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Genetic variation in an organic variety concept

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Abstract

Organic farmers currently depend on modern cereal varieties bred for high-input agriculture. In modern commercial varieties of self-fertilising species genetic variation is outruled resulting in highly phenotypically and genotypially homogeneous, high-yielding varieties, broadly adapted but potentially vulnerable to fungal diseases. As organic farming systems refrain from high input and any chemical inputs they need to stimulate the self-regulatory ability of the farm ecosystem through functional diversity at farm, field, crop and variety levels.

Organic farmers have fewer tools at their disposal to influence the environment to fit the crops. A relevant question is how breeding can contribute to adapting crops and varieties to the organic, lower-input environment by improving the buffering capacity of the farming system, and thereby yield stability. Functional genetic variation in varieties of self-fertilising species, such as is found in variety mixtures, multiline varieties and line mixture varieties, have been proven to stabilise yield and is an important tool for sustainable use of resistances. The concept of (isophenic) line mixture varieties suits modern organic agriculture the best. In that case the farmer can profit from both high phenotypic uniformity and large genetic heterogeneity, in mixtures in which field tolerance to several diseases is included. The phenotypic uniformity can overcome the disadvantages some traders and processors ascribe to mixed products. Another problem that is less easy to overcome, but should be addressed, is the legal restriction for achieving breeders' rights on genotype mixtures as one (composed) variety. The genetic basis for an organic breeding programme should be broadened and newly established, e.g., by creating composite cross populations followed by selection under organic farming conditions. This can provide a basis for selection of adapted lines leading to line mixture varieties. Because the environment in organic farming systems differs fundamentally from that in conventional farming, selection should be conducted under organic farming conditions. As the formal breeding sector cannot easily start breeding programmes for low-yielding crops such as cereals for the limited areas of organic agriculture, alternative options are discussed. The farmers' breeding approach, such as still exists in the Dutch potato breeding sector, can offer an opportunity to combine the knowledge and expertise of organic farmers and that of specialised breeders. A public-private approach at European level can enlarge the availability of better-adapted varieties for organic agriculture.

Keywords: genetic diversity, variety mixtures, isogenic multilines, isophenic varieties, cereals, participatory breeding, organic variety concept

Introduction

Organic farmers have fewer tools at their disposal to influence the environment to fit the crops, and hence a relevant question is how breeding can contribute to adapt crops and varieties to the organic environment by improving the buffering capacity of the farming system, and thereby yield stability for many crops. This question is urgent as most European countries have a policy to scale up organic agriculture. Further improvement and optimisation of the organic farming system are required to realise that.
Until now, organic farmers have been greatly dependent on varieties bred for conventional farming systems. These varieties are adapted to high-input farming systems but also comply with the very strict rules set by institutions responsible for variety testing in terms of phenotypic and genetic uniformity.
More genetic variation within a crop grown in one field, however, may be a tool for increasing yield stability through plasticity (the capacity to respond to environmental variation by an individual genotype) and through population buffering (adaptation using genetic variation among individuals of a population). To optimise the use of this tool proper insight into the role of genetic variation and of biodiversity in the functioning of the agro-ecosystem is needed. At the same time new, more flexible variety concepts are required.

Biodiversity plays a key-role in managing agro-ecosystems, especially in organic farming (Almekinders et al., 1995). According to the principles of organic agriculture and the EU regulations 2092/91 (Anonymous, 1991; IFOAM, 2002) no chemical inputs are allowed. Therefore, an organic farmer needs to enhance the self-regulatory performance of his farm ecosystem to increase physical, chemical and biological soil fertility and to manage weeds, diseases and pests, through several cultural practices, including organic manure input, greenmanuring, rotation, multiple and mixed cropping, and choice for adapted varieties. The two main fundamental differences between conventional and organic farming systems are: organic farming refrains (1) from chemical pest and disease protectants and (2) from (high) inputs of quickly releasing inorganic fertilisers, and therefore cannot overrule variation in farm environment by external factors as much as conventional farming systems can. Although the yield levels are on average 20-30% lower than in conventional systems, one cannot categorise the north-western European organic farming systems as low-input systems like many systems in developing countries. We rather describe organic systems as lower-input systems with not only lower yield levels but also a lower yield stability (Raupp, 1996; Lammerts van Bueren et al., 2002; Mäder et al., 2002). Therefore, one can state that within north-western Europe the set of environments of organic farming systems differ fundamentally from those of the conventional farming systems. And because of the absence of high levels of nitrogen within the set of organic 'environments' farmers will encounter more variation in soil conditions and a(biotic) factors than in conventional farming (Almekinders et al., 1995).

In Lammerts van Bueren et al. (2002c), the contribution of functional species diversity at farm and crop level to stability and the self-regulatory capacity of the organic farming system was discussed, desired variety characteristics were described and crop ideotypes were conceptualised. The desired traits included adaptation to organic soil fertility management based on low(er) and organic inputs; better root system and ability to interact with beneficial soil microorganisms; weed suppressiveness; soil, crop and seed health; high product quality; high yield level and high yield stability. From Lammerts van Bueren et al. (2002c) one can conclude that the two aspects of current varieties in north-western Europe that most influence yield stability are: inadequate adaptation to low(er) and slow-releasing organic fertilisers, and insufficient disease (field) resistance of varieties, see Chapter 3.

