Sustainable organic plant breeding

Final report: a vision, choices, consequences and steps

E.T. Lammerts van Bueren
M. Hulscher
M. Haring
J. Jongerden
J.D. van Mansvelt
A.P.M. den Nijs
G.T.P. Ruivenkamp

LOUIS BOLK INSTITUUT
natuurwetenschappelijk onderzoek

Research and innovation

Since 1976, the Louis Bolk Institute has been a pioneer in scientific research and innovation in organic farming, food and medicine. Spiritualization of science has always been an important element in the institute's work.

Where conventional research methods do not suffice, new methods are looked for, such as: phenomenology, participatory research, pictomorphological investigations and conscious-intuitive methods.

The Louis Bolk Institute engages in research for people who are prepared to think further than the material world, anthroposophy being an important source of inspiration.

Vormgeving: Fingerprint, Driebergen
Opmaak: STIP Grafische Producties, Driebergen
Foto's: Louis Bolk Instituut / A. de Weerd, en Vitalis Biologische Zaden BV

This publication (please mention number G24) can be ordered at the Louis Bolk Institute, Hoofdstraat 24, NL-3972 LA Driebergen, phone: **31 343 - 51 78 14, fax: **31 343 - 51 56 11, e-mail: info@louisbolk.nl

Contents

Foreword

Organic farming organisations (farmers, wholesalers, retailers and consumers), politicians and breeders have put organic plant breeding on their agendas as a result of our project on sustainable organic plant breeding. The project has also contributed to the public debate about a production chain free of genetically modified organisms (gmo-free). This has given an important impulse to the development of an organic plant breeding system for a gmo-free organic production chain. In this final report, we present a vision, choices and a step-by-step plan for the realisation of a sustainable plant breeding system for organic agriculture.

The project ran from September 1997 to May 1999 under the responsibility of the Louis Bolk Institute. The final report is the result of close collaboration between scientists from various disciplines connected with conventional and organic farming practices. The members of the project group were:
E.T. Lammerts van Bueren (agricultural scientist, Louis Bolk Institute), M. Hulscher (plant breeding scientist, Louis Bolk Institute), Dr M. Haring (molecular biologist, Amsterdam University),
Dr J. Hoogendoorn (plant breeding scientist, Centre for Plant Breeding and Reproduction Research CPRO-DLO) who was replaced in December 1998 by Dr A.P.M. den Nijs (plant breeding scientist, CPRO-DLO), J.D. van Mansvelt (biologist, Organic Agriculture Group, Wageningen Agricultural University),
J. Jongerden and G. Ruivenkamp (sociologists in technology, Technology and Agricultural Development Group, Wageningen Agricultural University).

The project group is grateful for constructive criticism from the consultative group, who are: R. Boeringa and C. Tielemans (working party for organic horticulture), Prof. J. van Damme (Netherlands Institute for Ecological Research), Prof. E. Goewie (Wageningen Agricultural University), Dr J. Lambalk (ENZA Seed), F. Schroën (National Reference Centre for Agriculture) and Dr J. Velema (Vitalis Organic Seed).

This project was funded by the Dutch Ministry of Agriculture, Nature Management and Fisheries (Department of Science and Knowledge Dissemination).

During the same period, the Technology and Agricultural Development Group (TAO) organised a number of workshops as part of its project “Working on agro-biodiversity”. The goal of these workshops was to join parties in the production chain for the propagation of seed and plant stock for farming systems that respect biodiversity (including organic farming systems). The substantive collaboration of the two project managers have benefited both groups, which is reflected in the fact that the two final reports tie in with each other.

Edith Lammerts van Bueren
Project manager

Summary

The prevailing opinion on farming systems today is that there should be respect for values such as sustainability, biodiversity, regional development and multi-functionality. This explains the growing popularity of organic agriculture. Plant breeding concerns, however, are a bottleneck in the further development of organic agriculture. Currently, organic farmers largely depend on varieties supplied by conventional plant breeders, even though organic farming conditions demand varieties with different characteristics than conventional varieties. Another problem is that conventional breeders are increasingly using gene technology to produce new, genetically modified varieties which are not allowed in organic farming. Continued dependence on conventional breeding systems is therefore undesirable. This project was launched in 1997 to develop a vision on organic plant breeding. One of the main objectives was to draw up criteria to assess the suitability of breeding and propagation techniques for use in organic breeding systems. In this final report, we present a list of acceptable techniques and propose a step-by-step plan to initiate and direct the development of an organic breeding system. In this project, we have focused on EU regulations for both organic and biodynamic production. The federation for biodynamic agriculture, Demeter International, will have to study the proposals in this report and determine whether additional requirements should be laid down for biodynamic breeding or propagation.

Organic farming means obtaining economically feasible yields without exhausting natural resources at and around the production site. Organic farmers aim to optimise yield while satisfying the conditions for organic production. Instead of chemical fertilisers, veterinary pharmaceuticals, pesticides, herbicides and growth hormones, more natural principles and methods are applied. The three criteria of organic production are *closed production cycles, natural self- regulation* and *agro-biodiversity*.

These criteria apply to functioning at farm level so that, in order to draw up a framework for an organic breeding system, we had to extrapolate them to the level of the plant. The three criteria of organic plant breeding are: *natural reproductive ability, ability to adapt independently to the environment,* and *genetic diversity with respect for natural species authenticity and species characteristic*s.

Equivalent criteria at the socio-economic level are: *close interaction between farmers, trade and industry and breeders; regulations geared to organic agriculture* and *cultural diversity* (see Table 1).

Table 1. The criteria of organic production at the three levels of organic plant breeding

Farm level	Plant level	Socio-economic level
- closed production cycles	- natural reproductive ability	- close interaction between farmers, trade and industry and breeders
- natural self-regulation	- ability to adapt independently to environment	- regulations incorporating organic principles
- rich variety of organisms: agro-biodiversity	- genetic diversity with respect for natural species authenticity and species characteristics	- cultural diversity: many different breeding programmes

Choosing breeding techniques

Our vision on organic plant breeding is based on the cyclic interaction between plant and environment, and between farmer (and the rest of the production chain) and breeder. Varieties will be optimally adapted to organic growing conditions when they have been selected, maintained and propagated in these conditions (i.e. favourable characteristics are high mineral efficiency, deep rootage, weed suppressive capacity, general field resistance to diseases and plagues, stress tolerance). These varieties will also better meet consumers' demands (for example, regarding taste and keeping quality).

Techniques at plant and crop level

On the basis of the criteria formulated in Table 1, we find that plant and crop based breeding techniques best suit an interactive organic breeding system. These techniques can be used to maintain parent lines and to select and propagate progeny in organic growing conditions. These techniques could even be used by farmers to carry out the selection process on their own farms or in the region, if necessary in consultation with a professional breeder. In this way, organic and regional differences would be taken into account throughout the selection process.

Techniques at cell level

Direct interaction between plants and their organic growing environment is bypassed when breeding techniques at cell level are used. During discussions on organic plant breeding, breeding techniques at cell level, while not automatically rejected like DNA techniques, did fall in a grey area of uncertainty. From a biological perspective, the cell is the smallest living entity and hence cell techniques could be used while respecting the organic principle to work only with living entities. On the other hand, the smallest unit of life encountered by farmers in daily farming practice is the whole plant in relation to its environment. From this perspective, cell techniques are an ecological detour and as such their use in organic breeding continues to be a point of controversy.

Cell techniques such as embryo culture and ovary culture have become increasingly common in conventional plant breeding and sometimes a crucial part of the process, for example in breeding and propagating tomatoes. An immediate ban on cell techniques which are so firmly embedded in conventional breeding would set organic farmers back twenty years and have dramatic economic consequences. Obviously, therefore, satisfactory alternatives will first have to be developed. We propose establishing transitional period of at least ten years during which varieties with characteristics resulting from cell techniques may continue to be used in organic farming and breeding while at the same time alternatives are developed that are more in keeping with organic plant health principles. We propose, however, to ban the use of certain cell techniques without delay: protoplast fusion, incorporation of cms (cytoplasmic male sterility) without restorer genes, radiated mentor pollen and mutation induction.

Techniques at DNA level

EC Regulation 2092/91 on organic production prohibits the use of genetically modified material in organic production. Such a ban is justified on the basis of organic farming principles:

- It is a one dimensional and drastic intervention in a plant's genetic make-up, which destroys its connection with its natural environment. To insert the desired DNA, the plant is first reduced to cell level and then reconstructed using tissue culture techniques. The (whole) plant x natural growing environment interaction is bypassed.
- There is insufficient knowledge of the risks connected with such reductionist methods; it is not unlikely that unexpected, detrimental effects on the ecosystem and public health will become evident in the long term.
- These capital-intensive breeding methods inevitably lead to patenting practices and the development of multinational breeding corporations, which together restrict the free exchange of genetic material and threaten genetic and cultural diversity.

DNA diagnostic techniques

DNA diagnostic techniques, which enable selection at DNA level, are also a form of gene technology but do not involve the genetic modification of DNA. There is no reason to ban the use of these techniques in organic plant breeding. The techniques, which are usually based on biochemical and molecular markers, could be used in special cases to supplement direct selection methods in the field, but their potential should not be exaggerated. The plant x environment interaction is of primary importance in organic plant breeding, so that selection in the field is irreplaceable.

The choices described above have been discussed at length by parties in the organic agriculture sector. Consensus has been reached on several points, as summarised in Table 2, below.

Table 2. List of recommendations regarding breeding techniques and their suitability for an organic plant breeding system

	Variation induction techniques	Selection techniques	Maintenance and propagation	Substances
Suitable for organic plant breeding	combination breeding crossing varieties bridge crossing backcrossing hybrids with fertile F1 temperature treating grafting style cutting style untreated mentor pollen	mass selection pedigree selection site-determined selection change in surroundings change in sowing time ear bed method test crosses indirect selection DNA diagnostic methods	generative propagation vegetative propagation: - partitioned tubers - scales, husks, partitioned bulbs - brood buds, bulbils - offset bulbs, etc. - layer, cut and graft shoots - rhizomes	
Not suitable, but to be provisionally allowed	embryo culture ovary culture in vitro pollination	in vitro selection	anther culture microspores culture meristem culture micro-propagation somatic embryogenesis	silver thiosulfate silver nitrate growth stimulants and colchicine (and related substances)
Not suitable, to be banned immediately	cms hybrids without restorer genes protoplast fusion radiated mentor pollen mutation induction genetic modification			

Action

In general, the characteristics of organic varieties - and by extension of organic plant breeding - differ from that of conventional breeding systems and conventional varieties. Realising an organic plant breeding system and subsequently steering it to meet changing demands is no less than a mammoth task. The many actions to be undertaken can be divided into short-term commercial and scientific activities, and longer or long-term commercial and scientific activities.

Propagation

Action must be taken in the short-term to ensure adequate quantities of organically propagated plants and seed. This is vital in consideration of Regulation 2092/91/EC which states that, as of 1 January 2000, all propagating material used in organic production must be of organic origin.

Additional measures are needed to accelerate the development of organically propagated varieties. Within the breeding sector, variety groups should be established to streamline communication in the chain. Variety groups should have a large contingent of farmers, as well as representatives from the trade branch and breeders. Members should communicate intensively with each other, share experiences, and participate in trials and variety assessments. Questions, wishes and bottlenecks could be recorded by variety groups and passed on to other parties in the chain.

Crucial actions to realise the organic propagation of plants and seed are:

- organic propagation of existing varieties (consult farmers and breeders to decide which varieties, recruit farmers to provide land, distribute a list of organically propagated varieties)
- additional information on varieties (ask farmers to list desired characteristics and selection criteria, screen existing varieties and test them in organic conditions using these criteria, establish a certification system for organic stock - e.g. green mark or green list)
- communication and awareness (set up and coordinate national variety groups, organise lectures, training courses and workshops for actors in the breeding chain, newsletter)
- legislation (draw up proposals for certification and organic breeding inspection system)

Breeding

- genetic sources (supplement the list of characteristics of gene bank stock with important organic characteristics, screen and test gene bank material for performance in organic conditions)
- stimulate organic breeding programmes (organic agriculture courses for breeders, selection courses for organic farmers, stimulate collaborations between breeding companies, individual breeders and organic farmers)
- legislation (amend protocols for cultural value and user value studies, amend legislation to enable marketing of organic breeds)
- funding (develop new, alternative sources of funding)

Research

The restrictions regarding breeding techniques make research for possible alternatives to enhance genetic variation necessary. Besides, research will be needed to work out (operationalise) the plant health concept, which is the basis of organic breeding. This includes aspects of adaptation to specific organic cultivation measurements and capacity of a crop to adapt. In this regard, genetic and fysiological buffering is of great importance.

Conclusion

► *A plant breeding system for organic production should be based on the organic concept of plant health and on the organic position on chain relationships. As the total land area under organic production is still relatively small, it is unlikely that commercial breeders will make large investments to develop organic breeding programmes without financial support from other parties, i.e. the government. In this early stage, it is vital that the government provides generous funding and plays an active enabling role. We hope that the action plan to stimulate organic plant breeding, as requested by the Dutch Parliament, will dovetail with the activities described above.*

1. Introduction

1.1 Justification

In the Netherlands, organic agriculture[1] is much talked about in all spheres of society - consumers, farmers, the government and agribusiness. This growing sector meets many of the demands that society now makes on agricultural production, but one of the bottlenecks to the further development of organic agriculture is plant breeding.

As yet, organic agriculture still depends strongly on conventional plant breeding programmes which are based on molecular, biochemical and physiological research and which are focused on increasingly low levels of incorporation. Plant breeding is part of the conventional agro-industrial production chain, and as such is characterised by economies of scale, productivity and uniformity. Consumers, on the other hand, are increasingly concerned about health and environmental issues related to agricultural production; their concern has now zeroed in on genetically modified foods. Society wants agricultural production systems which respect biodiversity and promote sustainability, regional development and multifunctionality. Organic agriculture is generally regarded as a shining example of such a system.

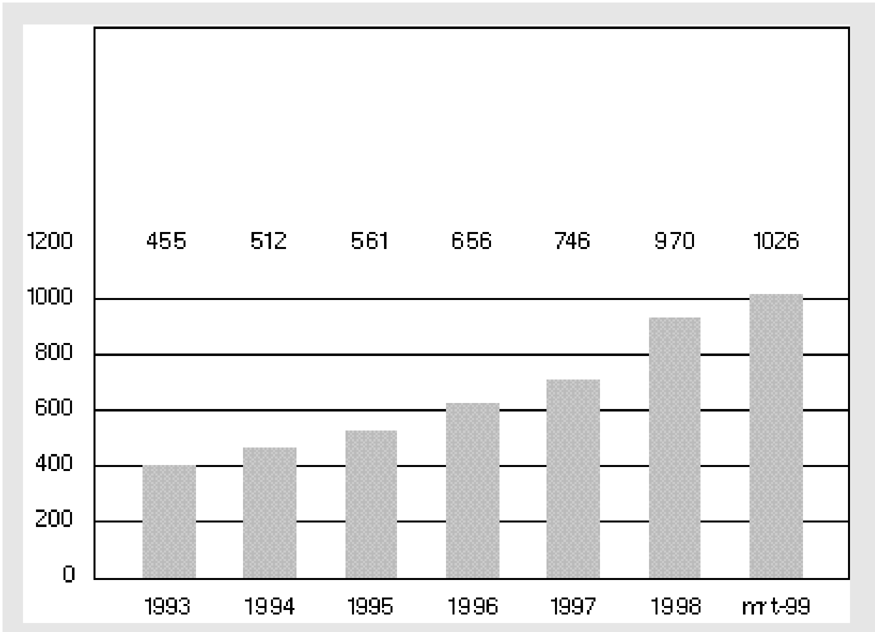


Figure 1. Number of organic farms in the Netherlands (Biologica)
(number of farms in March 1999, including farms in transitional period)

The supplement to Council Regulation 2092/91 to include a section on animal production and to be implemented in June 1999 prescribes that the organic production chain must be free of genetically modified organisms[2] (gmo-free). In February 1997, Parliament called for policy to stimulate the development of gmo- free food production chains in the short term. Organic agriculture was named as one example of such a production chain (Luttikholt, 1998), but if the organic sector is to remain gmo-free, farmers must be able to draw on a breeding system that aims to satisfy the sector's needs and conditions. In November 1998, therefore, Parliament accepted a motion asking the government to draw up an action plan, in consultation with breeding companies and the organic sector, to stimulate the development of an organic plant breeding system.

[1] Organic agriculture is understood to be that section of agribusiness which operates in accordance with Council Regulation (EEC) no. 2092/91 on organic production or in accordance with the private production standards set by SKAL. Both the organic and biodynamic agricultural methods (producing EKO-label products) meet SKAL standards.

[2] Directive 90/220/EC on the deliberate release into the environment of genetically modified organisms defines a genetically modified organism (gmo) as "an organism in which the genetic material has been altered in a way that does not occur naturally by mating and/or natural recombination".

1.2 Problem

Before the organic sector has a gmo-free organic plant breeding system which is a viable alternative to breeding systems based on gene technology, the sector will have to justify its oppostion to gmo's and explain what type of breeding system it would prefer.

