001, Wu 2002, Rufener Al Mazyad & Ammann 2002, Fitt & Wilson 2003, Naranjo & Ellsworth 2003, Men et al. 2003, Chen et al. 2004). Small farmers in developing countries who cannot afford cultivation technologies or pesticides derive the greatest economic benefit from the resistant varieties (Pray et al. 2002, Gressel et al. 2004).

Resistant Bt varieties have been cultivated widely in the USA, Canada and China since the1990s. In the EU there has been significant commercial cultivation of these varieties only in Spain. Commercial cultivation in the EU has been restricted by the slow approval of the varieties to the market for various reasons and the concerns about the possible environmental impacts of their cultivation. However, it has been estimated that, if resistant genetically modified crops were cultivated on about half of the maize, oilseed rape, sugar beet and cotton area, the use of pesticides would fall by 14.5 million kg, consumption of diesel oil by 20.5 million litres and the carbon dioxide emissions into the atmosphere by 73,000 tonnes a year (Phipps & Park 2002).

Allergies

In the discussion on genetically modified food concerns have been raised that the products of the genes transferred from other organisms to the genetically modified crops could be potential allergens. This would mean that a food ingredient which earlier did not cause any problems might become harmful to persons with allergies. This kind of situation emerged in **early breeding tests** (in 1991) when the gene of a valuable storage protein was transferred from Brazil nut (para nut) to soya to improve the feed quality of soybeans. However, further studies on this genetically modified soya revealed that the para nut protein concerned was in fact an allergenic one (which was not known in the beginning of the experiment), and hence this soya strain was never introduced into the market (Nordlee et al. 1996).

Procedures through which the possibility to produce an allergenic protein in a plant intended for food or feed can be minimised in biotechnology are laid down in the current statutes and international norms. Special attention is directed to genes derived from species of living organisms which in general are allergenic. **Novel foods** made from genetically modified plants are examined more thoroughly than any other foods during the history of mankind (Cockburn et al. 2004, Tammisola & von Wright 2005). The safety of modified protein is always verified in accordance with the common norms[59] of the World Health Organization WHO and Food and Agriculture Organization FAO (Codex Alimentarius 2003a, b). When using genetic modification the gene to be bred is known, which means that the properties of the protein (proteins[60]) it produces in the plant can be studied to ensure that it is harmless. Existing data on allergens are used as background information. Plants are known to have three groups of proteins to which the clinically relevant food

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[58] The need for pesticides has decreased even to a fifth and the most harmful substances, such as organophosphates and organochlorines, are no longer used.

[59] The joint body of the WHO and FAO which lays down international norms (Codex Alimentarius) worked for four years to adopt guidelines for procedures to be followed to ensure the safety of genetically modified plant species (especially concerning allergens).

[60] Unlike in mammals, in plants one gene produces almost invariably only one protein. This applies even more often to transgenes.

allergens belong, and the relationship of the protein coded by the modified gene must always be examined carefully. Today there is a lot of information available on the structure of the allergenic protein sequences and the composition of the transgene can be compared to these databanks. No method for screening allergens in advance is fully certain, but the allergenic properties of genetically modified foods can be verified much more thoroughly than those of novel foods produced by means of traditional methods.

Traditional breeding is often concerned with thousands of unidentified proteins whose allergenic properties usually remain unclear. In most cases no efforts are made to do this and no requirements concerning this have been laid down for the traditional breeding methods. Because of the use of a known gene and safety assessment of the produced variety, the Union of the German Academies of Science has estimated that the genetically modified plant varieties are in fact much safer in terms of allergies than new varieties produced by means of traditional breeding methods (UGASH 2004).