In the above-described context a relevant question for this chapter is in what way an altered variety concept with larger genetic variation within varieties can contribute to stabilising the yields in organic farming systems. To evaluate the role of such larger genetic variation we will review perspectives of enlarging within-field genetic diversity within one crop species. Simmonds & Smartt (1999) also stressed the role of more unrelated, genetic diversity in broadening the basis of a breeding programme. The current new varieties are mostly derived from a limited number of parental lines and are thus genetically related to each other. This aspect of broadening the basis of a breeding programme is even more important when we want to search for adaptation to organic farming. Because of the small markets for organic products we will immediately be confronted with the fact that the private breeders of the formal sector can/will not invest in breeding for organic farming of cereals. Therefore, a participatory approach is suggested in order to come to a public-private initiative that will give rise to varieties which are more adapted to organic farming. In this chapter we will limit the perspectives to some self-fertilising crops.

The potential of genetic variation within a variety

One strategy for gaining progress in yield stability in organic farming systems can be to profit from past experience in using genetic variation for disease control as an agronomic tool such as in line or variety mixtures of self-fertilisers, like wheat, barley and rice.

The idea of genotype mixtures re-emerged in breeding research in the middle of the 20th century to 'restore' (functional) genetic variation in varieties after some hazards had occurred with regular breakdown of the power of resistance genes in cereals, as in the Netherlands in the late

1970s (Jensen, 1952; Suneson, 1960; Groenewegen, 1978; Wolfe, 1985). These authors pointed out that modern breeding, supporting specialisation and genetic monocultures in modern agricultural systems, had over-extended the application of the pure-line theory, which started with the selection of the highest yielding genotypes out of the landraces[9]. This outruling of genetic variation in modern commercial varieties grown in temperate regions resulted in highly homogeneous, high-yielding varieties, also broadly adapted and thus grown over large areas, with increased vulnerability to fungal diseases, like rusts. This resulted in the foundation of the Committee on Genetic Vulnerability in 1972, which concluded that the genetic diversity of USA crops was too narrow for safety (Simmonds & Smartt, 1999). At that time Parlevliet & Zadoks (1977) investigated the potential of partial resistance in crops such as barley, which appeared to be based on polygenes, which were functional in different developmental stages of the plant. This approach is followed nowadays in many developing countries but is not increasing variation within varieties. Another approach was the application of variety mixtures, mainly of barley and wheat, like in the UK and USA. The use of mixtures was soon discouraged by processors demanding to keep the process of mixing qualities of the flour in their own hands. A well-known example of successful, large-scale use of variety mixtures from that period is that of barley mixtures in the former Democratic Republic of Germany (DDR) where 300,000 ha were cropped to mixtures reducing fungicide use by 80% at a time when chemical input had to be limited due to lack of finances (Aufhammer & Stützel, 1984; Wolfe, 1992). Recently, Zhu et al. (2000) showed that variety mixtures of rice (*Oryza sativa*) could provide disease control at a relatively large spatial scale (3,342 ha) to an extent of 94% reduction of blast (*Magnaporthe grisae*) so that fungicidal sprays were no longer applied by the end of a two year programme. The desirable glutinous, but disease susceptible and low-yielding rice varieties planted in mixtures with resistant, higher yielding, but non-glutinous hybrid varieties yielded 89% more than the crops consisting of one variety.

Nowadays a renewed interest in mixtures seems to have emerged and more variety mixtures are applied than is usually assumed in barley, wheat, rice, coffee, rape, soybean, potato, and beans (Finckh et al., 2000a). In the following sections we will describe the different types of mixtures and will discuss the concepts, results, obstacles and perspectives of this strategy for organic farming systems.

[9] **Landraces are domestication products of an evolutionary process of interaction over time between biotic and abiotic environments, and farmers' handling and selection of wild and weedy relatives, hybridisation with other cultivars, mutations and natural and human selection pressure (Harlan, 1992).**

Different types of genotype mixtures

The different options to mix genotypes include: variety mixtures, (isogenic) multiline varieties and (isophenic) line mixture varieties (see Box 2 for definitions). They are described in detail below.

Box 2. Different within-species genotype mixtures in self-fertilisers

Variety mixtures
Variety mixtures consist of 2-5 different lines within a single crop species. The components are pure lines – (usually) not bred for suitability as a component of a mixture – and registered as separate varieties, mixed by the seed producer or the farmer, and matched for a restricted number of traits like maturity and quality. Variety mixtures are genetically heterogeneous and phenotypically not uniform.

Multiline varieties (isogenic varieties)
Multilines are composites of (up to 10) lines that are isogenic for almost all agronomic traits, but only genetically dissimilar in resistance against one particular disease, based on a number of identified race-specific resistance genes.

Line mixture varieties (isophenic varieties)
Line mixture varieties are composed of (many) lines which are carefully selected for mixing ability on the basis of phenotypic uniformity for a number of traits but which are genetically different. The line mixture variety is composed to create variation for control of several diseases and high yield stability. The composition can also be based on positive yield interaction.