Ethical or cultural preconditions or restrictions on how we handle plants as elements of our cultural heritage are scarce in literature on ethics. Kockelkoren (1993) wrote that people's feelings about biotechnology are related to their fundamental views on nature. Recently, a start was made in ecclesiastic circles to establish basic principles with which to judge biotechnology in agriculture (Koelega et al., 1998).

Developing an appropriate breeding system for organic agriculture encompasses more than just figuring out how conventional technology can be used in organic farming. Organic and conventional farming may share some problems and questions, and these may to some extent be jointly tackled. In other areas, however, cooperation may be impossible, simply because the (social) structure of farming and production differ too strongly. Compared to their conventional farming colleagues, organic farmers are more dependent on farm conditions. Making the right farm management decisions requires knowledge of complex agro-ecological systems, knowledge which is gained through research at higher levels of incorporation (plant-ecosystem, farming systems, regional level). Organic agriculture research can count on more funding these days, but it is by no means enough in consideration of the government's policy aim to have 10% of agricultural land under organic production. Moreover, organic principles play little to no part in current breeding research.

Before an organic plant breeding system can be developed, we must find an answer to the question: What type of plant breeding system would match developments in organic agriculture?

In this report we also wish to counter the persistent notion in some circles that organic agriculture cannot do without genetic modification (Van Roekel, 1997). Later, we will also explain why organic agriculture rejects the use of genetically modified organisms.

1.3 Project design

The project was split up into four sub-projects:

Sub-project 1: A vision was defined and propositions were drawn up for a plant breeding system that respects the principles of organic agriculture. These were laid down in a discussion paper.

Sub-project 2: We chaired discussions on the vision and propositions presented in the discussion paper. We invited representatives from various branches associated with organic agriculture to participate in discussions on organic plant breeding. The consequences of the proposed choices with respect to (European) legislation and the sector's competitiveness were identified and debated. Discussions were also held at the supranational level (primarily with participants from Germany and Switzerland).

Sub-project 3: We designed a step-by-step plan for the realisation of an organic plant breeding system. The plan lists action to be taken both within and outside the sector and distinguishes between national and international action.

Sub-project 4: The results of the discussions regarding the principles of an organic plant breeding system were collected and presented in a final report.

1.4 Project execution

In the discussion paper that concluded sub-project 1 (Lammerts van Bueren et al., 1998) we described the general principles of organic agriculture in detail and extrapolated these principles to the specific domain of plant breeding. We reviewed plant breeding methods (crossing and selection methods, cell techniques, DNA recombination techniques and marker techniques) and assessed them from an organic perspective.

From September 1998 to March 1999, the propositions in the discussion paper were the subject of numerous discussions (sub-project 2). One national workshop and several regional meetings were organised for organic farmers and breeders in the Netherlands. Conventional farmers and breeders were also invited to attend forums, workshops, conferences and one-day extension courses to discuss the contents of the paper. In addition, two German-language workshops were held for German and Swiss organic farmers and breeders between December 1998 and February 1999, and one English-language workshop was held in January 1999 in the United Kingdom for organic farmers there. The discussion paper had been translated into German and English for these workshops abroad. A complete overview of the workshops is given in appendix 1. In the course of this sub-project, the principles for organic plant breeding as proposed in the discussion paper were improved and fine-tuned. An assessment was also made of what the consequences of certain choices would be for the organic sector.

The results of the discussions were presented in a draft paper which was sent to regional organic farmers' organisations and extension groups in the Netherlands for their approval. Their response was invariably positive. The conclusions could therefore be adopted in the final report, which also contains a vision of organic production in the Netherlands and a summary of suitable and unsuitable breeding techniques as agreed on by the Dutch organic agriculture sector. Due to time constraints, we were unable to communicate the conclusions to the international organisations that participated in the discussions, even though the results of the international workshops did contribute to the final results.

During the same period, the Technology and Agricultural Development Group (TAO) held a number of workshops as part of its project "Working on agro-biodiversity" (1. Genetic sources and agro-biodiversity; 2. Breeding for diversity agriculture; 3. Organic-friendly breeders' rights and marketing rights). The goal of the project was to bring together partners in the production chain and stimulate breeding programmes for farming systems which enhance biodiversity (including organic systems). In the TAO project, organic plant breeding was explored from a chain-oriented perspective, i.e. the project focused on what changes are necessary in the chain. In contrast, in our project we explored on practical breeding issues from an organic point of view. The two project groups have sought to dovetail the two final reports (this report and Jongerden et al. 1999) and for that reason the reports are jointly presented.

2. A vision on organic plant breeding

The vision on organic plant breeding presented below is based on the principles of organic agriculture extrapolated to the level of the farm and the socio-economic framework. The foundations and justifications for this vision, including references, are explained at length in the discussion paper "Sustainable organic plant breeding: defining a vision and assessing breeding methods" (Lammerts van Bueren et al., 1998). The final vision presented in this chapter is the result of a series of discussions with stakeholding parties in the organic and conventional sectors.

2.1 Organic agriculture: environmentally-friendly and people-friendly

Organic producers try to achieve an optimal economic yield without exhausting natural resources in and around the production site while adhering to organic criteria. Instead of synthetic chemical fertilisers, veterinary drugs, pesticides, herbicides and growth hormones, more natural principles and methods are applied. Organic farmers strive for closed production cycles, natural self-regulation and agro-biodiversity. These three criteria will be discussed in detail in section 2.3.

Organic farming is more than just an environmentally-friendly production method, it is also a source of wholesome food. When asked why they believe that organic produce is better for them, consumers most often refer to the fact that organic crops are not treated with chemical pesticides, i.e. that they are free of residues (De Waart, 1998). However, we want to develop a vision of food quality that encompasses more than just the absence of residues. For this, we looked to the biodynamic vision on people and nature for inspiration. We expect that a vision on food quality will eventually lead to operational criteria for organic or biodynamic production methods, ensuring that these methods are environmentally-friendly and people-friendly. The concept of plant vigour will be a crucial part of such criteria (Schmidt, 1995; Meyer-Ploeger, 1999).

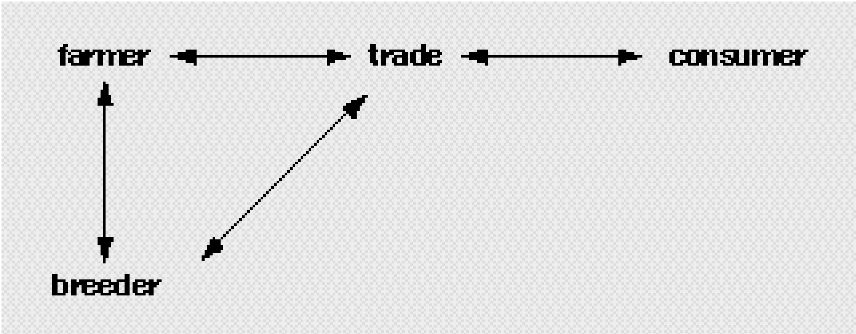
Concerns about plant breeding must be addressed before organic agriculture can evolve further. Plant breeding systems specifically for organic production are few and far between, even though the organic sector is striving to achieve a completely organic production chain. Until now, organic farmers have often had little choice but to use conventionally bred varieties designed for conventional systems based on the use of synthetic chemical fertilisers and pesticides. Despite these varieties' higher yield compared to old varieties - on organic farms, too - performance in organic systems could be vastly improved if varieties were bred for typically organic conditions.

The organic sector has listed its wishes regarding plant characteristics (product quality) and methods to develop new varieties (production quality). These methods should take into account organic principles about breeding techniques as well as related socio-economic conditions and structures.

2.2 Parties in organic plant breeding

Numerous people are involved in the production chain from breeder to consumer. In this report, we distinguish three main parties: farmers (growers and producers), trade and industry (manufacturers, retailers and wholesalers) and breeders (gene banks, seed companies, etc.). The relationships between these domains are pictured in figure 2. For a more detailed description, see Jongerden et al (1999).

Figure 2. The three main parties in the organic plant breeding chain



2.2.1 Farmers

An organic farmer is dependent on organic fertilisers and nitrogen-fixing legumes for mineral inputs and this in turn makes him dependent on regional and local circumstances. From an organic point of view, the farm is a functioning organism, a natural element in a dynamic environment. Improving performance, therefore, is a matter of repeated fine-tuning and precision regulation. In this process, organic farmers gain knowledge of and experience in dealing with regional and local possibilities and limitations. This experience explains their preference for varieties that perform well in many different growing environments and that are resilient enough to be able to adapt independently to natural seasonal variations in temperature and mineralisation. Such varieties result from breeding and selecting in specific regional and organic field situations.

2.2.2 Trade and industry

Parties in trade and industry, including consumers, demand products that meet certain quality standards (product grade, keeping quality, sorting quality and size). Consumers expect organic products to be good for their health and to be produced in an environmentally-friendly manner. For that reason, they prefer fresh, preferably unprocessed, tasty produce that keeps well and is free of chemical or synthetic additives. Some consumers also value produce which has a clear link with the season, a particular region or producer. Partly in response to consumers’ wishes, organic retailers are increasingly demanding varieties with species-specific and regional qualities, for example in taste, bouquet, colour and keeping quality.

2.2.3 Breeders

Breeding has become highly specialised, requiring specific experience with and knowledge of crossing and selection methods. Organic breeders should maintain and develop varieties in a sustainable manner, on the principle that these varieties are part of our cultural heritage. In practice, this means maintaining or if necessary increasing genetic diversity. Important conditions for the maintenance of genetic diversity are the free use and exchange of varieties among breeders, and the varieties’ ability to reproduce naturally in organic growing conditions.

2.2.4 Relationships in the organic production chain

The most important conviction that unites the three links in the organic production chain is that products, production methods and processing methods should respect the wholeness of the living entity as much as possible, to ensure that living entities - the farm organism, the plant organism and the human organism - retain their self-regulating ability.

That is why organic farmers use organic fertilisers, natural pesticides and other natural substances and methods. Why consumers buy fresh, unprocessed produce without chemical or synthetic additives whenever they can. And why organic breeders should only work at the level of the crop and plant. DNA techniques, and to a large extent cell techniques too, occur outside the context of the whole plant in its relation with the environment. These techniques manipulate bits of plants in sealed, artificial laboratory conditions. In view of the goal of organic breeding, they are an ecological detour.

Each party in the breeding process contributes specific knowledge and wishes. Close collaboration between the parties is a must if they are to overcome possible conflicts of interests and agree on a set of breeding goals. In particular, supermarkets' demands regarding product characteristics, which in effect are demands on breeding, can conflict with what organic farmers (or consumers) want. For example, supermarkets only want to sell carrots that are 10-15 cm long, have a uniform shape and a smooth skin. Such carrots can only be produced using hybrid varieties that are lacking in taste.

Organic farmers, too, may have wishes that differ from what conventional breeders are used to. For example, high yielding Golden Delicious is a popular cross-parent in apple breeding (Elstar and Jonagold result from crosses with Golden Delicious). But Golden Delicious is highly susceptible to disease, an undesirable characteristic from an organic point of view. Organic apple breeding programmes, therefore, should not be based on crosses with Golden Delicious.

An interactive approach to breeding may provide that intensity of collaboration which is so crucial to organic agriculture. A good start to interaction is to inform partners in the chain about various processes; for example farmers and trade and industry could learn about organic breeding projects at open houses or during site visits. Breeders should be able to justify their actions to downstream parties, because their products serve the rest of the chain, after all. Variety groups (see chapter 4) and selection on working organic farms could also play an important role in interactive breeding.

Conclusion: interactive breeding

► *The specific knowledge and skills of each of the three main parties are complementary. To optimise the use of available knowledge in organic agriculture, a more interactive approach to plant breeding, incorporating all parties in the chain, should be developed. Specifically, organic farmers and organic trade should have a part in the breeding process.*

2.3 Criteria at farm level

Most principles of organic agriculture pertain to farm management. Closed production cycles, natural self-regulation and agro-biodiversity are the foundations of a stable agro-ecosystem, which forms the basis of organic production because it achieves the best balance of sustainability and economic feasibility.

2.3.1 Closed production cycles

Most farms that convert to organic production in the Netherlands are specialised farms that depend on mineral inputs (arable production) or fodder and straw inputs (livestock production). In the future, however, organic farms will have to have closed nutrient cycles to reduce losses to an absolute minimum. This can be realised by reuniting arable and livestock production, either by establishing new, mixed farms or by intensive collaboration between specialised farms according to the Partner Farm concept (Baars, 1998; Van der Burgt et al., 1999). Such closed farm systems raise new challenges for plant breeders. For example, in closed mixed systems fodder crops must be grown that fulfil both the energy requirement of typical mixed-system livestock and the straw requirement for slurry composting.

2.3.2 Self-regulation

Soil fertility plays a key role in a self-regulating agro-ecosystem. Various aspects of soil fertility (soil life, humus content, structure) form the basis of healthy crop growth and as such are at the heart of organic farm management. An effective regime of fertiliser applications, biological nitrogen fixation and a carefully planned crop rotation scheme are requisites for good soil fertility. The decision to grow a certain crop is based on market demand and on-farm conditions; care should be taken at all times to prevent depletion of the soil. Compared to conventional farms, organic farming conditions are more diverse, which means that there is at least as much diversity in farm management styles. These different styles of farm management all require their own varieties. This is a task for plant breeders.

2.3.3 Variety of organisms: agro-biodiversity

The greater the diversity of crops and other organisms on a farm, the greater its natural self-regulating capacity. Natural features such as ditch bank vegetation, hedges and flowers provide shelter and food for the natural enemies of parasites. A rich varied soil life, legumes and cover crops contribute to soil fertility and prevent plagues of soil pathogens. Finally, many insects give farmers a helping hand with crop pollination.

2.4 Criteria at plant level

When the organic criteria at farm level, above, are extrapolated to the level of the plant, we get three criteria that can be used to in organic breeding programmes: natural reproductive ability, ability to adapt independently to the environment and genetic diversity while respecting natural species authenticity and species characteristics.

2.4.1 Natural reproductive ability

One type of closed production cycle at plant level is the cycle from seed to plant to seed, which we have called natural reproductive ability. We can give several reasons for our preference for varieties that are naturally fertile in organic growing conditions, or that at least have the potential to reproduce naturally. First, in an organic plant breeding system, all activities take place in organic growing conditions, from maintaining parent lines to crossing to selection. This automatically precludes any steps - such as fertilisation - being carried out in laboratories, so quite simply plants must be able to reproduce naturally. Secondly, in organic agriculture a plant's reproductive ability is regarded as a sign of vigour. Vigour is a vital quality which is indicative of health and nutritive value. That is why organic farmers prefer to use varieties that can complete their life cycle in organic conditions. Finally, natural reproductive ability ensures sustainable use of the cultivar, as progeny evolves to keep pace with the times and changing conditions.

Conclusions

- ▶ *Organic breeding may not affect a plant's potential for natural reproduction to ensure a sustainable development of the plant.*

- ▶ Crossing techniques involving pollination, fertilisation and seed formation on the plant may be used in organic plant breeding.

2.4.2 Ability to adapt independently to the environment

Why do genetically identical seeds sown in different plots each grow into a unique plant? According the concept of "plant x environment interaction", the environment (available nutrients, soil structure, moisture content, air temperature, etc.) and changes to that environment during the plant's growth have just as much influence on a plant's appearance (phenotype) as its genes. In other words, a plant (genotype) is continuously interacting with its environment.

Conventional breeders recognise this to some degree as reflected by their breeding programmes, where trial plots or breeding stations are situated in different geographical regions around the world, so that plants can be selected for local climate conditions. In doing so, conventional breeders seek to develop varieties with a fairly stable phenotype. At the same time, however, conventional farming conditions are adapted as much as possible to the needs of the varieties used. Applications of chemical fertilisers and pesticides reduce inter-local differences in soil fertility and resistance to disease and thus increase a variety's area of distribution.

In organic agriculture, on the other hand, environmental diversity is respected and farmers try to optimise their use of natural resources with minimal synthetic, external inputs. Varieties with a high adaptive capacity perform best in these conditions. In addition, organic farmers have only limited possibilities for intervening when things threaten to go wrong during the growing season. That is why varieties for organic farming must be resilient and flexible. This does not mean that adaptation to local conditions is not important in organic agriculture - it is. The challenge for organic agriculture lies in finding the balance between varieties that are adapted to specific, local growing conditions ("specialised") and varieties that can adapt to different conditions, that have high resilience and therefore perform well in many different environments ("generalised"). What organic farmers really want are varieties adapted to local conditions (specialists) with a high resilience (generalists).

A common misunderstanding

Conventional breeders tend to extrapolate a variety's performance ranking from one environment to another, stating that ranking is independent of environment. This does not mean that it is unnecessary to breed plants for specific environments. Consistency in the ranking of an existing variety does not rule out the possibility that a better performance might have been achieved if the variety had been bred for specific local environmental conditions. An understanding of genotype x environment interactions is required to follow this line of reasoning.

A common misunderstanding

Conventional breeders tend to extrapolate a variety's performance ranking from one environment to another, stating that ranking is independent of environment. This does not mean that it is unnecessary to breed plants for specific environments. Consistency in the ranking of an existing variety does not rule out the possibility that a better performance might have been achieved if the variety had been bred for specific local environmental conditions. An understanding of genotype x environment interactions is required to follow this line of reasoning.