When considering the allergies we should bear in mind that many of the traditional food crops are potentially allergenic (wheat, nuts, sweet pepper, kiwi fruit, soya, strawberry) (Karlsson et al. 2004). In certain cases it seems to be possible to remove the allergens with **the greatest immunological significance** from the edible parts of the important food crops through breeding, especially gene technology (Tammisola 2003, 2004a, Karlsson 2004). When the production of a harmful protein is shut down, people suffering from allergies in whose allergy spectrum the protein in question is important benefit from the result. Studies have shown that about 20 of the 1,400 seed proteins of soya may cause allergies and seven of these have proven significant among the American adult population. The two most serious allergenic proteins in soya have already been removed and the work to shut down the third is under way. The researchers aim to combine these three improvements into the same soya strain by crossing so that the immunological strain caused by unintended intake of soya could decrease by 95 per cent (measured by the IgE level) among the American people who are allergic to soya (Herman 2003, 2004, Herman et al. 2003).

Origin of a gene

One major topic in the discussion on gene technology has been the possibility to transfer genes between species, which has been limited in traditional plant breeding.[61] Doubts have been raised as to the consequences of this among people who consider the crossing of the borders between species as basically unnatural or fear that it may have unexpected negative impacts, whose severity cannot yet be assessed due to the lack of experiences. According to the other, prevailing view, what is important in terms of biology is not the origin of the gene (information) but its functioning, i.e. what the gene does in the organism and which protein it codes (Cockburn et al. 2004). It should also be noted that the borders between the species are also quite frequently crossed in the evolution of plants and traditional plant breeding.

In **early gene technology** genes and structural parts of genes (such as gene regulatory sites) of microbial origin were often used in the genetic modification of plants. The main reason was that at that time there was very little detailed information on plant genes available for breeding purposes. Thanks to **modern gene mapping programmes** the situation is very different today, when we know thousands of plant genes and their regulatory sites. Many of these function in the plants more

[61] Many species of bacteria are capable of transferring genes naturally to the plant genome, which is taken advantage of in certain gene technology methods. Unlike we used to think, not only agrobacteria but also species of certain other bacterial families are capable of transferring genes to plants (Gelvin 2005, Broothaerts et al. 2005).

efficiently than the corresponding sequences of microbial origin. At present it is possible to use structural parts of pure plant origin in the genetic modification of plants (e.g. the Clean Gene Crops™ principle of Boreal Plant Breeding) (Swords 2004). A gene obtained from a cold resistant microbe or Arctic Sea salmon, for example, could protect agricultural crops against damages caused by cold[62], but far more efficient cold resistance genes have already been found e.g. in rye-grass (Sidebottom et al. 2000, Pudney et al. 2003). It has been suggested that valuable genes to improve the quality and ecological sustainability of cereal crops may be found from the genetic resources of the more than 10,000 known wild grass species (Chandler & Wessler 2001).

Theory of plant breeding

Genetics is considered to have started as a science when Gregor Mendel published his research results in 1866. They showed that heredity is based on small units in the genome that do not mix with each other, which later on started to be called genes (Mendel 1866).

However, the studies by Mendel were forgotten for a few decades. At the same time statistician Francis Galton, second cousin of Darwin, laid the foundation for quantitative theory of statistics (biometrics). In formulating the theory Galton relied on the results of selection tests he made on beans. He also developed the concept of correlation, regression analysis and use of twins in the study of heredity.

When Mendelian laws of heredity were rediscovered in 1900, the breeders began to apply these very quickly. For ideological reasons, however, the so-called holistic view of heredity became dominant in the Soviet Union. According to this, the genome was a uniform whole, which means that the genes presented by the "reductionist" Mendel could not exist. Genes were an invention of capitalists to crush the working class (Lyssenko 1948). The holistic movement in the Soviet Union was led by agrologist Trofim Lyssenko, whose doctrines included the view that acquired properties can be passed on to the next generation. Stalin supported these views and these "laws of nature" were ratified by decisions of the Party meetings in 1948. Biologists who defended the "Mendelian-Morganian" genetics were put to prison (Lyssenko 1948).

During the 20th century, however, the breeding of quantitative properties was mainly based on biometrics. The theory of quantitative genetics became mathematically more and more complex, but it relied on several simplifying assumptions concerning both plant populations and the genetic basis of genes. The properties were influenced by a large number of genes, each with an equally small impact.