Variety mixtures
Variety mixtures consist of 2-5 different varieties within a single crop species, registered as separate (pure line) varieties, mixed by the seed producer or the farmer, matched for a restricted number of traits like maturity and quality. Variety mixtures need no specific breeding programme and can be composed yearly by combining existing varieties. Research and experience, however, must show the best combinations. Research results showed that the application of variety mixtures can offer possibilities to control highly specific, biotrophic air-borne diseases, such as rusts and powdery mildews in specific agro-ecosystems, and also soil-borne diseases and abiotic stresses in agricultural crops by providing host diversity effects[10] (Suneson, 1960; Browning &

Frey, 1969; Wolfe, 1985; Finckh & Mundt, 1992; Akanda & Mundt, 1996; Smithson & Lenné, 1996; Finckh et al., 1999; Garrett & Mundt, 1999; Finckh et al., 2000a, b).
Although disease reduction and quality improvements have been recorded in organic trials with variety mixtures, the main problem for the variety mixture approach in optimising the organic farming systems is the absence of sufficient availability of varieties adapted to this type of agriculture to use as components in a mixture.

Multiline varieties (isogenic varieties)
The reduction of fungal diseases in cereal variety mixtures triggered the development of multiline varieties in the 1970s. Multiline varieties are composites of up to 10 lines that are (near-)isogenic for almost all agronomic traits, but only genetically dissimilar for identified (race-specific) resistance genes of one disease (Jensen, 1965; Browning & Frey, 1969). Multiline varieties have therefore characteristics in common with both pure line tolerant and horizontally resistant varieties. The propagation of the lines is separate during the first phase of development, but when the stage of foundation of seed is reached all desired lines are brought together in equal proportions and are propagated together. It is not easy to develop multiline varieties for more than one target disease.
Marshall & Pryor (1978) distinguished the 'dirty crop' and 'clean crop' approach. With the latter all lines are resistant to all prevalent races of the disease to be controlled and in the 'dirty crop' approach each line carries a different single resistance gene, but none of the lines is resistant to all known pathogen races. The lines of a multiline variety have been backcrossed four to eight times with the high yielding basic line and have 90-99% of their genes in common (Groenewegen, 1978). The Dutch multiline winter wheat variety Tumult (containing 5 lines) outyielded its backcross parent by 6% from 1972-1976 and therefore restored the potential yielding ability of the backcross parent in its former sound, productive period (Groenewegen, 1978).
A problem especially for conventional agriculture is the fact that the development of a multiline variety is time-consuming, because of the backcrossing procedure with the high-yielding variety, which carries the risk that other new varieties will outyield the multiline variety in the mean time.

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[10] It is interesting to know that this concept of mixing more and less susceptible genotypes also occurs in wild populations. Wild populations in crop centres of origin and diversity do not always consist of resistant individual genotypes only. Lenné et al. (1994) reported that most studies have shown that, although useful sources of resistance are available in wild populations, albeit at low frequency, susceptible plants are more common than resistant plants. Population defence mechanisms such as escape and avoidance supported by the heterogeneous character of natural plant communities and lack of linkages between competitive ability and resistance/susceptibility are considered responsible for the survival of susceptible plants.

This does not apply to the same extent to organic agriculture because organic farmers do not demand higher yield in the first place, but reliable and higher yield stability. The problem for organic farming is the fact that no adapted organic varieties are available for multiline breeding.

Line mixture varieties (isophenic varieties): an alternative?
To meet the advantages of both multiline varieties (that can only control one target disease but are highly uniform) and variety mixtures (which have a more balanced disease tolerance but lack uniformity) line mixture varieties or 'component varieties' can be a compromise (Groenewegen, 1978). Line mixture varieties are composed of compatible lines carefully selected for phenotypic uniformity for a number of important traits, but are genetically heterogeneous, because of their descendance. Lines for such a mixture can be selected from different crosses or from first or second backcrossings of highly diverse (disease resistant) and/or partly adapted 'donor' parents. The segregating generations must be tested for several diseases and must be kept as broad as possible to enable enough selection possibilities on adaptation, mixing ability and agronomic traits, such as yield. The line mixture composition should also be based on selection for fitness in mixtures and the combining ability.
Ignoring the (current) legal restrictions (see below), for organic agriculture line mixture varieties can be a better option than variety mixtures and multiline varieties being phenotypically highly uniform but genetically heterogeneous.

Advantages of genotype mixtures

The main advantages of genotype mixtures for organic farming systems are their higher ability of disease control, greater resistance against abiotic stresses and their greater yield stability. These advantages are described in detail below.