Mineral uptake efficiency and rootage

To give an optimal yield on a certain plot, cultivars must be adapted to in situ seasonal fluctuations in nutrient availability. This applies in particular to soil nitrogen. Mineralisation processes are notoriously slow off the bat in early spring, giving rise to nitrogen shortages in the early stages of growth. Cultivars with a passive and active response to such situations are usually the ones that cope best. Active nutrient mobilisation by the plant (Scheller, 1988) is a combination of deeper rootage and a more efficient nitrogen uptake. These two characteristics are important determinants of a plant's suitability for organic growing conditions and are therefore important selection criteria in organic plant breeding.

Weed reduction

Synthetic chemical herbicides are not allowed in organic farming, so crops must have some intrinsic means of countering weed growth. Vigour and competitiveness, particularly in the seedling stage, are important indicators of weed suppressive ability. The structure of a crop, the number, size and position of the leaves, tillering - especially in poorer conditions - and firmness all contribute to a plant's weed suppressive ability and as such are important selection criteria in organic plant breeding (Müller, 1998).

Resistance to disease and plagues

Organic agriculture stresses the prevention of diseases and plagues. Varieties that perform well in this respect, especially when supported by crop management measures, tend to have a high polygenetic, or all-round, resistance. Absolute monogenetic resistance is not desirable in organic production as this type of resistance is fairly easily broken. As yet, commercial breeders show little interest in developing varieties with polygenetic resistance because of the work and expense involved and because conventional farmers still demand absolute resistance[3]. A plant's structure, its pattern of growth and its heterozygosity all contribute to field tolerance, resilience and restorative ability. These factors are therefore considered important selection criteria. Preferably, breeders should aim for broad resilience by limiting homozygosity to a functional minimum. In other words, some variation within a variety is desirable. In organic agriculture, the use of heterozygous varieties is more appropriate than sowing a mix of homozygous varieties in the field, which only gives a semblance of diversity.

Conclusions

- ▶ *Organic agriculture has a different concept of plant health. Characteristics should not simply be added to existing varieties, rather new plant types should be developed whose growth pattern is better suited to organic conditions. Important selection criteria include: mineral uptake efficiency, rootage, weed suppressive ability, and polygenetic resistance to disease and plagues.*

- ▶ *Varieties that are optimally adapted to environmental factors such as soil type, climate and disease pressure (resilience and restorative ability) can be developed by breeding and selecting in organic conditions at the level of the plant or crop.*

- ▶ *An organic breeding system should strive to maintain the greatest possible genetic diversity in a variety. A variety should not be made more homozygous than functionally necessary so that it retains its adaptive potential.*

- ▶ *Organic plant breeding should focus on increasing and maintaining the genetic diversity among varieties of one cultivar, thus reinforcing the varieties' local identities.*

2.4.3 Genetic diversity while respecting natural species authenticity and species characteristics

Natural species authenticity

Plants have different defences against cross-pollination with other species, for example, the ability to distinguish pollen on the stigma. These mechanisms help to preserve a species' identity. An often heard question in discussions on the use of biotechnology in plant breeding is whether the line of species authenticity may be crossed. This is a difficult question, especially as there is no clear biological definition of what a species is. Biologists generally use the term species when the following two conditions apply to a group of individual organisms:
- the individual organisms have a high degree of similarity;
- the individuals can produce fertile offspring through sexual reproduction.

[3] Conventional breeders are working on polygenetic resistance now that selection using DNA marker techniques have become commonplace.

There is no black-on-white definition for a species and some plant species are so flexible that they defy any attempt at definition. Take, for example, the wild cabbage (Brassica oleracea), which through domestication has been cultivated to many different forms. And at the other end of the spectrum, spontaneous cross-pollination can give rise to new species, too.

The mere fact that spontaneous crosses do occur naturally among some plants is no reason to freely allow such practices in plant breeding. In nature, spontaneous crosses are the exception rather than the rule and they always occur within set, natural limitations. In organic plant breeding, it may be acceptable to cross the line of natural species authenticity provided fertilisation and embryo growth occur naturally on the plant (i.e. there is no need to resort to techniques to incorporate change at cell level) and progeny resulting from the cross are fertile.

Plant quality

A species, regardless of whether it is wild or cultivated, has distinct characteristics which set it apart from other species. These characteristics may pertain to a plant's shape, colour, keeping quality and taste. Although taste is a fairly subjective characteristic, taste does give a variety "character". The perception of taste is subjective, but the description of taste may be objective (think of criteria for wine-tasting, cheese, tea and tobacco). These characteristics are partly hereditary and partly the result of environmental influences. A variety's characteristics may be changed by breeding, sometimes for the worse as in conventional breeding where too strong a focus on quantity has in many cases diminished quality.

Region-specific characteristics

If a cultivar is adapted to or used in a particular environment, it may subsequently acquire specific characteristics resulting from the interaction with that environment. Such region-specific characteristics could be used to promote regional products like bread and beer.

Nutritional value

Most cultivars are eaten by people, who believe that fruit and vegetables are good for them because of their nutritional value. However, the concept "nutritional value" is not clearly defined. The general assumption is that "healthy crops make for healthy eating". Presumably then, plants that have grown in a well-balanced, steady manner without the use of pesticides and harmful substances (natural toxins, pesticide residues) and which contain sufficient proteins, minerals and vitamins are healthy. Well-balanced or harmonious growth takes the middle road between pervasion and stagnation. In biodynamic circles in particular, harmony in the plant's gestalt and ability to mature are considered important factors of food quality (Bauer, 1988). A plant is said to have developed harmoniously if under the given conditions, its development has been optimal in each phase of growth. For example, in wheat crops, the preference goes to varieties with a clear distinction between vegetative and generative development, which is expressed in the plant's overall development and morphology (Kunz, 1983; Kunz et al., 1991). Species-specific characteristics such as keeping quality, taste, colour and bouquet will be optimally developed (though not maximised) if a cultivar is allowed to grow in a harmonious manner. The sum of these quality characteristics is called "maturity". Since only ripe or mature (harvest-ready) crops are healthy to eat, ability to reach maturity could be adopted as a selection criterion in organic breeding (Bauer, 1988). However, further research is required to develop the concept of nutritional value and how it may relate to plant breeding (see also section 2.1).

Conclusions

- *Organic plant breeding aims to respect natural species authenticity. Crosses between species should not be forced if fertilisation and embryo growth do not succeed on the plant.*

- *Organic plant breeding aims to achieve a species-specific equilibrium for an optimal development of species-specific and region-specific characteristics, such as taste, colour, bouquet and shape.*

2.5 Socio-economic criteria

In modern plant breeding, there is a strict division between breeders whose task is to produce new varieties and farmers whose task is to use them. A less distinct division with more consideration for farmer-breeder interaction is believed to be more productive in organic agriculture. Another limitation of conventional plant breeding is its focus on standard varieties and strains that do not take into account the great variety of organic farming conditions. These limitations are economic, institutional, technical and conceptual in nature (Hardon et al., 1993). Economic, because the costs of a breeding programme and the commercial objectives of propagators result in varieties that cover the largest possible geographical range. Institutional, because of the limited possibilities for breeding crops for specific environments. Technical, because techniques are used which conflict with organic agricultural principles. And finally, conceptual because of conventional breeders' product-oriented approach common to technology development which largely ignores alternative uses of new techniques and their products (Jongerden et al., 1996, 1999). These limitations must be overcome if breeding programmes are to be developed which better meet the needs of organic farmers. To this end, breeders should seek closer ties with organic farming practice.

2.5.1 Farmer-breeder interaction

An organic breeding system involves selecting varieties in situ, that is on a working farm. The process of adapting to local production conditions is ongoing in organic breeding. Farmers can play an active part in this selection process, but this does require the relationship between farmers and breeders to be redefined. In this new interactive relationship new propagating material and new varieties could be developed. The interactive approach to breeding is quite common in developing countries, where it is known as participatory plant breeding (Van der Heide et al., 1996).

Organic agriculture does not oppose specialisation and professionalism provided that there is ongoing interaction at a high level of incorporation, as for example when specialised farms form collaborations. If a farmer does not have the skills required to propagate seed and elects to outsource that part of the plant-seed cycle, it is vital that he or she keeps in touch with the propagator and vice versa. Interaction ensures an optimal use of all available knowledge and experience and ultimately leads to a better breeding result. Figure 3 depicts how different parties' knowledge about breeding-related aspects is intertwined and how added value may be obtained from the synthesis of this knowledge, for example in participatory breeding programmes where farmers do most of the selection themselves.

Conclusion

- *Organic plant breeding should be more interactive than conventional breeding to ensure that the wishes of farmers and trade and industry are considered and to optimise the use of all available knowledge and experience.*

2.5.2 Legislation

The Seeds and Planting Materials Act protects the intellectual rights of ownership, or breeders' rights. Usually, a variety only qualifies for breeders' rights if it is new, distinguishable, homogeneous (uniform) and stable. Organic agriculture, however, requires varieties which are fairly heterogeneous so that they can adapt to different regional soil and climate conditions, which are resilient and have a high resistance to disease and plagues. The goal is functional homozygosity: breeding plants no further on certain characteristics than is necessary for crop growth and mechanical harvesting. As a result, the varieties may not have that degree of uniformity currently demanded for registration as a variety. Strictly speaking, however, unregistered varieties may not be marketed and this is where legislation and the needs of organic agriculture clash.

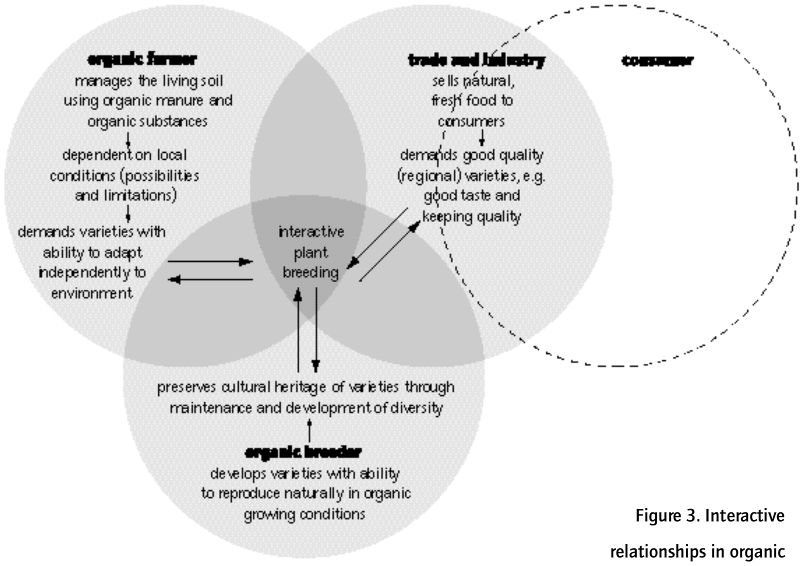


Figure 3. Interactive relationships in organic plant breeding

Patent law is also a potential threat to organic breeding. In principle, farmers have the right to propagate their own seed, which in organic farming is a crucial step in the continuous process of adapting a variety to local production conditions. This right is called farmers' privilege. The law says that farmers' privilege only applies to unpatented varieties or genes. This is cause for concern as the patenting of new varieties or even of specific genes is becoming commonplace in conventional breeding.

Organic agriculture aims to improve the self-regulating capacity of the agro-ecosystem, both in the ecological sense and socio-economically. Amendments to existing legislation to curtail the power of modern capital-intensive forms of breeding are required to stimulate a greater diversity of breeding initiatives. Specifically, we propose amendments to regulations regarding intellectual property rights, registration criteria, licensing and protection against environmental and health risks.

Conclusion

- ▶ *Legislation (registration requirements, user values, farmers' privilege) must be amended to facilitate the development of organic breeding systems.*

2.5.3 Funding structure

Breeders' rights, registration with the National Varieties List and research for a recommended listing cost a lot of money. Professional breeders are only prepared to make these investments if they expect to make a reasonable return. These costs do not encourage breeders to make the extra effort to develop many different varieties for specific conditions. Moreover, cultivation and user value studies will have to be expanded to include criteria for organic farm systems, which might raise costs even further. Another additional cost of an interactive organic breeding system is the need for an organisation which deals with the outsourcing of (part of) the selection and propagation process to organic farmers. Quite simply, seed or plant sales alone could never cover the entire cost of an organic breeding programme. A new funding structure based on new sources of funding will therefore have to be developed.

Conclusion

- ▶ *New sources of funding need to be developed to realise an organic breeding system.*

2.5.4 Cultural diversity

Conventional varieties are increasingly bred for highly conditioned circumstances and large fields. This inevitably means a loss of genetic diversity. Advances in gene technology and technology patenting are only accelerating this trend. This capital-intensive type of breeding is fast becoming the exclusive domain of multi-nationals that can afford to pay patent holders huge sums of money for a licence or even for the patent itself. Corporate mergers are also narrowing the genetic basis of breeding programmes (Heselmans, 1998). Mergers cut the number of breeding programmes for a cultivar, and take away breeders' right to freely exchange crosses and seed. Cultural inbreeding and genetic erosion will be the ultimate result.

In addition to these biological arguments, we can also cite moral or ethical objections to the practice of patenting organisms or parts of organisms (genes). Basically, patenting means that characteristics of organisms which have developed over centuries either in the wild or through the efforts of local farming populations, suddenly become private property simply because that person or company found, identified and isolated the characteristics. This is a denial of centuries of tradition and custom. It also conflicts with the international biodiversity treaty, which states that all life forms have their own intrinsic value (Van der Hoeven, 1998).

In summary, organic agriculture favours the development of many different breeding programmes, for example: organic programmes set up by conventional breeders, programmes by specialised organic breeding companies, and programmes in which organic farmers carry out (part of) the selection process in situ in consultation with a professional (organic) breeder.

Conclusions

- ▶ *Socio-economic and legal conditions must be changed to facilitate organic breeding. Breeders must retain the right to freely exchange genetic material.*

- ▶ *Genetic diversity can be maintained and developed if there is adequate diversity in breeding companies and programmes. Monopolistic practices do not serve the interests of organic agriculture.*

- ▶ *Patenting organisms or parts thereof (genes or DNA sequences) is in conflict with the principles of organic agriculture.*

2.6 Summary

The vision on organic plant breeding can be summarised as follows:

Organic agriculture has a different concept of plant health. Breeding efforts should not concentrate on adding one or more characteristics to existing varieties, but on developing new plant types whose style and pattern of growth are more suited to organic farming conditions. The criteria of organic plant breeding are:
- breeding and selection must be carried out in organic growing conditions at the level of the plant or crop, so that varieties can optimally adapt to organic conditions related to the soil, climate, disease pressure and weed prevalence.
- organic breeding may not affect a plant's potential for natural reproduction to ensure the sustainable development of the plant.
- there should be maximum functional genetic diversity in a variety and homozygosity should be limited to the minimum required for modern farming practice, so that resilience and adaptive capacity are retained.
- genetic diversity among the varieties of one cultivar should be maintained or enhanced.
- there should be respect for natural species authenticity. Species should not be crossed if seed formation and embryo growth do not succeed on the plant.
- breeders should seek to achieve a species-specific equilibrium in which species-specific and region-specific characteristics, such as taste, bouquet, colour and shape, can develop optimally.

The vision on organic plant breeding is based on an ongoing interaction between plant and environment, and between farmer (and the rest of the chain) and breeder. The following principles can be drawn up:

- Organic plant breeding should be more interactive than conventional breeding to ensure that the wishes of farmers and trade and industry are included in the breeding goal and to ensure an optimal use of all available knowledge and experience.
- As long as organic agriculture only serves a small market, other sources of funding will need to be developed to ensure that there is a greater diversity of varieties for the organic market.
- Legislation (registration requirements, user values, farmers' privilege) must be amended to facilitate the development of organic breeding systems by both organic farmers and breeders.
- Socio-economic and legal conditions must be changed to facilitate organic breeding. These changes must safeguard the free exchange of genetic material between breeders.
- Patenting organisms or parts thereof (genes or DNA sequences) is in conflict with the principles of organic agriculture.
- Genetic diversity can be maintained and developed if there is adequate diversity in breeding companies and programmes. Monopolistic practices do not serve the interests of organic agriculture.

The primary criteria of the vision on organic plant breeding are summarised in table 3.

Table 3. The criteria of organic plant breeding, on the basis of the principles of organic agriculture

At the level of the farm system	At the level of the plant	At the socio-economic level
- closed production cycles	- natural reproductive ability	- close interaction between farmer, trader and breeder
- natural self-regulation	- independent ability to adapt to surroundings	- regulations taking into account organic agriculture
- variety of organisms (agro-biodiversity)	- genetic diversity with respect for natural species authenticity and species-specific characteristics	- cultural diversity: multiple breeding programmes

3. Consequences

The vision on organic plant breeding as described in the previous chapter naturally has consequences for breeding programmes. One of the objectives of this project was to draw up recommendations for Skal or EU regulations on organic plant breeding and the use of conventionally bred varieties in organic agriculture. To this end, we organised discussions with stakeholding parties to assess breeding techniques on their suitability for organic breeding. The consequences of participants' choices are described in this chapter.