The unrealistic assumptions of biometrics started to be criticised already in the 1960s[63]. At that time, however, only few plant genes had been found and the matter remained unclear. Towards the end of the century the amount of information on genes increased dramatically and the critique proved well founded. According to the current view, the trait value is usually influenced very strongly by only few genes, while several other genes may have some impacts on it (in addition, a large number of genes have slight impacts on various properties).

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[62] No such agricultural products, e.g. the "fish strawberry" media often talks about, have ever entered the market.

[63] Breeding based on quantitative genetics and biometrics has produced fair [good] results, even if it is founded on an oversimplifying model of heredity (infinite number of genes, each with infinitesimally small impact).

The new information on genes (systematic gene mapping) has made it possible to find such genes with great or medium impacts. Instead of the oversimplifying old statistical theory we can often apply the more accurate Mendelian genetics in breeding.

Some of the modern representatives of the holistic thinking[64] accuse the applied plant biologists of playing with Legos and reductionism, and they even claim that the bioindustry operates on the basis of forty-year-old scientific conceptions (Smith 2005). The classic "one gene - one enzyme" principle (Beadle & Tatum 1941) that this probably refers to used to be a Nobel prize winning breakthrough in genetics. Since then the six decades of biological research work has produced further and more detailed information on heredity and the functioning of cells.

Humans and other mammals are capable of producing a greater variety of proteins than the number of genes they have. One reason for this are the genes of the immunological system, which after "training" are capable of producing a wide variety of antibody proteins against the wide range of microbes present in their surroundings. On the other hand, 40-60 per cent of the human genes code more than one protein. The reason for this is the alternative splicing which takes place as they process the information, which means that one gene may produce various forms of a certain protein.

In plants the evolution has found another solution to the protein-level diversity. In plants one gene usually codes only one protein, but several closely related gene forms which differ from each other only slightly may be present in the genome. Alternative splicing is rare in plants. For example, of the 28,000 genes of thale cress only 4.6 per cent were capable of alternative splicing. In most cases no introns needed for splicing are constructed into transgenes, which means no alternative splicing can take place in them.

What are the implications of this information for breeding? Plants were bred for over 11,000 years without a scientific basis, animals perhaps even longer. However, the scientific information accumulated over the past few decades has led to better understanding of the interactions between genes (which as phenomena were also known to Mendel). Better understanding and skills do not weaken but improve the possibilities of breeding.

Is modern breeding precise or not? There may be complications in precision surgery, even if it is more accurate and involves fewer negative impacts than traditional, more massive surgery. Precision medicines may have side-effects, but less frequently than old medicines whose functional mechanisms were unspecific. Natural sciences are not mathematics, which means that the level of precision that can be achieved must always be viewed in proportion to the reality in the field.

Similarly, we can talk about precision breeding, even if in biology everything cannot be under 100 per cent control. In many respects the new breeding is far more precise than traditional breeding.[65]

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[64] The most prominent one is biochemist Mae-Wan Ho

[65] The following factors are the most important ones. The original genotype of the variety developed as a result of breeding work can be preserved because the plant need not be exposed to sexual propagation which would break down its gene composition to add the necessary gene. Only the desired gene is inserted to the plant without transferring thousands of undesired genes or gene forms - measured at the DNA level about one millionth of the external DNA transferred to a plant genome in crossing is inserted to it. The code of the gene form inserted to the plant can be constructed and tested in advance, before insertion, so that it functions as desired, while in traditional mutation breeding the change in the gene cannot be determined in advance, which means that per each desired change there are hundreds of thousands of other, unforeseeable changes in the genome. When useful genes are introduced to plants in the traditional way by crossing with wild species, they may be accompanied by dangerous harmful genes, and long-distance crossing may also trigger chaotic genetic modification in the plant.

In the ideal case the plant is modified only as far as is absolutely necessary, which in most cases is not possible by means of the traditional methods.