Disease reduction
Most research on the effects of genotype mixtures is carried out on variety mixtures, but effects and mechanisms behind the different types of genotype mixtures are roughly comparable. Mostly the research results tend towards reduced disease levels compared with the mean disease level of the pure stands, but increased disease over the average is found in some circumstances (Akanda & Mundt, 1996; Finckh & Mundt, 1992). Both phenomena can be due to selection changing the frequencies of the genotypes in the mixtures at harvest compared to the planted frequencies. This can mean either a reduction in overall disease severity due to selection for the more resistant genotype or an increase in overall disease severity when selection is moved towards the more susceptible genotype. According to Finckh et al. (1999), the frequency as well

as density of susceptible plants in barley mixtures are important factors for disease suppression in genetically diverse host populations. This observation is confirmed by Garrett & Mundt (2000a) in trials with wheat variety mixtures. These effects suggest a great complexity of epidemiological and ecological interactions occurring in variety mixtures where disease and plant-plant interactions all affect one another. The underlying mechanisms by which genotype mixtures reduce disease severity usually include the following (Finckh & Mundt, 1992; Calonnec et al., 1996; Smithson & Lenné 1996; Garrett & Mundt, 1999; Finckh et al., 2002a):

- physical blockage of inoculum transmission among plants of different genotypes,
- dilution of compatible inoculum via increasing the distance between plants of the same genotype,
- increased tillering for more competitive and/or resistant cultivar(s) in a mixture,
- inhibitive competition among virulent races,
- possible effects of induced resistance on reducing infection efficiency, and
- lower rates of sporulation or lesion expansion in genotype mixtures.

The efficiency/effectiveness of disease control by mixtures depends on the pathogen and its means of dispersal (Lenné et al., 1994). For instance, diseases for which existing levels of resistance are currently inadequate and with powdery spores, which are wind-dispersed, like rust, have more potential to be controlled through mixtures.
Environmental conditions and management decisions also influence host-diversity effects on disease through their effect on factors such as host density, and duration and intensity of the infection. Darwinkel et al. (1981) noted from their research on winter wheat that rust infection level was limited through retardation of the infection rate specifically in the early stage of the infection period.
For some host species, genotypes with race-specific resistance may not exist, but mixtures of genotypes with different levels of race-non-specific (partial) resistance may contribute to disease control. Both or all genotypes can be infected by the same pathotypes but with different levels of severity. For genotypes with different levels of race-specific resistance (different susceptibility) genotypes may be infected by different races. When the genotypes are not isolines, other aspects of their genetic background are also likely to influence host-diversity effects on disease, such as growth compensation by the more resistant or less susceptible plant genotypes (Heath, 1991; Garrett & Mundt, 1999).

Abiotic stress

One can argue that generally the potential gains from using mixtures are likely to be greater for disease control than for protection against abiotic stress (Wolfe, 1985; Finckh & Wolfe, 1998). From these authors it was concluded that mixtures can survive abiotic stress (drought, frost, etc.) better through compensation or niche differentiation, but cannot reduce the direct effects of abiotic stress other than by avoiding or escaping it. However, Woldeamlak (2001) concluded from his research in mixed cropping of barley and wheat in Eritrea that there is variation among genotypes in drought resistance as a component crop and the use of drought tolerant genotypes could optimise productivity of the mixtures. In the organic experiments with mixtures similar conclusions emerged concerning e.g. the character of weed suppression which might be directly influenced by competition or indirectly influenced because better disease control makes the mixture components more vigorous and competitive (M.S. Wolfe, personal communication, 2002).

Yield stability

Besides beneficial effects in controlling biotic and abiotic stresses, mixtures have been shown to stabilise and in some cases to increase yields but rarely over that of the best single variety (Lenné et al., 1994; Smithson & Lenné, 1996; Finckh et al., 1999). However, this is a post-hoc argument: it is important to stress that, in practice, it is often not possible to predict which single variety will be best in a future season, which adds therefore to the value of reliability in the performance of mixtures. Yielding ability of a variety in a mixture and that in a pure stand are not necessarily correlated. This indicates that the interactions between plant genotypes in mixtures are complex. Mixture components can be differently influenced by their companion cultivars, resulting in a difference in performance among different mixtures. Finckh & Mundt (1992) found that mixtures of wheat varieties yielded between 0 and 5% more than the mean of the pure stands in the absence of the disease, and between 8 and 13% in the presence of disease. They found that only a few wheat mixtures yielded more than the highest yielding pure stand in a given location and year, but that no mixture yielded less than the lowest yielding pure stand. Finckh et al. (1999) also reported yield reductions in certain barley mixtures, due to stronger intragenotypic competition compared to the intergenotypic competition. What Woldeamlak (2001) has shown for wheat and barley crop mixtures also applies to intra-specific mixtures (Smithson & Lenné, 1996): some genotypes are more suitable in mixtures than others and they have to complement each other, not only in resistance against pests, weeds and diseases but also in aspects such as resistance against abiotic stresses, ripening time, morphology, architecture, and growth.

Disadvantages of genotype mixtures

Genotype mixtures also have disadvantages. These are mainly related to the lack of uniformity required by processors and end users and by legal restrictions. These aspects are discussed below.

Processing and marketing demands
Besides the positive results on yield stability, however, there are also constraints from the marketing and processing side demanding uniformity. In theory variety mixtures, but in principle also line mixtures, may be of economic interest when susceptible host genotypes have superior agronomic or processing characteristics that merit protection through deployment in combination with an agronomically inferior, but resistant, genotype. An example of winter wheat in the Netherlands showed, however, that despite several research projects in the Netherlands (Darwinkel et al., 1981) most Dutch conventional farmers abandoned mixtures as soon as disease resistant varieties became available in the 1980s. This is also true for the organic farmers partly due to the relatively poor baking quality of winter wheat mixtures at that time. This was one of the reasons why organic farmers switched from winter wheat to spring wheat varieties (Lammerts van Bueren & Osman, 2002). Now, 20 years later, interest in application of mixtures in organic agriculture has been renewed as

- the number of available, high-yielding and resistant varieties of spring wheat with good baking quality has dropped, and
- certain successful genotype components for combinations are now available.