3.1 Choosing breeding techniques

One of the main principles of the vision on organic plant breeding is that there should always be interaction between plant and environment, and between farmer (and trade and industry) and breeder. Ideally, breeding programmes should be developed in consultation with partners in the organic production chain and selection should be carried out by farmers in organic growing conditions. This would result in varieties optimally adapted to organic growing conditions with characteristics that would satisfy all partners in the chain.

3.1.1 Techniques at plant and crop level

The consequence of the criteria for organic plant breeding as set out in chapter 2 is that we must reappraise the role of technology in plant breeding. Preferably, interactive organic plant breeders should only use techniques at the level of the plant and crop. Parent lines would have to be maintained in organic conditions, just as progeny would be selected and propagated in organic plots. Techniques at the level of the plant or crop allow farmers to carry out the selection process themselves on their own farm or in their own region, though possibly in consultation with a professional breeder. In this way, organic management and regional influences would be incorporated in the selection process.

Hybrids

When using hybrids, F1 progeny must be maintained by repeatedly crossing the parent lines, since generative propagation of the F1 defeats the purpose of hybridisation. This end-of-the-line nature of hybrids is why some - chiefly biodynamic - growers and breeders object to their creation or use. Nevertheless, biodynamic farmers are known to use hybrids simply because seed-propagating varieties with comparable yields are not (yet) available or because buyers' demands regarding uniformity and size can only be met by using hybrids. The objection stated above is not shared to the same extent by ecological growers, although they, too, would welcome improvements in seed-propagating varieties as well as a more relaxed attitude on the part of buyers.

Seed-propagating varieties could equal hybrids in uniformity and yield if they were to become the focus of breeding programmes. Hybrid progeny cannot be generatively propagated, which thus effectively keeps farmers from collecting seed themselves. Although this may be an incentive for breeders to invest in hybrids, such varieties do not serve the long-term interests of organic farmers. For this reason, more effort should be put into the development of seed-propagating varieties.

The use of hybrids in organic agriculture is justified in the following situations:

- comparable seed-propagating varieties are not available;
- homozygous lines still have enough vigour to be propagated in organic growing conditions;
- the F1 is fertile and can be used as a cross-parent, i.e. no cms without restorer lines (see also section 3.1.2 on cms).

3.1.2 Techniques at cell level

Cell techniques such as the culture of embryos and ovaries are used to incorporate characteristics of wild plants in cultivars. Embryos are cultured after pollination and seed formation on the plant because there is a reduced chance that they will grow successfully on the plant. In such cases, the embryos or ovules are isolated from the plant and placed in a culture containing all the necessary nutrients and hormones. These crosses could be created in natural circumstances, but it would be a case of beating the odds, which would require a much greater number of plants.

Techniques at cell level bypass the direct interaction between the plant and its (future) growing environment. During our discussions, it became apparent that breeding techniques at cell level fall in a grey category between the unacceptable DNA techniques and the approved methods of breeding at the level of the plant. From a biological perspective, the cell is the smallest living entity and hence cell techniques could be used without violating the organic principle to work only with living entities. On the other hand, the smallest unit of life encountered by farmers in daily farming practice is the whole plant in relation to its environment. From this perspective, cell techniques are an ecological detour and as such their use in organic breeding continues to be a point of controversy.

In conventional breeding, however, cell techniques have been used since the 1930s. For some crops, such as tomatoes, they have become a crucial step in the maintenance of the cultivar (see appendix 3). In effect, cell techniques are synonymous with breeding programmes based on specific, hereditary, usually monogenetic resistance or characteristics. In organic breeding, however, we are not interested in incorporating absolute resistance, but in developing varieties that are better able to cope with existing growing conditions. Such a plant might have deeper or more elaborate rootage to survive plagues of insects or fungi. Organic breeding objectives are based on a different concept of plant health. More research is required to work out the operational details of this concept and to enable the development of a breeding system that is less dependent on cell techniques.

An immediate ban on cell techniques that have been used for decades might do more harm than good for some crops and varieties, and have dramatic economic consequences for farmers. Obviously, therefore, satisfactory alternatives will first have to be developed. We propose establishing a transitional period of at least ten years during which varieties with characteristics resulting from cell techniques may be used in organic farming and breeding while at the same time alternatives are developed that are more in keeping with organic plant health principles. A condition for using such varieties in organic agriculture is that they have the potential to reproduce naturally in the organic growing environment. In addition, characteristics which have been incorporated using cell techniques should also be receptive to traditional cross methods.

Why can cms plants (without restorer genes) never be used as cross parents?
Imagine a breeder who sees a promising cms hybrid and wants to cross it with his own lines or plants. The cms plant (plant A) is male sterile (does not produce functioning pollen) and can therefore only be used as a mother plant. Crossing plant A with a fertile father (plant B) yields plants that have a 50% share of genes from each parent, including the cytoplasmic male sterility as that is always inherited from the mother. The only thing the breeder can do now is cross the progeny with a fertile plant. This F2 generation will have inherited 25% of plant A's genes, again including the cms characteristic. Eventually, the breeder will get a generation which has 0% of plant A's genes, but these plants will still be male sterile. The only characteristic that can be transferred from a cms cross-parent is the cms characteristic, and if that is what you want, one cross is all it takes. Every other characteristic is lost in the backcross. And because plant A is sterile, there is no way of using it other than as the mother plant.

In order to stimulate the development of organic breeding programmes which are not dependent on cell techniques, we propose setting up a special "green mark" programme in which participating breeders pledge to not use cell techniques. Varieties or lines produced with cell techniques and originating from before a certain date (e.g. 1-1-2001) may be used as foundation stock. Varieties and lines produced with cell techniques after 1-1-2001 would not be allowed in green mark breeding programmes (for a "green plus" varieties list see 3.2).

Protoplast fusion

Protoplast fusion goes one step further than the techniques described above. Protoplast fusion is carried out with loose, unconnected cells (without membranes) that are in no way recognisable as plant material. This technique is applied when two species differ so much that a successful cross could never be achieved by natural methods. This is also a major reason for rejecting the technique in organic plant breeding. The consequences of rejecting this technique are not that far-reaching, as it is fairly new in conventional breeding, too. Protoplast fusion is primarily used to transfer cytoplasmic male sterility from one species to another (for example, from radish to cabbage). The technique has been patented, which is another reason to not use it in organic breeding programmes.

Cytoplasmic male sterility (cms)

Organic agriculture rejects the use of techniques that negatively affect a plant's natural reproductive ability. The sector particularly opposes cms hybrids without restorer genes. There are plenty of alternative seed-propagating varieties or hybrids without cms (also see appendix 2).

Unfortunately, the use of cytoplasmic male sterility in modern hybrids is growing. Although cytoplasmic male sterility occurs naturally in some species, breeders are currently using protoplast fusion to transfer the characteristic to other species as well. These new hybrids are subsequently patented. The absolute cms in cabbage, for example, originates from radish. Cms hybrids differ from non-cms hybrids in a number of ways:

- the advantage of using cms hybrids in practice is that inbred plants (deviants) do not occur in the field as is the case with non-cms hybrids (sometimes more than 10%);
- other breeders cannot acquire the mother line by searching for inbred plants because these do not exist; this gives the breeder who owns the mother line a competitive advantage;
- other breeders cannot incorporate any of a cms hybrid's hereditary characteristics in their own breeding material; the breeder of the cms hybrid has exclusive access to the gene pool, so that he is the only one who can incorporate the selected characteristics in marketable varieties and profit from them (see inset). Ultimately, however, cultural inbreeding will occur and this may lead to genetic erosion. These practices therefore go against the grain of organic agriculture.

Why can cms plants (without restorer genes) never be used as cross parents?
Imagine a breeder who sees a promising cms hybrid and wants to cross it with his own lines or plants. The cms plant (plant A) is male sterile (does not produce functioning pollen) and can therefore only be used as a mother plant. Crossing plant A with a fertile father (plant B) yields plants that have a 50% share of genes from each parent, including the cytoplasmic male sterility as that is always inherited from the mother. The only thing the breeder can do now is cross the progeny with a fertile plant. This F2 generation will have inherited 25% of plant A's genes, again including the cms characteristic. Eventually, the breeder will get a generation which has 0% of plant A's genes, but these plants will still be male sterile. The only characteristic that can be transferred from a cms cross-parent is the cms characteristic, and if that is what you want, one cross is all it takes. Every other characteristic is lost in the backcross. And because plant A is sterile, there is no way of using it other than as the mother plant.

The free exchange of varieties, hybrid or otherwise, will always form the basis of sustainable breeding. This was one of the primary considerations that led to the establishment of breeders' rights for plants, as an alternative to patenting. If every single variety was patented, breeding would be made impossible. But cytoplasmic male sterility, too, makes breeding impossible.

Breeders who work with cms can use other breeders' non-cms varieties, but they in turn cannot use the cms varieties. There is no mutual exchange of benefits or sharing of profits. This one-way breeding is a form of parasitism. Breeders have a responsibility to maintain cultivars because they are part of our cultural heritage, resulting from centuries of cultivation and breeding. These cultivars cannot be maintained without natural reproduction and genetic transfer.

As cms becomes more and more common in modern varieties, fewer varieties will remain for use in breeding programmes. Eventually, modern varieties will no longer be able to be crossed to broaden the genetic basis of a breeding programme. Programmes will stagnate due to the erosion of genetic diversity. Thus, although cms may seem like an attractive way of getting ahead of the competition, it is ultimately a dead-end road. In effect, each cms hybrid is like a dead twig on a cultivar's family tree.

Breeders will need restorer genes for the infusion of new genetic material. These genes could be transferred from one species to another through genetic engineering. But it is likely that this quality will be patented just as cms was and therefore only be available for cms breeders.

Breeders who do not use cms will always be in an underdog position and on top of that, will end up in a cut-throat competition with each other. If there are no restorer genes, these breeders will not be able to incorporate the genes in cms varieties. At the same time, however, cms breeders will gratefully cash in on each improvement in non-cms varieties. Breeders who use cms techniques are not taking their responsibility to maintain cultivars and in the long term they will drive non-cms breeders into economic extinction. The question is whether, in the current system of breeding, non-cms programmes can feasibly co-exist with cms programmes.

Artificial induction

The artificial induction of mutations in DNA by radiation, chemical mutagens or other means is completely random and largely harmful. According to our vision of organic plant breeding, direct manipulation at DNA level is undesirable. Artificial induction is therefore unsuitable for use in organic breeding. An immediate ban on this technique will have little impact, as the technique is currently rarely used in conventional breeding. The same applies to radiated mentor pollen.

3.1.3 Techniques at DNA level

Genetic modification is not allowed in organic agriculture (amendment to EU regulation 2092/91 on organic production, effective June 1999). This is justified on the basis of the following organic principles:

- It is a one-dimensional, drastic intervention in a plant's genetic make-up which upsets the plant's relation to the environment. The desired DNA can only be incorporated by first reducing the plant to cell level and then "reconstructing" it using tissue culture techniques. This destroys the historical plant x environment relationship.
- It is a reductionist method that increases the chances of undesirable and unpredictable ecological and health risks in the long term.
- It is a capital-intensive type of breeding in which multi-nationals hold patents on living organisms and impede a free exchange of genetic material, thus reducing genetic and cultural diversity.

3.1.4 DNA diagnostic techniques

Genetic engineering has also enabled selection at DNA level without actually modifying plants' genetic make-up. These techniques are based on biochemical and molecular markers and may complement field selection methods. The potential of these indirect selection techniques should not be exaggerated, however. Although there is no reason why these techniques should not be applied in organic breeding, selection in the field will always be the primary method of selection because it incorporates the plant x environment interaction.

3.1.5 Conclusions

▶ *In table 4, below, we have summarised our recommendations regarding the suitability of breeding techniques in organic plant breeding on the basis of the vision of organic plant breeding. The working party for legislation for organic agriculture will be asked to incorporate these recommendations in new (European) regulations.*

Table 4. A summary of recommendations regarding breeding techniques and their suitability for organic breeding

	Variation induction techniques	**Selection techniques**	**Maintenance and propagation**	**Substances**
Suitable for organic breeding	combination breeding crossing varieties bridge crossing repeated backcrossing hybrids with fertile F1 temperature treating cutting style grafting style unradiated mentor pollen	mass selection pedigree selection site-determined selection change in surroundings change in sowing time ear bed method test crosses indirect selection DNA diagnostics	generative propagation vegetative propagation: partitioned tubers scales, husks, partitioned bulbs brood buds, bulbils offset bulbs, etc. layer, cut and graft shoots rhizomes	
Not suitable, but to be provisionally allowed	embryo culture ovary culture in vitro pollination	*in vitro* selection	anther culture microspores culture meristem culture micro-propagation somatic embryogenesis	silver thiosulfate silver nitrate growth stimulants and colchicine (and related substances)
Not suitable, but to be banned immediately	cms hybrids without restorer genes protoplast fusion radiated mentor pollen artificial mutation induction genetic modification			

3.2 Monitoring and certification

Above, we indicated which techniques are suitable for use in organic breeding programmes and which are not. A monitoring system should be set up to enforce regulations governing the use of breeding techniques to ensure that varieties approved for organic farming have indeed been bred and propagated in accordance with organic principles. EU regulations on organic breeding will probably go no further than list approved and prohibited techniques. Most cell techniques, however, leave no trace in plants, so that monitoring for direct evidence of wrongful use would be fruitless. Instead, more indirect monitoring methods will have to be used, for example audits of the production process. The inspection organisation for organic agriculture in the Netherlands, Skal, carries out process inspections to enforce compliance with EU regulations for organic production. In conventional breeding, too, process inspections are becoming more popular as part of private certification schemes carried out by NAK-AGRO Nederland BV (arable crops), NAK-G (vegetable crops) and NAK-S (ornamental stock). The standards set by private certification schemes may exceed legislative requirements. In addition, such certification systems can be developed and implemented in a relatively short period of time while EU regulations for organic breeding are still pending.

Varieties lists

The following categories might be included in varieties lists:

- a black list for varieties that are not allowed in organic agriculture;
- a white list for varieties produced in conventional breeding programmes using approved techniques, including provisionally allowed cell techniques;
- a green list for white-list varieties that have been organically propagated and that perform well in organic growing conditions. These varieties satisfy EU regulations on organic production;
- a green-plus list for varieties that have been produced in organic breeding programmes without cell techniques, which have been organically propagated and which perform well in organic growing conditions.

A special certification system could be developed to tie in with the last category, so that varieties in this category could be awarded a special quality mark on top of Skal's EKO mark.

Certification system

The following criteria could apply for an organic seed/plant stock certification system:

- Parent lines must be maintained in organic growing conditions, for example soil cultivation under glass (or mesh).
- Crosses must be made under glass (mesh) or in the field. Parent plants must be rooted in soil (in pots or open soil), not in substrates that do not comply with Skal guidelines. Crosses may only be made using approved crossing techniques (see table 4).
- Selection of the F1 progeny must be carried out in organic conditions. If necessary, seedlings may be tested under glass, even if the crops are normally grown in the field. However, only approved selection methods (see table 4) may be used. Following generations (F2 onwards) must be selected in normal organic growing conditions. From F3 or F4, selections will be extended to different organic trial plots in different regions. Preferably, these plots should be situated on working organic farms. Farmers participate in the selection process, the outcome of which is subject to environmental influences. In this way, region-specific varieties are developed.
- Varieties must be propagated and maintained in normal organic growing conditions. If desired, these activities may be carried out in soil cultivation under glass or mesh. Only approved propagation techniques (see table 4) may be used.
- The following information should be recorded by farmers in order to apply for certification:
  the parent lines;
  the techniques used;
  selection conditions of the F1;
  selection conditions of the F2 to Fn;
  propagation methods and conditions;
  maintenance methods and conditions.

Monitoring

Skal could monitor breeders participating in the certification system, perhaps jointly with NAK. The easiest monitoring system would probably be audits of registration applications. Breeders wanting to register a variety would have to provide detailed information on what techniques they used and whether plants have been selected in organic growing conditions. Breeders would not be required to give a step by step account of the development of the variety.

A breeder could submit a signed declaration that a variety was bred in accordance with organic certification criteria. Skal or NAK could then verify this through an audit of the registration application. If the outcome of the audit is positive, seed/plant stock would be awarded a certificate and/or EKO mark.

3.3 The difference between organic and biodynamic production

In this project, we have focused on EU regulations for both organic and biodynamic production. The federation for biodynamic agriculture, Demeter International, will have to study the proposals in this report and determine whether additional requirements should be laid down for biodynamic breeding or propagation.

3.4 Missing links and research

Facilitating the development of organic breeding programmes encompasses more than simply laying down a list of approved techniques and an accompanying system for enforcement. Organic breeding is based on a different concept of plant health which requires a new set of regulations and new fundamental or strategic research. Some important issues will be described in chapter 4.

The current breeding system does not take into account organic principles. Structural changes will be required before an interactive chain approach, which is crucial to organic breeding, can be realised. A framework for organic breeding cannot be constructed by the organic sector alone; existing (conventional) institutions will have to change their course, too.

3.5 Stimulation policy

Breeding is a long-term activity and it would be unrealistic to expect the market - which is more focused on the short term - to independently launch a professional organic breeding system when the demand for organic products is still relatively small. Various institutions who participated in the discussions in this project were keen to contribute to an organic breeding system (Netherlands Federation of Seed Producers - NVZP, General Netherlands Inspection Service - NAK, Varieties list committee, CPRO-DLO, Centre for Plant Breeding and Reproduction Research - CGN, and Wageningen University and Research Centre), but do not want to act alone.

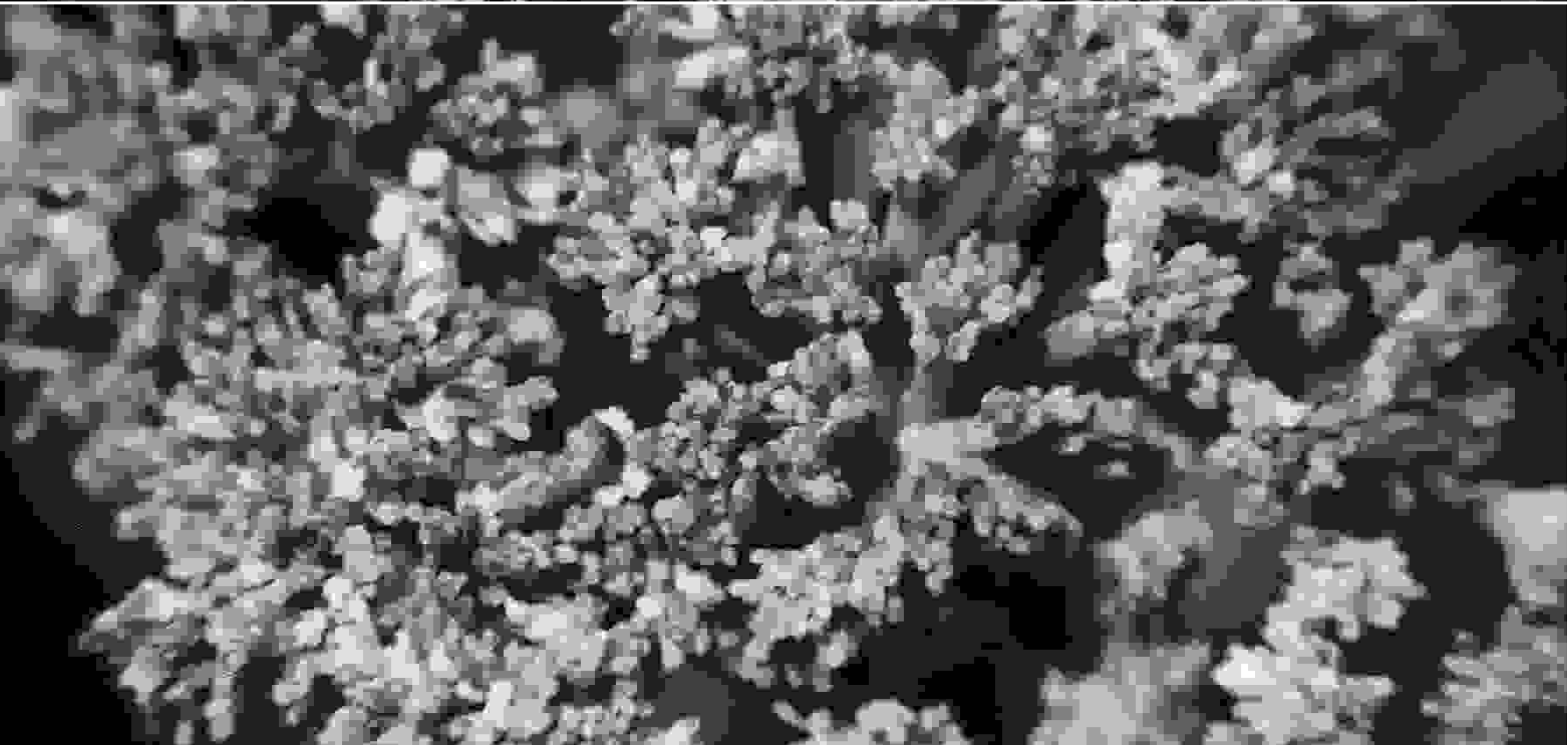
Commercial parties, too, showed real interest by actively participating in the discussions. This does not mean that every seed company is ready to make an investment; they will first want to examine the costs and benefits. Naturally, private companies will only want to participate when it is to their benefit and will be unwilling to invest time, money and effort if competitors benefit, too. This applies just as much to breeding companies as it does to organic farmers.

To overcome these difficulties, the government will have to draw up policy to stimulate and finance the development and marketing of organic breeds in a joint effort with private parties. Organisations and institutions need professional skills and money. If they receive no commitment for either, the development of an organic breeding system will surely stagnate.

3.6 Future expectations

Currently, organic agriculture is based on conventional breeding. Additional efforts and investments will be required to set up an organic breeding system for the organic production chain. We expect (or hope) that conventional farmers - who are also moving towards more sustainable production - will also want to use organic varieties in the future. The project group expects that conventional and organic breeders have more interests in common than currently recognised and that this will become evident in time.





4. Necessary measures

A great many activities will have to be undertaken if an organic breeding system is to be set up on the basis of the vision on organic breeding presented in this report. In this chapter, we review the main bottlenecks. Many problems will need to be accurately identified by feasibility studies and project proposals. The list of activities can be divided into those yielding results in the short term and more long-term measures. More research is needed in addition to the practical measures listed here.

One short-term goal is to have enough organically propagated stock of varieties suitable for organic growing conditions in pursuance of EU regulation 2092/91 which states that, from 1 January 2001 all seed and plant stock used in organic production must be of organic origin. Long-term activities are more focused on the breeding process itself.

In the pioneering period of organic agriculture, the sector's efforts went into production and retail, i.e. the last steps in the organic chain. Once that was achieved, the sector then moved up one link, and laid down the compulsory use of organic plants. Now, EU regulation 2092/91 stipulates that all seed and plant stock used in organic production must be of organic origin. In other words, as the sector develops, organic principles move upstream in the chain (see figure 4), so that in the end the chain will be organic from beginning to end.

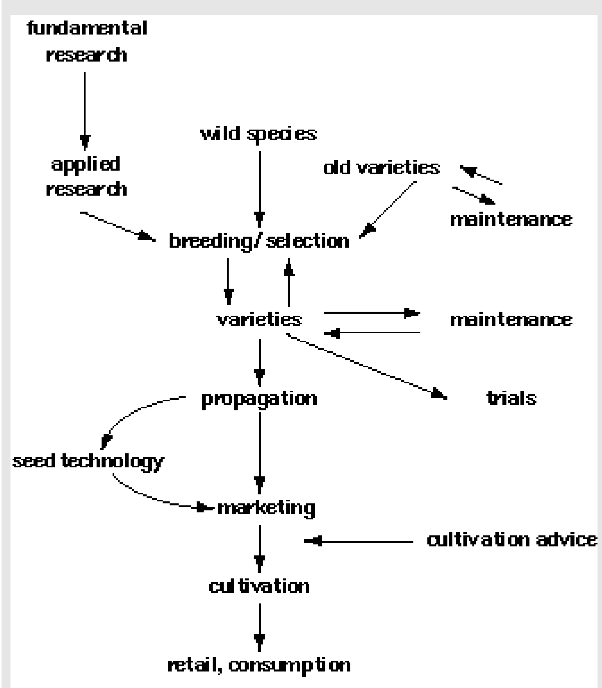


Figure 4. The breeding chain from research to marketing

On 1 January 2001, there must be enough organically propagated seed and plant stock for all organic farmers. Considering the time remaining to this deadline, it is crucial that organic propagation, i.e. propagating seed and plant stock in organic growing conditions, is started without further delay. And with organic agriculture growing exponentially, now is also the right time to encourage the adoption of organic methods in other steps of the breeding chain.

4.1 Propagation

The activities and concerns described in this section must be addressed in the short term to ensure that enough organically propagated seed and plant stock is available by 2001. These activities also lay the foundations for organic breeding activities.

Organically propagating existing varieties

- Organic farmers must tell breeders which varieties they would like organically propagated. Regional extension groups or national crop groups (which would first have to be established) could act as intermediaries.
- Breeders could also check their own records to see which varieties are popular with organic farmers. They could then enter into an agreement with organic farmers to propagate these varieties in situ.
- For a fee, organic farmers would be prepared to let their land and share their knowledge for organic propagation purposes.
- Each year (November at the latest), a list of organically propagated varieties should be drawn up by Skal and sent to organic farmers.

Until now, the conventional breeding sector has not made the effort to propagate seed and plant stock in organic growing conditions. The sector will have to be prodded into action; better lines of communication between the organic sector and the breeding sector is a first requisite. In addition, Skal could charge farmers a levy when conventionally propagated varieties are used, which would effectively stimulate the use of organically propagated varieties. However, economic dissuasion only makes sense when enough organically propagated varieties are available for farmers to choose from.

Information on varieties

If a farmer is to make an informed choice from the many varieties on the market, he must have access to information on varieties' performance under organic conditions and typically (or uniquely) organic characteristics which are less developed in conventional varieties.

- Organic farmers should draw up a list of desirable characteristics and selection criteria per cultivar. This information could be collected by regional extension groups or national crop groups (yet to be established).
- Breeding companies could screen their varieties (including varieties that were not developed for the Dutch market) for these characteristics.
- Varieties that look promising (on paper) could be tested in organic growing conditions.
- Varieties with the best performance in organic growing conditions could receive a special recommendation on the varieties list (e.g. a green mark, or be included in a special, new category). Alternatively, a green varieties list or green-plus list could be drawn up.
- Organic farmers could indicate how existing varieties could be improved for use in organic farming. Regional extension groups or national crop groups (that would first have to be established) could act as intermediaries.

Communication and awareness

- National crop groups should be established to provide a framework for communication between farmers, trade and industry and breeders.
- Communication within the chain could be improved through lectures, courses for organic farmers, trade and industry, breeders and consumers, and the publication of a newsletter on organic breeding.

Legislation

- The recommendations laid down in section 3.1.5 (table 4) could be adopted in an EU regulation on approved techniques for organic breeding after they are worked out in more detail. This is the responsibility of the working party for legislation for organic agriculture of the Ministry of Agriculture, Nature Management and Fisheries.
- The recommendations in section 3.2 for the certification of the organic breeding process will be further developed in conjunction with the organic sector and the breeding sector.
- The details of a monitoring system for the certification system mentioned above must be worked out by Skal/NAK.

Conclusion: key role for crop groups

Good communication between partners in the breeding chain is essential to many of the activities described above. National crop groups could play a key role as intermediaries between organic farmers and breeding organisations and commercial companies. These groups, consisting of organic farmers and representatives from trade, should be set up as soon as possible, so that all partners in the breeding chain have optimal access to each other's knowledge and experience. In addition, farmers could participate in variety trials through their position in national variety groups.

Stichting Zaadgoed, founded in 1998, acts as a knowledge and coordination centre for organic breeding. National crop groups could be coordinated by this organisation (see appendix 4). National crop groups might also act as a broker between breeding companies, individual breeders and organic farmers who are actively looking for partners in an organic propagation programme.

4.2 Breeding

Existing varieties which are deemed suitable for organic agriculture would not need to be organically bred right away. For other cultivars, however, organic varieties should be developed as soon as possible. The group of varieties which qualify for organic breeding in the short term can be divided into a subgroup of varieties which currently do not possess desirable organic characteristics and varieties which are bred using techniques not allowed in organic breeding.

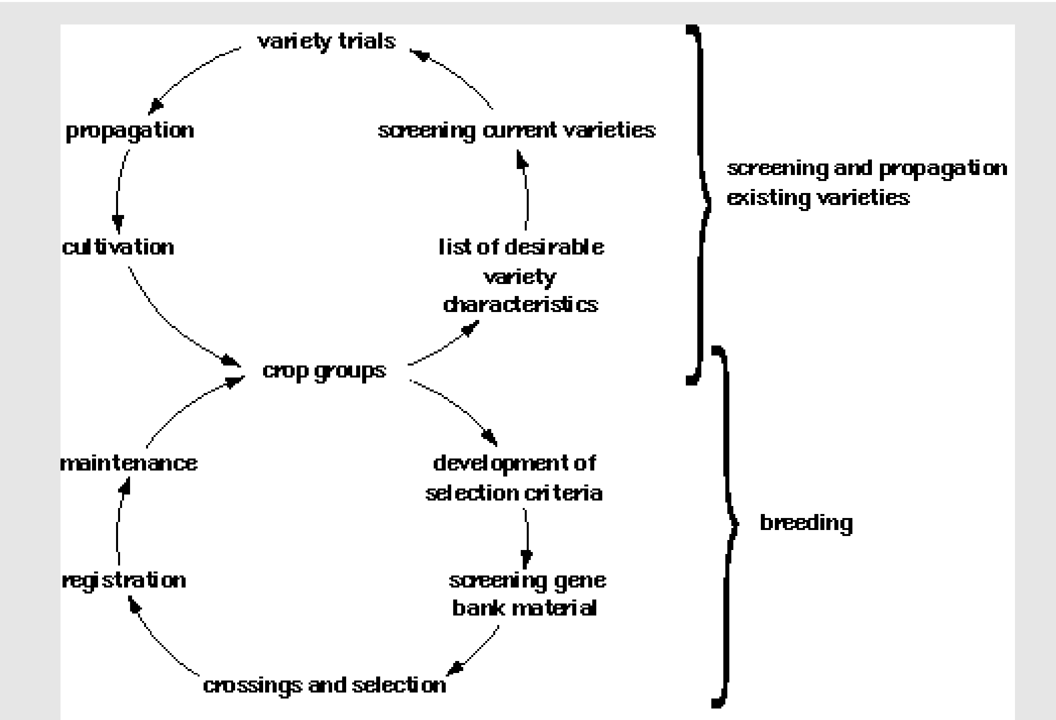


Figure 5. A flow chart of organic breeding and propagation

Genetic sources

- Lists characterising gene bank stock could be extended to include typically organic characteristics, so that finding suitable stock is made easier for organic breeders.
- Gene bank stock could be screened for desirable organic characteristics.
- Organic trials of gene bank stock based on primary organic selection criteria could yield suitable foundation stock.

Stimulating organic breeding programmes

- It is important that breeders follow courses in organic agriculture to acquire an understanding of organic principles.
- It is important that organic farmers follow courses in plant selection to increase their knowledge of and participation in plant breeding.
- Collaborations between breeding companies, individual breeders and organic farmers are crucial and should be encouraged (see crop groups).
- Annual meetings for organic breeders and farmers - at the national and international level - should be organised to share experiences, dovetail activities and facilitate market-oriented and product-oriented work methods. In the Netherlands, Zaadgoed Foundation took the initiative and organised

such a meeting in the spring of 1999.
- Annual public, scientific meetings/conferences - at the national and international level - on organic breeding should be organised to stimulate the exchange of scientific expertise and joint research projects. Stichting Zaadgoed is actively seeking to collaborate with other organisations.

Legislation

- Research is necessary to determine how user value and cultivation value studies may be adapted to incorporate organic performance criteria.
- Studies should be carried out into the possibility of amending registration requirements, since organic varieties are by definition less uniform or less productive than conventional varieties, but compensate this with other valuable qualities.

Funding structures

In this report, we have stated that organic breeding cannot be funded from variety sales alone. There is a much greater variety of organic farming conditions, so that compared to conventional agriculture, more varieties must be bred for a smaller arable area. Studies into user value and cultivation value will be more expensive because more characteristics need to be assessed. The chain approach must be emphasised, because in the end the consumer will have to pay the extra costs of providing the organic sector with special adapted varieties. This costs will be considerable: in the conventional breeding one estimates a need of 10 million Dutch guilders to develop one variety, not taking into account the costs of previous biotechnology research. The time for return of investment of a variety will logically be influenced by the turnover of seeds, thus the acreage. Small acreages automatically lead to a long period to reach return of investment, which makes decisions to invest in new breeding programs more difficult.
In the development of the practical breeding in the Netherlands/Western Europe we see the government withdrawing itself more and more and a concentration on funding of fundamental and strategic research. The times that the Dutch Ministry of Agriculture funded practical breeding of for instance strawberry and apple at the former Wageningen research institute IVT and now CPRO-DLO are already history. Also CPRO-DLO has realised that the costs of for instance their apple breeding program cannot be covered on the basis of licences on achieved plant breeders rights (in spite of the fact that CPRO's variety Elstar has a very good market share). They are keen on searching for a broad collaboration within the whole chain as the only opportunity to keep up their breeding programme. This is a general development in Western Europe. To cover these additional costs, alternative sources of funding will need to be developed. The main problem here is, having rejected the normal commercial set-up of conventional breeding programmes, what structure could be given to a product-oriented organic breeding programme, in particular with respect to the input of knowledge and capital?

Research and contract research

The restrictions in regard to breeding techniques make research for possible alternatives to enlarge genetic variation necessary. Besides research will be needed to work out (operationalised) the plant health concept, which is at the basis of organic breeding. This includes aspects of adaptation to specific organic cultivation measurements and adaptive capacity of a crop. In this regard genetic and fysiological buffering is of great importance. Some aspects thereby are:
- root development and mineral absorption efficiency;
- weed suppressive capacity;
- in situ versus ex situ maintenance;
- resistance breeding in combination with cultivation measures;
- seed-transmitted diseases;
- adaptive capacity;
- alternatives for growth stimulants, silver nitrate and silver thiosulfate in the cultivation of cucumbers and pickles.