In a two-year mixture trial with current spring wheat varieties conducted by the Louis Bolk Institute under organic farming conditions, the baking quality of certain variety mixtures was improved without yield reduction (Osman & Schaap, 2002). In both experimental years the yield of three out of the five mixtures was not statistically different from the highest yielding variety in pure stand, and in both years all field-grown mixtures produced better bread than the highest yielding components in pure stands. In both years there were mixtures of which the baking quality was superior to the quality of the individual varieties. With such a result variety mixtures can provide farmers more stability in yield and processing quality, which means a higher price through the premium for better baking quality, but also income stability. The acceptability of cereal genotype mixtures in the market depends on the co-operation of the processors. Malters, millers and bakers are nowadays used to mixing the cereals themselves after the harvest of single varieties. In the example of malting barley in the DDR there was no problem of acceptability by malters (Wolfe, 1992).

Legal restrictions
Worth noting is the legal restriction on selling variety mixtures. In contrast to the regulations in the USA, in many countries in Europe there have been or still are legal restrictions to sell seed mixtures. Even in cases where there has been selection for uniformity such mixtures have been refused on the definition of 'purity' (Finckh et al., 2000a). Due to repeated breakdown of powdery mildew resistance in barley varieties, now in Denmark for instance, cereal variety mixtures can be sold as seed mixtures if they comply with strict minimum criteria, including a.o. agronomic and quality benefits, restricted number of components, and resistance level (Finckh et al., 2000a).
Groenewegen (1978) and Wolfe (1985) stressed the legal difficulties with respect to registering isogenic multiline varieties for breeders' rights as a result of the 'pure-line syndrome', leading to a system in which the protection of the single lines or varieties in mixtures is hardly guaranteed. It took Groenewegen's multiline Tumult many years of disagreements on how to register and propagate, but to date it has not been possible to register a multiline variety as one variety in the European Union. The different components have to be registered as separate pure lines, and can be included as a mixture in the trade register of the NAK (the Dutch seed control agency) as is usual with grass mixtures (H. Bonthuis, personal communication, 2002). According to Wolfe (1985) this is the reason that attention has shifted from multiline varieties to variety mixtures. The same problem may occur with registration and breeders' rights of line mixture varieties as with multiline varieties if line mixture varieties are to be considered as one variety.
To be able to exploit the benefits of functional genetic variation within varieties, reconsideration and adaptation of the regulations for registration which are still based on the pure-line theory is needed. It is beyond the scope of this contribution to further discuss this complex issue.

Selection for adaptation to organic farming: material and target environment

For the three above-described options of genotype mixtures there are hardly any wheat varieties available as components for the mixtures that are adapted[11] to organic farming. To gain adapted components and thus adequate progress the genetic basis for an organic breeding programme should be broadened and newly established. Merely obtaining other germplasm for organic varieties is not the only issue. The hypothesis in this contribution is that such germplasm can be obtained best by conducting the selection process in organic farming environments because the environments of organic agriculture (target environments) differ fundamentally from the formal, conventional selection environment. Both approaches will be discussed below.

Material

An approach to broaden the genetic basis of an organic breeding programme can start by composite crosses[12] with a (large) number of selected crossing parents to be grown as a bulked hybrid population. Those selected crossing parents can consist of modern varieties bred for high yielding ability, but also of varieties produced before 1960 (before the period of high inputs of inorganic fertilisers) that are capable of more efficient nutrient uptake under lower input conditions (Foulkes et al., 1998), and from old landraces[13] for a broader genetic basis as a source for adaptation ability (Hawtin et al., 1996; Heyden & Lammerts van Bueren, 2000). Population samples from the F2 generation can be grown for several generations under organic conditions without conscious selection to give the population the chance to show adequate co-evolution with the environment and to determine after several generations the adaptation to organic farming conditions. This approach can form the basis for further selection of genotypes/lines (Müller, 1989; Finckh et al., 2000a; Welsh, 2002). These lines in development or pure lines can be crossed again as parent for a next cycle in order to enlarge the number of alleles and recombine the alleles that are important for adaptation to organic farming systems. During the activity

- adapted lines can be selected as potential new varieties,
- and lines which are sufficiently isophenic can also be combined into line mixture varieties.

These line mixture varieties do have the same advantages as variety mixtures. However, the greatest advantage of this approach is that they are adapted to organic farming and that research on best combinations cannot only increase yield but also yield stability.

Target environment

Most crucial for adaptation is not only creating the presence of a diversity of (field) resistance against several air-borne diseases, but also or more importantly to adapt to the lower-input, organic soil and nutrient management system, resulting in higher yield stability under more variable conditions.