A lot of effort has to be done to build bridges between already achieved knowledge (or in development) by research groups in agriculture and breeding, and organic farmers who ask for special requirements for developing crops and varieties.

Research should preferably be carried out by academic institutions (such as Wageningen University and Research Centre) in collaboration with Louis Bolk Institute, Stichting Zaadgoed and private companies.

A platform should be established to make an inventory of problems and priorities and to develop research proposals. Farmers could contribute their ideas to the platform through the crop groups.

Reference

Baars, T., 1998. Modern solutions for mixed systems in organic farming. In: H. van Keulen (ed.), 1998. Mixed farming systems in Europe. AP Minderhoudhoeve-reeks nr 2 (1998). Wageningen Agricultural University

Bauer, D., 1998. Harmonie, internal publication. Dottenfelderhof

Biologica, 1999. Ekomonitor 5, April 1999, Utrecht

De Waart, S., 1998. Voeding Biologisch: goed, beter, best? Biologische en gangbare groenten en fruit vergeleken: een overzicht. Louis Bolk Instituut, Driebergen

Hardon, J. and W. De Boef, 1993. In: De Boef, W., K. Amanor and K. Wellard. Cultivating knowledge: genetic diversity, farmer experimentation and crop research. IT Publications

Heide, W., R. Van der Trip, and W. De Boef, 1996. Local crop development: an annotated bibliography, IPGRI

Heselmans, M., 1998. De plant als machine. NRC Handelsblad 20-1-1998, Rotterdam

Jongerden, J. and G. Ruivenkamp, 1996. Patronen van verscheidenheid, een verkennend onderzoek naar de afname van agro-biodiversiteit in Nederland en naar initiatieven om agro-biodiversiteit binnen en buiten agro-industriële productieketens te bevorderen. Wetenschapswinkel & Werkgroep Technologie en Agrarische Ontwikkeling, Wageningen

Jongerden, J. and G. Ruivenkamp, 1999. Institutionele veranderingen in de veredeling (working title), in progress.

Kockelkoren, P., 1993. Van een plantaardig naar een plantwaardig bestaan; ethische aspecten van biotechnologie bij planten, Ministry of Agriculture, Nature Management and Fisheries

Koelega, D. and N. Renkema, 1998. Biotechnolgie God vergeten? Projectgroep Biotechnologie, ethiek en landbouw. Raad van Kerken, Driebergen

Kunz, P., 1983. Entwicklungsstufen bei Gerste und Weizen - ein Beitrag zu einem Leitbild für die Züchtung. Elemente der Naturwissenschaft 39:23-37

Kunz, P. and C. Karutz, 1991. Pflanzenzüchtung dynamisch. Die Züchtung standortangepasster Weizen- und Dinkelsorten. Erfahrungen, Ideen, Projekte. Forschungslabor am Goetheanum, Dornach

Lammerts van Bueren, E., Hulscher, M., Jongerden, J., Haring, M., Hoogendoorn, J., van Mansvelt, J.D. and G.T.P. Ruivenkamp, 1998. Sustainable organic plant breeding, sub-project 1; discussion paper, Louis Bolk Instituut, Driebergen (also available in Dutch and German)

Luttikholt, L., 1998. Biologische landbouw vrij houden van genetisch gemodificeerde organismen. Ekoland 4, 1998

Meyer-Ploeger, A., 1999. in progress

Müller, K. J., 1998. Erweiternde Kriterien für die Züchtung von Sommerspeisegersten im Organische Landbau, Schriftenreihe Institut für organische Landbau, Verlag Dr. Koster, Berlin

Scheller, E., 1988. Die Stickstoffversorgung der Pflanzen aus dem Stickstoffwechsel des Bodens. Ein Beitrag zu einer Pflanzenernährungslehre des Organischen Landbaus. Verlag J. Margraf Weikersheim

Schmidt, G., 1995. Grundlagen für eine Dynamische Ernährungslehre, Rosa Fischer-Löw Verlag, Dornach

Van der Burgt, G., T. Baars and W. Nauta, 1999. Koppelbedrijven (in progress)

Van der Hoeven, L., 1998. Patenten op levend materiaal bedreigen biodiversiteit. Lineair December 1998: 10-11

Van Roekel, A. 1997. Biologische sector en CPRO-DLO in discussie over veredeling. Ekoland 12, 1997

Appendix 1

Overview of discussion sessions about sustainable organic plant breeding

1998		# partici-pants
15 May	Driebergen, presentation and discussion at the International Circle for biodynamic agriculture	15
28 May	Wageningen, participated in TAO-workshop on diversity-farming and genetic sources	30
23 June	Driebergen, presentation during thematic consultation with the Department of Agriculture of the Ministry of Agriculture, Nature Management and Fisheries	10
24 June	The Hague, presentation and discussion with the parliamentary parties' spokespersons for (organic) agriculture	10
11/12 Sept.	Gent, lecture and workshop at the International Conference 'Green Banks' about biotechnology and organic agriculture.	40
15 Sept.	Wageningen, lecture for the Studium Generale lecture series 'From uniformity to diversity'	60
30 Sept.-4 Oct.	Frick (Switzerland), poster presentation at the FAO-workshop 'Research methodologies in Organic Agriculture'	60
5 Oct.	Wageningen, participated in TAO-workshop on breeding systems for diversity-farming	30
5 Nov.	Driebergen, workshop on organic breeding at the Knowledge Fair for Organic Arable and Vegetable Production	15
9 Nov.	Utrecht, presentation and discussion with the executive committee of the Dutch Federation of Organic Farmers	10
10 Nov.	Groningen, lecture for KLV members about 'gene technology and organic agriculture'	40
21 Nov.	Driebergen, Biodynamic farmers' autumn conference about organic plant breeding	80
27 Nov.	Driebergen, workshop with representatives from the organic production chain and other, conventional stakeholding parties in the fields of research, trade and government.	40
10 Dec.	Dornach (Zwitserland), workshop with German and Swiss organic breeders	20

1999

10 Jan.	Cirencester, (England), workshop during the international conference on Organic agriculture with Prof. Martin Wolfe and Rijk Zwaan-England	60
11 Jan.	Wageningen, participated in TAO-workshop 'Breeders' rights and marketing must go organic'	30
19 Jan.	Lelystad, regional discussion meeting with Flevo-BD-EKO farmers' extension group	20
22 Jan.	Driebergen, meeting with Prof. D. Reheul of the Department of Plant Breeding at Gent University to discuss possibilities for collaboration in organic breeding	4
3-5 Feb.	Dornach (Zwitserland), 3 day workshop with biodynamic farmers at the international conference 'Die Zukunft unserer Kulturplflanzen'	50
13 Feb.	Dronten, lecture at the Biodynamic farmers' winter conference about biodynamic plant and animal breeding: theoretical and practical issues	80
16 Feb.	Marum, lecture and discussion during the extension day on genetic modification, will organic farmers miss out? organised by the northern division of the Dutch Organisation for Agriculture and Horticulture (NLTO)	70
25 Feb.	Grubbevorst, lecture and discussion during mini-symposium on 'Biotechnology: boon or bane for horticulture?' organised by the professional association for horticulture ZON	100
1 Mar.	Vorden, regional discussion meeting with organic farmers from the north-east of the Netherlands	15
3 Mar.	Giessenburg, regional meeting of organic farmers in the province of Zuid-Holland	15
4-6 Mar.	Wageningen, workshop during the First European Congress on Agricultural and Food Ethics	15
8 Mar.	Wageningen, guest lecture for the Plant Breeding Section 'Why does organic agriculture oppose biotechnology?'	40
9 Mar.	Zwolle, lecture at annual meeting of NVZP - potato section	60
18 Mar.	Wolfheze, presentation about breeding systems for organic agriculture for the Plant Production section of the Dept. of Agriculture of the Ministry of Agriculture, Nature Management and Fisheries	20
19 Mar.	Driebergen, MCKS extension day about norms and values regarding gene technology	10
26 Mar.	Lelystad, presentation and discussion for Cebeco-breeders	20
26 Mar.	Wageningen, lecture and discussion for the Plant Breeding extension circle	60

The following articles were published in connection with the discussion report:

Lammerts van Bueren, E. and M. Hulscher, 1998. Visie over biologische plantenveredeling moet op agenda, Ekoland 10:14-15.

Lammerts van Bueren, E., 1999. Züchtung – ökologisch; Die Zukunft der ökologische Pflanzenzüchtung gehört auf die Tagesordnung, Lebendige Erde 1:14-15.

Den Nijs, A.P.M. and E. Lammerts van Bueren, 1999. Towards breeding for organic agriculture: cross pollination required between conventional breeders and organic farmers. Prophyta June 1999-05-03.

Wolfe, M. and E. Lammerts van Bueren, 1999. A question of breeding. Organic Farming 61:16-18.

Appendix 2

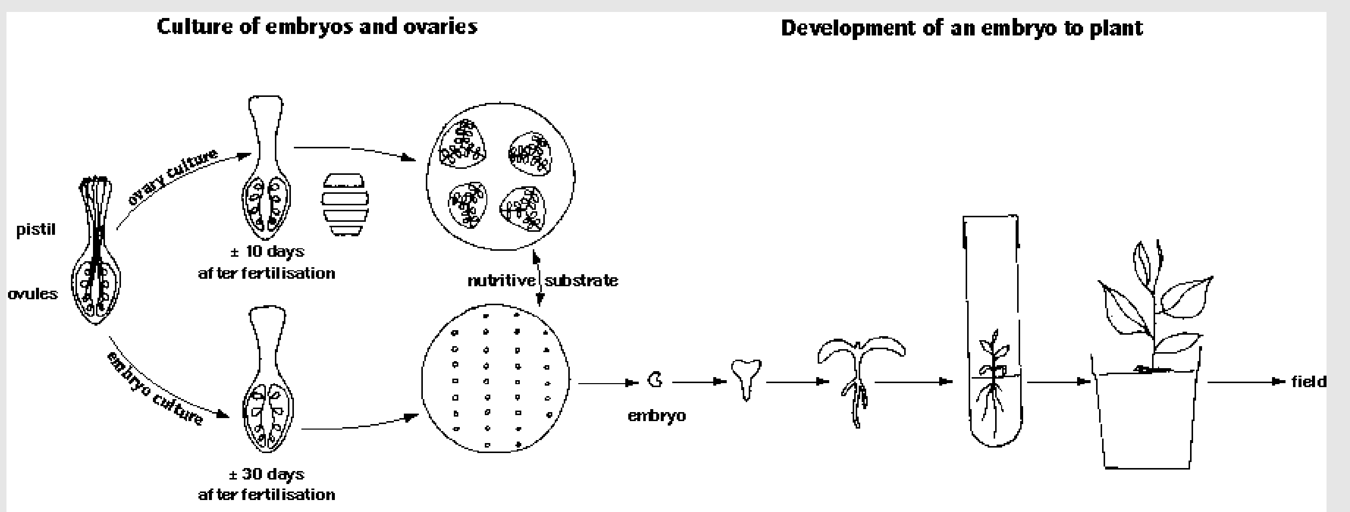
A description of cell techniques and cms hybridisation

The consequences of not allowing these techniques in organic breeding and suggested alternatives

Common cell techniques in conventional breeding are:
a. culture of embryos and ovaries;
b. in vitro pollination and fertilisation;
c. protoplast fusion;
d. culture of anthers and microspores followed by haploid duplication, sometimes supported with colchicine or related substances;
d. micro-propagation (including somatic embryogenesis);
e. meristem culture;
f. in vitro selection.

a. Culture of embryos and ovaries

In embryo culture, the embryos (germs) resulting from pollination and fertilisation on the plant are extracted and grafted on an artificial substrate where they allowed to grow to maturity.



Reproduction occurs naturally, on the plant. The embryos on the plant are theoretically viable but not all embryos would survive, either because the endosperm (tissue in seed which provides food for the embryo) develops poorly or because the mother plant's condition is poor. The artificial substrate gives all the embryos an equal chance to develop and germinate. Embryo culture is used once or twice in the early stages of a variety's development (the first backcross poses a considerable threat to embryo survival). Subsequent backcrossing, selection and propagation are carried out under glass or in the field.

Embryo culture (and ovary culture) is commonly applied in organic breeding, particularly when disease resistance traits from wild relatives or varieties are incorporated. Cultivars often differ so strongly from wild relatives that crosses are difficult. Embryo culture raises the chances of a successful cross. The technique is widely used in the breeding of tomatoes, capsicums, zucchini, lettuce, wheat and other cultivars. In some cases, 80-100% of the varieties of these species are the result of a species cross, and often embryo culture was used in the breeding process to successfully develop the cross. Since its introduction in the 1930s, embryo culture has become so common in conventional breeding that it is hard to imagine a time when the technique was not used. And the use of embryo culture and ovary culture will increase in the future as characteristics from wild relatives such as plant structure, generative development, taste and keeping quality are incorporated. Testing the success of a cross is easy with DNA marker technology to screen progeny for the desired genes (characteristics).

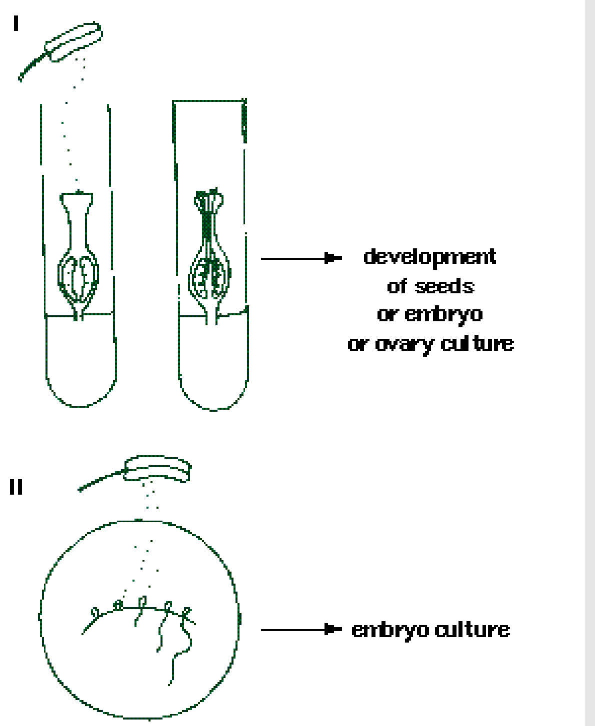
If the culture of embryos and ovaries were to be banned immediately from the organic production chain, numerous varieties would be lost to organic farmers (see appendix 3). That is why we propose establishing a transitional period during which existing varieties are accepted while a serious effort is made to develop alternatives. In the long term, crosses with wild varieties will become increasingly difficult to make as plants will gradually lose their ability to form seed. The wish to use wild plants as cross parents is basically a wish to incorporate certain "isolated" characteristics in a cultivar. Other solutions that take into account the whole plant and its biological growing conditions might prove just as satisfactory.

Another problem related to the decision to phase out embryo culture is the enforceability of such a rule. There is no way of screening the finished product to see whether it is the result of embryo culture. Such information can only be found in breeders' records, provided they are complete.

b. In vitro pollination and fertilisation

In vitro pollination and fertilisation are carried out in controlled conditions in a laboratory. Ovaries are isolated from the plant, with or without part of the style and stigma and placed on a substrate. Ovaries are then fertilised by pollen applied to the stigma or the substrate; the pollen germinates naturally and grows towards the ovaries. After some days or weeks, the embryos are cultured according to the embryo culture method, above.

In vitro pollination and fertilisation



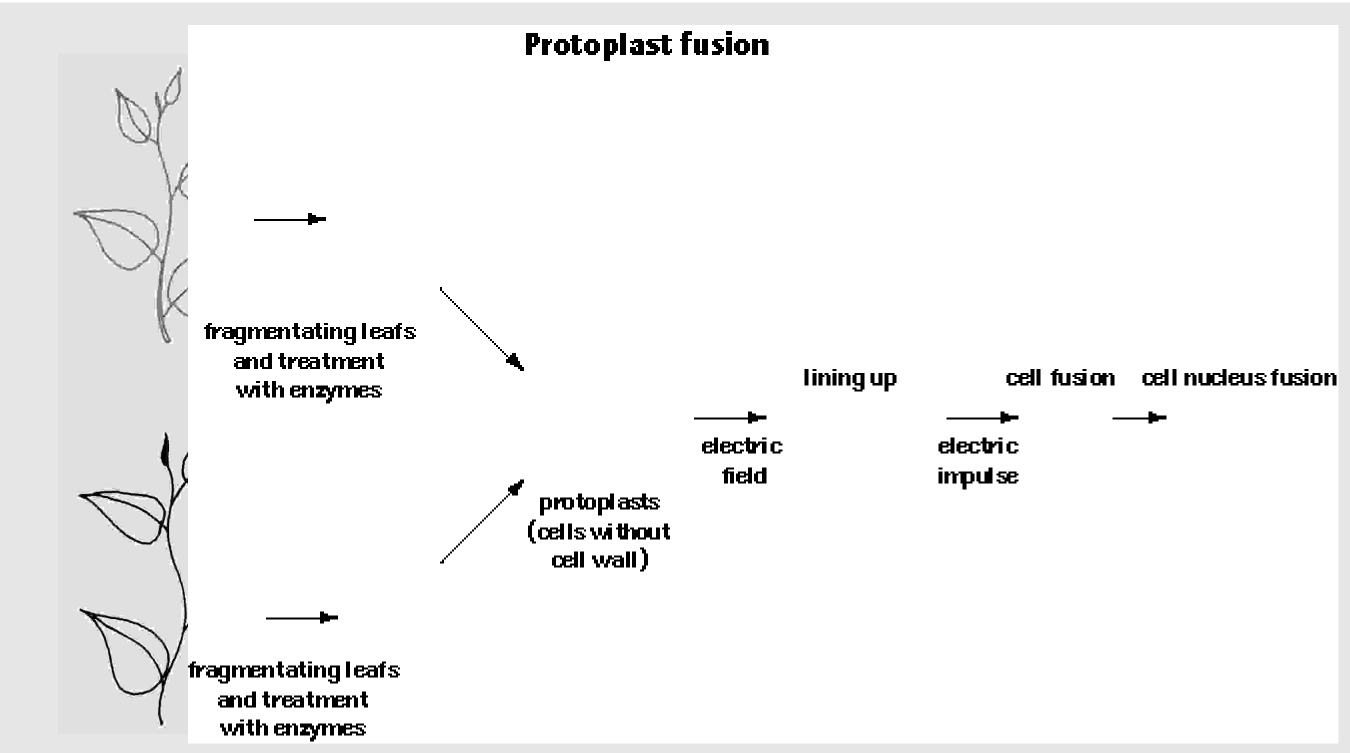
In vitro pollination and fertilisation methods are used in cases where fertilisation on the plant would not succeed, for example when species are crossed which are too far removed for natural reproduction. These methods violate natural species authenticity. The techniques are mostly used in floriculture to obtain new shapes and colours.

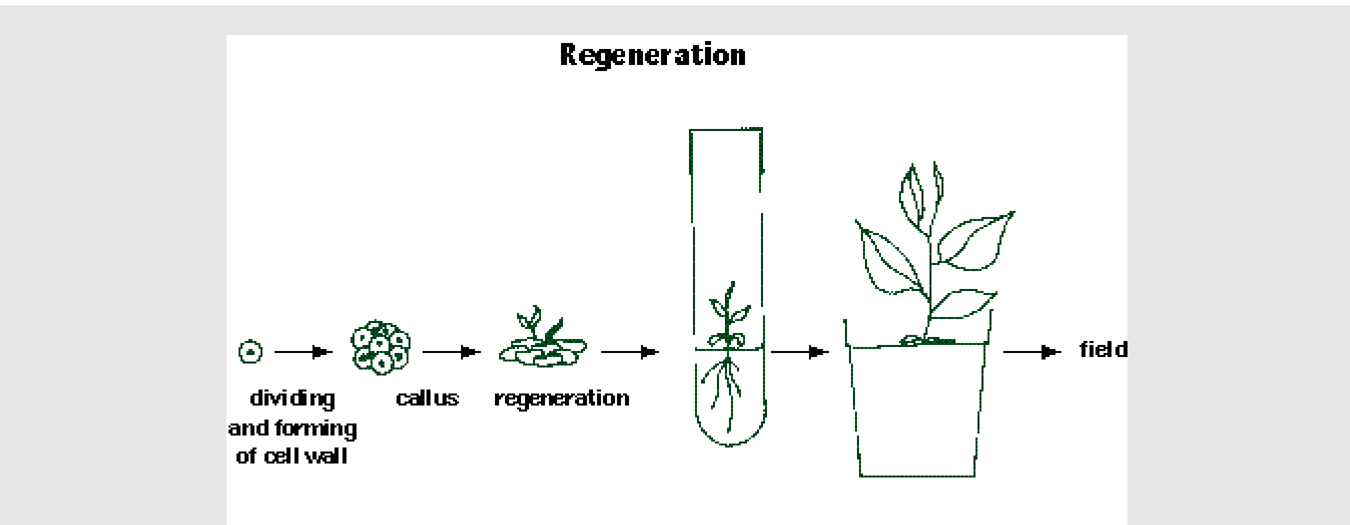
In vitro pollination and fertilisation are not yet so widely used that a ban on the technique would raise major problems for organic producers. It does not look as if the technique will ever be widely used in conventional breeding. The difficulty of enforcing a ban on the use of this technique is that it leaves no trace in the resulting plant.

c. Protoplast fusion (and cms)

Protoplasts are isolated plant cells without a cell membrane. Protoplast can be obtained by incubating pieces of, for example, leaf tissue until the cell membranes dissolve. Chemical or electric stimulants are used to fuse protoplasts from different species, resulting in a tetraploidy which is cultured using tissue culture techniques. The resulting plant has characteristics from both parents, though not all will be expressed. Protoplast fusion is basically hybridisation at the vegetative level.

Protoplast fusion is most commonly used to incorporate cytoplasmic male sterility in hybrid varieties. A well-known example of this is cms which occurs naturally in radish and is incorporated in cabbage. Recently, cms in sunflower has been incorporated in chicory (witlof). These hybrid chicory varieties are not yet available on the market, but that is only a matter of time. Some breeding companies do nothing in their hybrids programme but incorporate cytoplasmic male sterility.





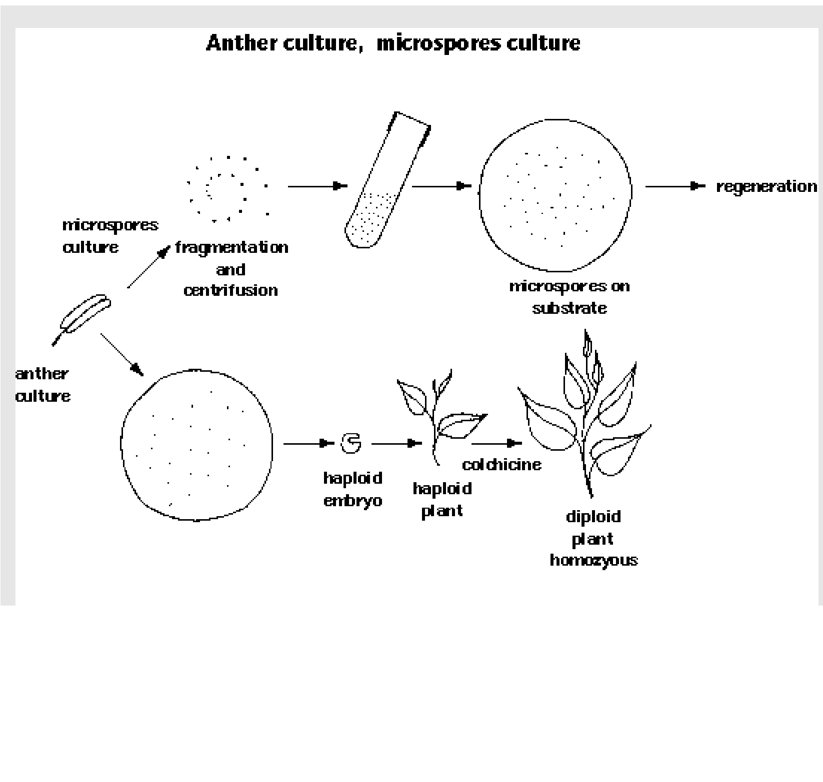
Protoplast fusion can also be used to make combinations of species which are difficult to cross (such as species which do not flower). The technique has been used in potato breeding to develop cultivars which are crossed with wild relatives. As yet, none of the potato varieties on the market have been developed with protoplast fusion, but again, this is only a matter of time.

If the organic agriculture sector makes a stand against protoplast fusion, this “no” automatically extends to the practice of incorporating cytoplasmic male sterility from other species. The short term consequence of such a decision is that organic farmers will have to find alternatives for some hybrids. First, however, an inventory will have to be made of which hybrids are produced with protoplast fusion, as seed catalogues do not state explicitly which techniques have been in the production of a hybrid. Sometimes, these hybrids are referred to as “super-hybrids” and “non-inbred hybrids”. The plants resulting from protoplast fusion are no longer regarded as genetically modified and as such they do not have to be registered with COGEM (the committee for the authorisation of genetically modified organisms of the Ministry of Housing, Spatial Planning and the Environment). This is an additional obstacle to the effective enforcement of a ban on protoplast fusion.

Alternative hybridisation techniques do exist. The self-incompatibility of cabbage which prevents it from fertilising itself could form the basis of an alternative hybrid programme. Organic agriculture will have to collect self-incompatible (hybrid) varieties for breeding. Cytoplasmic male sterility, too, occurs naturally in many cultivars, but restorer genes usually co-exist with natural, species-specific cms so that male fertility is restored in progeny (fertile F1). In tomato breeding, for example, it is profitable to emasculate the stamen because each flower produces a large quantity of expensive seed. In addition to hybrids, organic breeding should also work on developing seed-propagating varieties. For decades, breeding programmes have concentrated on developing hybrids in favour of seed-propagating varieties. That means that there is still considerable scope for improvement, and profit, in varieties of the latter kind.

d. Anther culture, microspores culture and gynogenesis

In the culture of anthers or microspores (young pollen grains), generatively developing young anthers or microspores of an F2 (developing population) are placed on substrate. Vegetative development is induced with hormones, so that new haploid plantlets (with one set of chromosomes from the father) develop in the subsequent process of cell division, regeneration and differentiation. Haploid plants, however, are weak and form no seed. The number of chromosomes must therefore be doubled, which may occur spontaneously in tissue culture or is chemically induced (e.g. using colchicine). The result is a homozygous diploid plant. These are often referred to in practice as DH lines (DH= doubled haploid). Haploid plants can also be obtained by culturing dissected ovaries (gynogenesis).



The culture of anthers and microspores is a fast way of obtaining homozygous plants. These plants can then be used as a cultivar or as parent lines for F1 hybrids. The use of doubled haploids in breeding is expected to increase in the future, especially for common cultivars. Doubled haploids are already being produced in breeding programmes for barley and cabbage. The technique facilitates selection for recessive characteristics because genes are not overshadowed by the dominant allele.

The main reasons that breeders use this technique are that it speeds up the breeding process and eases selection. The technique does not produce new characteristics or combinations. An immediate ban on varieties produced using this technique would narrow the number of barley and cabbage varieties that could be used in organic production. This problem could be avoided by establishing a transitional period in which alternatives for these varieties could first be developed.

Another method of obtaining haploid plants is pollen-induced parthenogenesis (in barley, the cultivar is crossed with the wild relative H. bulbosum, after which H. bulbosum chromosomes are eliminated). Sometimes spontaneous doubling occurs, resulting in diploid homozygous plants. In other cases, the haploid plantlets must be treated with colchicine (e.g. in wheat after parthenogenesis induced by maize pollen). The use of colchicine, however, is not considered suitable in organic plant breeding, so that in these cases parthenogenesis is not an option.

Again, enforcing such a ban is made difficult by the fact that anther or microspore culture and colchicine duplication techniques leave no trace in mature plants.

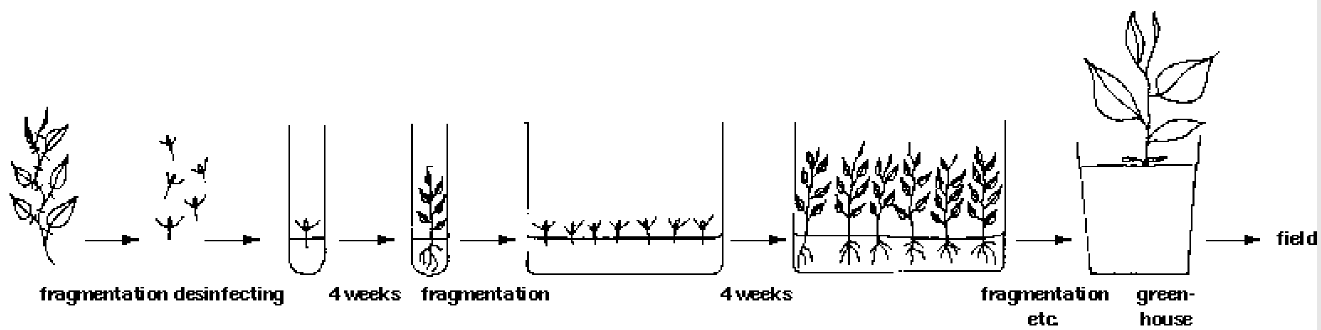
e. In vitro micro-propagation and somatic embryogenesis

Depending on the species, some part of a plant - most commonly, a piece of stem with an axillary bud, or part of a leaf or bulb scale - is cultured in vitro. These sections of plant grow out to shoots, which can in turn be cut and propagated. This may be repeated several times, so that the number of plants - and thus the amount of labour involved - increases with time. When enough plants are made, they are grown until their roots develop, they are then hardened off and transferred to normal glasshouse and/or field conditions. In somatic embryogenesis these sections of plant do not grow out to shoots but to somatic embryos, which look like an embryo but which have root and shoot buds. Somatic embryos are usually propagated in a liquid medium.

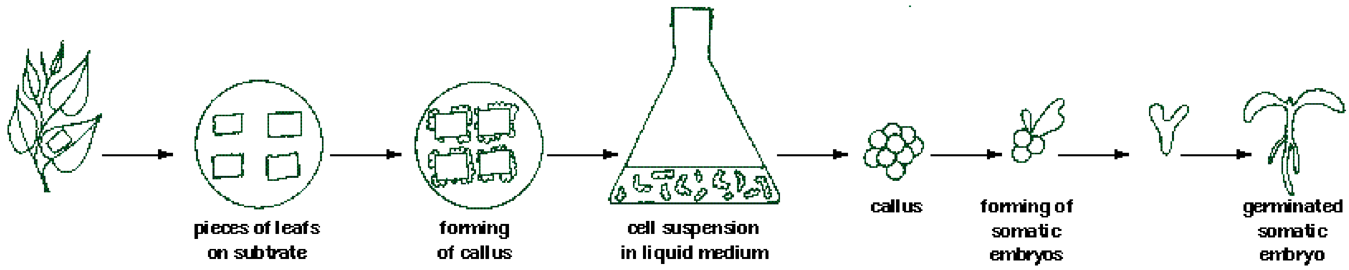
In vitro micro propagation is becoming increasingly popular in breeding, because it is fast and disease-free. Growers can start with "clean" stock. The propagation of many ornamental plants - for example lilies and alstroemeria occurs almost entirely in vitro. In fact, one of the selection criteria used by floricultural breeders is the suitability of a plant for in vitro propagation.

Micro-propagation is a quick way to obtain sufficient quantities of stock to market, particularly in the case of varieties which reproduce vegetatively such as bulbs, tubers, root stock and rhizomes.

In vitro micro-propagation



Somatic embryogenesis



Alternative varieties which have not been propagated in this manner are not readily available; a transitional period is needed before a hard ban can be laid down in organic plant breeding. Plants that have a lengthy juvenile phase, too, are increasingly propagated with this method. In vitro propagation is also becoming the preferred technique for maintaining the parent lines of hybrids or cross-pollinators, sometimes because it is more practical (genotype of cross-pollinators would otherwise be lost), and sometimes because the parent lines do not reproduce well in normal glasshouse conditions.

For other cultivars, satisfactory alternative propagation methods do exist, for example, scaling lilies and husking hyacinths, partitioning daffodil bulbs, growing chrysanthemum shoots, cutting potato tubers, layering the shoots of fruit trees and roses.

Tissue culture is not allowed in the production of organic stock: propagation must take place in normal organic growing conditions (i.e. in soil) and this is enforced by Skal. If organic agriculture says "no" to in vitro micro-propagation, the sector will have to accept that, for some cultivars, it will have to wait longer to obtain new varieties compared to conventional farmers. This may have dramatic economic consequences for organic fruit growers in particular.

f. Meristem culture

Meristems are isolated from the plant and placed on a substrate where they grow to new plants. These can be propagated in vitro. After they have formed roots and hardened off, the plants are transferred to glasshouses. The objective of meristem culture is to obtain virus-free varieties. Sometimes this is the only way of obtaining healthy stock, especially in the case of vegetatively propagated varieties such as flower bulbs (lilies, gladiolus) and potatoes.