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11 Ceccarelli (1996) defined adaptation in an agronomic context as follows: A genotype or breeding line, or cultivar will be considered adapted to a given type of condition (climate, agronomic, soil) when it is able to give an economic production, and not necessarily only survives in that set of conditions. This recognises that there could also be adaptation without economic productivity, but not economic productivity without adaptation.

12 In barley, the composite cross populations have been shown to be a powerful instrument: innumerable elite varieties released in the 20th century have their origin in composite cross populations produced in California in the 1920s (Harlan & Martini, 1929). It is one of the approaches that is called evolutionary plant breeding (Allard & Adams, 1969).

13 Hawtin et al. (1996) pointed out that plant breeding in the formal sector depends on four main sources of diversity: wild relatives, mutation, landraces and modern cultivars. Of these four it is argued that the variability in landraces is the most under-exploited.

Ceccarelli et al. (2001) discussed the fundamental problem in plant breeding of the relationship between the selection environment and the target environment. If economics is not the main issue plant breeders agree that direct selection in the target environment is always most efficient (Falconer, 1952). The efficiency of breeding programmes also depends on how large the genotype x environment (G x E) interactions are that can change the ranking of breeding lines. Ceccarelli et al. (2001) pointed out that it is important to distinguish between those interactions that change the ranking of varieties in the same location (or type of environment) over time, and those which change the ranking between different locations. In the first case heterogeneous varieties are required to stabilise yields by minimising G x E interactions, and in the latter case the G x E interaction should be exploited by selecting directly in the target environment and achieving adapted varieties. Simmonds & Smartt (1999) defined this last approach as decentralised selection. Ceccarelli et al. (2000) pointed out that decentralised selection is most effective when it is conducted in a participatory manner taking the farmers' knowledge of crops and environments into account.

Participatory approach

There is increasing experience in participatory plant breeding methods in the developing countries but for many years there has also existed a participatory system in the Dutch potato breeding sector. Van der Zaag (1999) has described the history of this system in the Netherlands. The idea behind both systems and the possible implications for organic breeding programmes will be discussed in this section.

A decentralised approach

A participatory approach should be considered also for organic breeding programmes because a major constraint for the formal breeding sector (including the commercial seed companies) is to start any special breeding programme at all for organic farming. The market of organic products is still limited[14] and special organic breeding programmes are economically not feasible (Ruivenkamp & Jongerden, 1999; Lammerts van Bueren & Osman, 2002). Therefore, a participatory approach will be discussed in order to arrive at a public-private initiative which will aim at obtaining varieties which are more adapted to organic farming. The reason for proposing the involvement of organic farmers is not merely because of lower costs (see Box 3), but also

[14] In the Netherlands the total proportion of the area of organic agriculture in the total agricultural land use was 1.9 % in July 2002 (Anonymous, 2002). Several governments of European countries aim in their policy for 10% organic agriculture of the total agricultural area in 2010 (a.o. LNV, 2000). The average of the area of organic agriculture among the EU countries in 2001 was 2.8% (SÖL, 2002).

because, certainly at this stage of the development of organic plant breeding, knowledge of organic farming and the needs of organic farmers is very limited in the formal breeding sector. An approach in which organic farmers closely participate, will benefit from both parties involved. This problem of the gap between knowledge of the formal breeding sector and requirements of local farmers was also recognised in developing countries and has lead to many forms of participatory plant breeding and selection methods (Ceccarelli, 1996; Almekinders & Elings, 2001; Ceccarelli et al., 2001). We have noticed in various contacts with breeders from the formal sector in Europe that such a strategy of participatory, decentralised breeding is not broadly accepted but at least thinkable for developing countries but certainly not for modern, industrialised agriculture. In modern agriculture, plant breeding has become a specialisation away from farmers' 'normal' activities. Nevertheless, there is still an accepted participatory approach in the Dutch conventional potato-breeding sector, which we will first describe below. The question is whether this approach can be transferred to other crops in organic agriculture to enlarge the availability of better-adapted varieties for organic agriculture. We believe that such a public-private approach at the European level can enlarge the availability of better-adapted varieties for organic agriculture.

The model of farmer breeders in Dutch potato breeding

In the history of the Dutch potato breeding sector farmers as farmer breeders (in Dutch: 'hobby-kwekers') have had a very important role in developing a diversity of new varieties in co-operation with the commercial breeding companies (Van der Zaag, 1999). Until 1937, the number of potato breeders in the Netherlands was limited because making crosses in potatoes requires time and specialisation. In 1938, an organisation to stimulate breeding and research for the potato (COA) was founded in which the government, the national seed control organisation, research and potato breeding companies co-operated. One of the aims was to provide farmer breeders with true seeds of potato after having made specific crosses and introduced new resistance genes and other promising characteristics, so that during the following years they could do the selection work with their farmer breeders' eye. This well-organised co-operation between researchers and farmers resulted in the production of many successful new potato varieties, which no other country could surpass. This is a unique co-operation and allocation of tasks between science and practice. The researchers gave access to interesting traits in wild germplasm by conducting complex crossings between the wild relatives and modern varieties to establish crossing parents, and offered the numerous farmer breeders the seedlings for further selection. The farmer breeders with their dedication, long experience and developed farmer's eye could, often better than the formal breeders, select the most promising phenotypes among the seedlings (Van der Zaag, 1999). Because of the many farmer breeders involved large numbers of

Box 3. Dutch co-operative farmer breeders' model in potato breeding for organic agriculture.