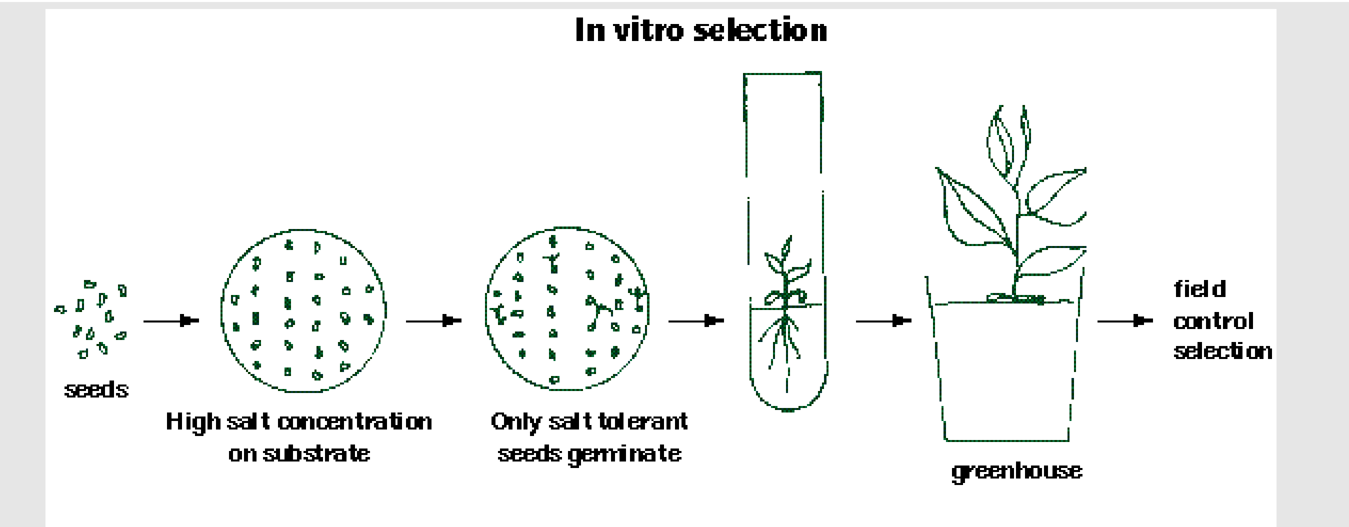
Meristem culture is a way of getting around the problem; the cause of a viral infection is ignored. Virus-free plants obtained through meristem culture must subsequently be cultivated in a virus-free environment (a glasshouse without any infected plants). As infections are bound to occur sooner or later, new virus-free stock must be propagated every few years.

Organic farmers will have great difficulty acquiring and maintaining virus-free stock if meristem cultured plants are banned. An alternative method which could be tried to rid stock of a virus infection is to use only juvenile stock in propagation, such as the innermost scales of a lily bulb or garlic bulb, or the bulblets on the stem of a lily or garlic plant. These methods, however, are less effective than meristem culture, nor are they suitable for every plant. A ban on meristem culture would drastically reduce the durability of some varieties.

g. In vitro selection

Plants, tissue or isolated cells can be cultured on substrate. If a breeder wants to select plants for tolerance to a certain substance, that substance (for example, salt) is added to the substrate. The breeder then simply waits to see which plants or cells continue to grow well. The plants that pass this test can then be propagated in vitro. When they have grown roots and are hardened off, they are ready to be moved to the glasshouse or open field, where subsequent selection takes place.

In vitro selection is used to screen large numbers of plants or cells for a certain characteristic, for example, salt tolerance. It is actually a preliminary selection, which cuts the number of plants that will need to be evaluated in the field. During the in vitro period, however, the plant is isolated from its normal growing environment. It is possible that plants which have considerable merit for organic farming could be eliminated in this preliminary selection. And plants which do pass this stage still have to prove their worth in organic conditions. According to the vision of organic agriculture, the interaction between a plant and its environment is just as important as its genetic characteristics.



In vitro selection leaves no evidence in the plant. A ban on varieties which have been selected in vitro at some stage in the breeding process would mean that organic farmers would have to stop using some conventional varieties. However, at this time we cannot say varieties exactly. A ban on in vitro selection in organic breeding is not expected to be a major setback.

Appendix 3

A brief review of the state of conventional breeding per cultivar

Below, we give a brief review of the state of conventional breeding per cultivar and state which problems might arise if cell techniques are banned in the organic production chain.

Summary

Organic agriculture could face problems in the short-term with respect to the following cultivars:

Tomatoes	nearly all varieties dependent on embryo culture
Lettuce	some varieties produced with embryo culture, some without; difficult to distinguish
Capsicums	nearly all varieties dependent on embryo culture
Cucumber	multiple applications of silver nitrate and gibberelin
Pickles	multiple applications of silver nitrate and gibberelin
Wheat	some varieties produced with embryo culture, some without; difficult to distinguish
Potted plants	embryo culture, micro-propagation, in vitro dissemination
Triticale	single application of colchicine
Grass	colchicine used in tetraploid ryegrass
Arboriculture	growth regulators used to prompt shoots to take root
Cut flowers	embryo culture and in vitro propagation common

Conclusion

- *Banning embryo culture techniques will have drastic short-term and long-term consequences, because alternative methods do not currently exist.*
- *Potential problems in the breeding and/or propagation of cucumbers, pickles, triticale and trees warrant a second look. More research should be carried out to find alternatives for silver nitrate, gibberelin and other growth regulators.*
- *The number of cultivars of which all varieties are unsuitable for organic production will grow as cell techniques and genetic modification are becoming more popular in conventional breeding. It is crucial that a start is made now to set up an organic breeding system before suitable foundation stock becomes scarce.*
- *Short-term problems can be avoided by establishing a transitional period during which alternatives can be developed for techniques which are inherently inappropriate for organic production.*

Cultivar	**State of breeding**
Tomatoes	The resistance genes in today's tomato varieties come from wild tomatoes. Often, they have been incorporated in the cultivar using embryo culture. There are almost no varieties which have been developed without embryo culture.
Cucumber	Plenty of varieties are available which have been produced without embryo culture. However, breeders use strictly female lines which are treated with silver nitrate or gibberelin to induce a masculine blossom (for seed production). The Ministry of Agriculture, Nature Management and Fisheries has asked the organic sector to make a decision about the suitability of silver nitrate and gibberelin. Alternative methods to induce a masculine flower do exist, but as yet they are inconsistent and unpredictable. With further research, feasible and reliable alternatives could probably be developed.
Capsicums	Many varieties are the result of species crosses with wild peppers using embryo culture.

Lettuce	Many varieties are the result of bridge crosses with wild varieties (to incorporate, for example, resistance to lice). Embryo culture was commonly used to achieve these crosses. It would be extremely difficult if not impossible to find out which varieties (or derived varieties) result from embryo culture.
Endive	The varieties that are now on the market have not been produced with cell techniques. However, it is only a matter of time before such varieties do become available. Breeders are currently developing cms hybrids in which cms from sunflower is incorporated by protoplast fusion. This type of cms has been patented. The organic sector has ample varieties with which to set up an organic breeding and propagation programme.
Chicory (witlof)	Most varieties have been produced without cell techniques. However, the production of hybrids which incorporate cms plasma from sunflower will take off in the future. There are enough varieties for an organic breeding and propagation programme.
Leeks	Most varieties still produce seed and have been developed without cell techniques. The first hybrids containing a genetic male sterility (gms), that is sterility expressed on the chromosomes, have just become available on the market. In the future, hybrids incorporating cms from onions will also be marketed. This cms is incorporated in leeks by protoplast fusion. Some hybrid parent lines can only be maintained through tissue culture. These hybrids should not be used in organic production, except when propagation with bulbils or offsetting bulbs (after mother plant dies) is still possible. Currently, however, there are plenty of other varieties which can be used in organic farming and breeding.
Cauliflower	Most varieties on the market are hybrid. Many feature cms plasma from radish which is incorporated by (asymmetric) protoplast fusion. There are enough other hybrid varieties based on self-incompatibility, as well as seed-forming varieties. Problems need not arise if the organic sector ensures that suitable varieties are maintained. Self-incompatible hybrids produce more self-fertilising seed than cms hybrids, which is disadvantageous from the grower's point of view. There are enough varieties for an organic breeding and propagation programme.
Broccoli	Seed-forming varieties are rare. See the section on cauliflower, above. Anther culture is commonly used, but enough suitable varieties remain for organic breeding and propagation.
Headed cabbage	See cauliflower, above. Anther culture is commonly used, but enough suitable varieties remain for organic breeding and propagation.
Brussels' sprouts	Nearly all varieties on the market are hybrid. These hybrids are based on self-incompatibility. Another popular method is to create double haploids in anther culture. However, enough suitable varieties remain for organic breeding and propagation.
Carrots	Hybrid varieties incorporate cms from carrots. Cell techniques are not yet applied on a large scale. Enough suitable varieties remain for organic breeding and propagation.
Onions	Existing varieties are not based on cell techniques. Half of all varieties are seed-forming. Hybrids are based on naturally occurring cms in onion. Enough suitable varieties remain for organic breeding and propagation.

Kohlrabi	Cell techniques, especially anther culture, are common in the breeding and propagation of kohlrabi. Most varieties on the market are self-incompatible hybrids. Enough suitable varieties remain for organic breeding and propagation.
Eggplant	Cell techniques are used occasionally on existing varieties. Their application will increase in the future. Currently, however, enough suitable varieties remain for organic breeding and propagation.
Melon	There have been numerous crosses with wild varieties. In some cases these have been achieved with embryo culture. Other cell techniques have been experimentally applied on existing varieties, but their application will become more widespread in the future. Currently, however, enough suitable varieties remain for organic breeding and propagation.
Zucchini	Many species crosses have been made, some with embryo culture. Enough suitable varieties remain for organic breeding and propagation.
Radish	Current varieties do not depend on cell techniques. Naturally occurring cms in radish is used. Enough suitable varieties remain for organic breeding and propagation.
Pickles	Enough varieties are available that have been developed without cell techniques. As with cucumber, however, the use of silver nitrate and gibberelin is a problem here.
Spinach	Varieties now on the market have not been developed with cell techniques and are dicotyledonous. Enough suitable varieties exist for organic breeding and propagation.
Beetroot	Varieties that are now available on the market have not been developed with cell techniques. Three-quarters of the varieties are seed-forming. Hybrids have cms which occurs naturally in beets. Enough suitable varieties exist for organic breeding and propagation.
Beans	Cell techniques have not been used to develop varieties now on the market. All varieties are seed-forming. Enough suitable varieties exist for organic breeding and propagation.
Pumpkin	Current varieties are not based on cell techniques. Enough suitable varieties exist for organic breeding and propagation.
Sugar maize	Current varieties incorporate naturally occurring cms in maize with restorer genes. These varieties are not based on cell techniques. Enough suitable varieties exist for organic breeding and propagation.
Potatoes	Many of today's varieties have resulted from past crosses with wild relatives. These crosses succeeded without embryo culture. Crosses with S. vernei, however, do require colchicine to make plants tetraploid. These lines have mainly been used to breed starch potatoes. Most potato varieties available today have been developed without cell techniques. In the future, however, varieties based on embryo culture, protoplast fusion or anther culture will be marketed. Enough suitable varieties exist for organic breeding and propagation.

Sugar beets — Sugar beets are cross-pollinating and highly heterozygous. Tissue culture is used to maintain specific genotypes. It is uncertain whether all breeding companies resort to this technique. Marketed varieties which require tissue culture should not be used in organic production, nor should new varieties dependent on this technique.

Fodder beets — See sugar beets.

Wheat — In the past, many crosses have been made with wild plants, and in some case embryos have been cultured. This technique is quite common in the breeding of wheat varieties. A lot of research is being carried out into the possibilities of anther culture and microspores culture and a few varieties are already available that are based on these techniques. Another, more common technique to obtain doubled haploids through interspecies hybridisation with maize followed by chromosome elimination and colchicine treatment. In the next ten years, breeders will successfully develop new genetically engineered varieties with improved baking quality. This could be achieved by inserting more of an existing gene in the plant. The effects of this technique on the plant and on yield are as yet unknown. A potential problem regarding the availability of suitable varieties for organic production is that it may be difficult or even impossible to find out which varieties have at some stage been subject to embryo culture.

Barley — Research is being carried out into culturing anthers and microspores. Barley is more receptive to these techniques than wheat, so that they are fairly frequently applied. Colchicine is not usually required to obtain double haploids, as spontaneous doubling occurs quite frequently in vitro. Another method of obtaining double haploids is trigger pollination with H. bulbosum, but this method is less popular. Many resistance genes in wild barley have been incorporated in cultivated varieties. These crosses usually succeed without embryo culture. Enough suitable varieties exist for organic breeding and propagation.

Oats — Varieties currently available result from “normal” crosses.

Rye — Hybrid rye varieties have cms with restorer genes which occur naturally in rye. Enough suitable varieties exist for organic breeding and propagation.

Triticale — This cultivar is the result of a cross between wheat and rye. The crosses have generally been obtained without embryo culture, though colchicine is used to double the number of haploids.

Fodder maize — A naturally occurring cms in maize is used. This cultivar is a favourite with genetic modifiers. However, enough suitable varieties still exist for organic breeding and propagation.

Grass — In the 1950s and 1960s tetraploidy was induced in many ryegrass varieties using colchicine. Tetraploid varieties now on the market are either new or progeny of these early tetraploids. However, there are still enough diploid varieties on the market. The use of colchicine is much more sporadic in other grass species. Organic producers would only suffer under the proposed changes if they primarily use tetraploid ryegrass.

Bulbs	Micro-propagation is extremely popular in bulb propagation. In fact, this is the sole technique used to propagate lilies. Currently, the technique is not used commercially for tulips, which are propagated either in the field or in the cask. The disadvantage of vegetative propagation is that many diseases are passed on to progeny. Meristem culture is often used to create disease-free lines. Species crosses using embryo culture are quite common, especially in lily breeding. However, enough suitable varieties exist that are not the result of cell techniques.
Cut flowers	Some cultivars have varieties based on tissue culture or mutation induction. These techniques are widely used in the breeding of chrysanthemums, roses and alstroemeria. It is thought that 60% of chrysanthemums are the result of mutation induction. The technique is not quite as common in rose breeding. Nearly all new varieties of alstroemeria are developed with embryo culture. Many ornamental cultivars are propagated using tissue culture methods. However, enough varieties of cut flower cultivars exist that are suitable for organic breeding and production.
Potted plants	Cell techniques have become inherent to conventional breeding programmes for potted plants. The most common techniques are embryo culture, in vitro dissemination and micro-propagation. Problems are to be expected for numerous cultivars (gerbera, orchids, cyclamen, begonia).
Border plants	Enough suitable varieties are available.
Fruit trees	Most fruit varieties are old and resulted from spontaneous mutations and crosses. The apple and pear varieties currently available on the market were developed without cell techniques. New root stock is propagated using tissue culture methods to obtain large numbers in a short period of time. DNA markers are used in selection. Transgenic varieties are being developed and will be marketed in the future. Currently, there are still enough varieties for use in organic production.
Strawberries	Today's varieties were developed without cell techniques. Strawberries are not receptive to in vitro micro-propagation and the technique is not allowed (except for the variety Rapella). In France, some stock is propagated in vitro, but that is then propagated in the field a number of times before being sold to growers. Transgenic varieties are being developed and will be marketed in the future. Currently, there are still enough varieties for use in organic production.
Other fleshy fruit	Current varieties have been developed without cell techniques. Meristem culture is sometimes used in raspberry breeding to rid existing varieties of disease. Transgenic varieties are being developed and will be marketed in the future. Currently, there are still enough varieties for use in organic production.
Mushrooms	Until now, cell techniques and transformation techniques have not been used. However, research is being carried out into the potential of transforming mushrooms and oyster mushrooms. DNA markers are used in selection. Currently, there are still enough varieties for use in organic production.

Arboriculture

Cell techniques, particularly embryo culture and in vitro selection, are becoming more common in breeding woody species. New varieties are often developed using one or more of these techniques. Micro-propagation is used on a small scale. New root stock is often propagated in vitro to obtain large numbers in a short period of time. The traditional method of striking cuttings now also includes a hormone treatment (with growth regulators such as auxine) to stimulate root formation. The use of these regulators poses a problem to the organic sector.

Appendix 4

The objectives of Stichting Zaadgoed

The objectives of Stichting Zaadgoed, a foundation established for the promotion of organic plant breeding, as laid down in April 1998 are:

Objectives

- To promote the sustainable use of cultivars.
- To promote agro-biodiversity.
- To promote and develop breeding methods and techniques especially for organic agriculture (hereafter to be referred to as ‘organic breeding methods’).

Justification

- The foundation’s involvement is crucial to the further development of organic breeding as conventional plant breeding organisations are not strongly focused on the three objectives, above.
- The foundation primarily acts in the interests of the organic sector on the basis of organic principles; the foundation’s objectives are based on convictions in that sector.

Tasks

- To develop policy proposals, strategies and a vision for breeding in the organic production chain and to assess breeding methods for their suitability for organic breeding.
- To stimulate, initiate, coordinate and commission actual breeding activities by professional organic breeders for professional organic production. Breeding efforts shall initially focus on growing conditions in the Netherlands, which does not necessarily diminish the value of such varieties for other countries.
- To develop, initiate and maintain national and international contacts with, for example, organic agriculture organisations and agricultural ministries.
- To obtain sufficient funds each year to finance the professional stimulation and coordination of activities for organic plant breeding in the Netherlands.
- To promote organic breeding through publications, lectures and extension days for breeders, farmers, consumers, retailers, wholesalers and scientists.

The Executive Committee of Stichting Zaadgoed are:

Edith Lammerts van Bueren (Louis Bolk Institute)	chair
Saskia Kneulman (Louis Bolk Institute)	secretary
Oscar van den Boezem (Organisation for Organic Producers and Processors)	treasurer
Coen ter Berg (organic farming consultant)	member at large
Prof. Jos van Damme (Utrecht University and NIOO/Heteren)	member at large
Louise Luttikholt (Platform Biologica)	member at large

ZAADgoed

Stichting Zaadgoed
c/o Louis Bolk Institute
Hoofdstraat 24
3972 LA Driebergen
the Netherlands

phone: 0343 - 517814
fax: 0343 - 515611
e-mail: zaadgoed@louisbolk.nl