Niek Vos, organic arable farmer (52 ha) in Marknesse (The Netherlands) is, besides running his arable farm, also one of the farmer breeders in potato according to the Dutch potato farmer breeders' model in co-operation with the commercial potato breeding company C. Meijer (Kruiningen, The Netherlands). Every year he receives about 2000 first year clones out of 15 crossings. Every year Niek Vos evaluates the results of last year with the breeders and discusses which crossing parents will be used for the new crossings that could fit his aim: a potato variety adapted to organic growing conditions and resistant against potato late blight. He selects the most resistant clones during three generations. Usually no more than 4-16 clones are left over after the screening in the first year. He plants a minimum of 5 potatoes per clone up to 20 in the third year. He records the results and details about growth and infection carefully and exchanges the results with the breeder every year. This gives the breeder more information about the results of a crossing. If the farmer considers a clone promising after three years he delivers it to Meijer and the company will do further tests to see if it can end up in a variety and will find a suitable market for it.

Co-operation with farmer breeders enlarges the chances of finding promising clones, because the farmers, each with their own farmers' eye and speciality, can screen a large number of clones every year. The farmer usually gets the clones for free and is not paid for his selection work. Only when one of the clones ends up as a variety is he paid on a 50%-50% basis per area of seed potato produced of that particular variety.

Vos's experience is that the strong aspect of this farmer breeders' model is that the expertise of both breeders and farmers are utilised and complement each other. He as a farmer can profit from the background knowledge of breeders concerning the selection of crossing parents, their genetic basis, and the types of crossings, and does not have to bother about time-consuming crossings but can still have an influence on the choice of parental germplasm.

seedlings could be screened. The farmer breeders received compensation for their selection work depending on the volume of seed potato sales of the specific variety. In 1963 the breeders' rights were officially regulated, and the potato trade centres could monopolise a variety. At that time the potato seed trade companies no longer wanted to depend purely on farmer breeders and built their own selection facilities. When the government decided to withdraw from providing seedlings and clones, the seed trade companies could take over. It still saved the farmer breeders from complex crossing activities. Next to the co-operation between research and practice, and sharing the dedication to and knowledge of the crop, the success of this breeding system was also due to the close relationship between farmer breeders and the exporters of seed potatoes. The exporter gathers a lot of information on growing conditions and consumer requirements, by travelling around the world, and can provide the farmer breeder with useful information to take into account during the selection process. The number of farmer breeders increased to over 200 in 1960 and is now rapidly decreasing. Although the input of the farmer breeders has relatively decreased compared to the input of the companies' own breeding stations, still the farmer breeder system exists in the Dutch potato sector. Some organic farmers participate in this system, see Box 3.

Discussion and conclusions

Because organic farming management and environments are fundamentally different from conventional ones, organic farmers need specific varieties that are adapted to their low(er) input farming system and can perform higher yield stability than the currently applied, conventional varieties. Therefore, we have discussed two strategies:

a) more (functional) genetic variation within a variety grown in one field has the potential to allow adaptation to environmental variation and disease control, and can contribute to stabilisation of yield levels over seasons and over fields (Simmonds & Smartt, 1999), and
b) the selection process needs to be carried out under organic conditions for sufficient adaptation.

We have described three options for improving genetic diversity within varieties of self-fertilisers, i.e. variety mixtures, multiline varieties, and line mixture varieties. When a special programme for organic agriculture is considered then the option of line mixtures is to be preferred, being genetically heterogeneous and phenotypically highly uniform. Antagonists of genotype mixtures argue from the past success in plant breeding that it should be possible to produce a single genotype that is outstanding in all respects by selecting for those genes that code for stability. Among such approaches Parlevliet (Parlevliet & Zadoks, 1977) has developed the strategy of partial resistance avoiding absolute resistance to increase the durability of resistance by allowing a certain minimum level of disease, such as the 'dirty crop' genotype mixture model. The theory of partial resistance fits well into the organic strategy because organic farmers strive to keep the disease pressure as low as possible through different management strategies and therefore in principle do not need absolute resistance, but are satisfied with field resistance against diseases. However, in the short run, total disease control and yield stability are more assured with line mixtures.
Another approach of proponents of the single genotype strategy is that of applying molecular techniques for gene pyramiding for horizontal disease resistance. Whereas genetic modification is not compatible with organic agriculture (Anonymous, 1991), molecular markers can contribute to

increase the efficiency of selection procedures with special emphasis on traits of complex inheritance, such as yield, yield stability and durable resistance components to pests and diseases (Kraakman et al., 2000). Although the approaches of partial resistance and of marker-assisted breeding can certainly contribute directly to organic agriculture, they can contribute even more when they are incorporated into the concept of line mixture varieties of self-fertilising species. It should not be underestimated how different genotypes due to their purposely selected and indirectly selected, different genetic background can build up a buffering capacity contributing to their 'basic resistance' by reducing the risk of rapid spread of disease through a crop (Heath, 1991).

Line mixture varieties can be considered as a sort of 'improved or modern concept of landraces'. The result can be that line mixture varieties, as in the concept of landraces, are well adapted to the abiotic and biotic environmental variation of organic farming systems. This application of various forms of controlled crop heterogeneity as within-field intraspecific genetic diversification fits into the ecological principles of organic agriculture of managing biodiversity on all different levels of the farm-ecosystem. Such theories are also recognised in integrating disease management to resistance durability (Zadoks, 1979; Jeger et al., 1981; Wolfe, 2000). Mundt et al. (2002) stress that successful cultivars must be integrated in a complex system of overall crop management, also at a regional scale. The strategy described above is feasible for self-fertilising crops such as wheat. But it is also conceivable that it could benefit potato production (cross pollinator of which seedlings are clonally propagated) in organic agriculture where late blight is a great problem. The idea of variety mixtures of potato has not been viewed as promising in the past, but recently research on this issue has been started (Garrett & Mundt, 2000b). The perspectives for potato variety mixtures to reduce late blight infections are now also being studied for organic conditions with promising results (Philips et al., 2002). Many questions on epidemiological and ecological understanding of potato variety mixtures are not yet answered. To overcome the problem of phenotypic heterogeneity the line mixture variety model is certainly worth considering.

Modern conventional varieties are usually widely adapted varieties and have a high turnover rate. A question still to be answered is whether breeding for organic farming can also focus on widely adapted varieties, or should focus on 'specialists', meaning more regionally adapted varieties. Organic farmers might need a larger diversity of varieties than conventional farmers to cope with the larger variation among and within their agro-ecosystems. At this stage of experimenting it can be reasoned that one should start this process in the short run for limited regions and after that one can investigate how such results can be extrapolated to other or larger regions.

Establishing a new pool of genetic resources for organic agriculture is a time-consuming process, but in the long run necessary to gain substantial progress in yield stability. In the short run, mixtures composed of the best available existing varieties can give some improvement, and should be exploited more in organic agriculture.

The constraint, however, of the costs of an organic breeding programme for the limited area of organic agriculture opens the possibility of decentralised participatory breeding as illustrated with the Dutch potato farmer breeders' model. The advantage of such a model for modern European organic farming systems is that it integrates the expertise of both the farmers with their farmer's eye and that of the breeder's eye, and that farmers can handle large numbers of lines. Ceccarelli et al. (2001) had the experience through several comparisons that farmers could not only handle a large number of lines but could often better select for yield than breeders of the formal sector. This is also confirmed by Van der Zaag's (1999) description of the Dutch potato farmer breeders.

Hawtin et al. (1996) stress that participatory plant breeding approaches cannot only bring scientific expertise to elaborate the problems faced by farmer groups that have until now been neglected by the formal breeders, but may also help to ensure the maintenance and co-evolution of the gene reservoir managed by farmers within organic farming systems, and can remain a resource for all crop improvement efforts in future. The intergenotypic interactions in such a population of composite crossings maintaining genetic diversity in populations must not be underestimated (Allard & Adams, 1969).

Genetic variation has proved to be a powerful instrument in reducing the risk of diseases and the risk of breakdown of resistances. It is not only a matter of developing resistant crops or resistant cropping systems that reduce pest populations, but it fits a sustainable, organic agriculture to develop tolerant crops that can be high-yielding despite infection or infestation (Alexander & Bramel-Cox, 1991).

Organic farming is committed to maintaining, promoting and increasing (agro)biodiversity within agricultural systems not only from a philosophical point of view but also from the practical side of maintaining productivity. In breeding especially it will be a challenge to see how far we can move away from the pure-line theory and utilise genetic variation in a functional way. Organic agriculture, therefore, owes to itself the need to apply pressure for basic public research to explore such strategies of 'restoring' and enlarging functional genetic variation as much as possible, even if the legal framework is not yet ready to cope with it.

5

Strategies for organic propagation of seed and planting material

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Abstract

Due to the EU regulations 2092/91 for organic farming, the organic sector needs to close the organic chain by 2004, and thus to develop efficient schemes to produce adequate quantities of organically produced seeds and planting materials. Organic seed (planting material) is seed (planting material) produced by a crop that is planted and raised organically for at least one generation in the case of annual crops, and for two growing seasons in the case of biennial and perennial crops. Problems associated with organic seed production can be categorised into: a) market problems, b) technical problems, and c) problems with quality standards. After an overview of the three problem areas, the roles of the different actors in developing a strategy towards organic production of seeds and planting material, are described. For successful production of organic seed and planting material, intensive communication between and mutual commitment of farmers, traders, breeders and governmental organisations are necessary. Farmers together with traders should be involved in variety testing and designing of crop ideotypes to identify the desired variety traits. Breeders can influence further improvement of organic production not only by organically propagating the best suitable, existing varieties, but also by integrating organic traits in future breeding programmes. Furthermore, a great effort is needed to carry out comprehensive and coherent activities related to the development of empirical knowledge and research-based information on adapting and improving cultural practice for organic seed production, developing resistant varieties for healthy seed production, developing protocols for seed health testing, assessing threshold values, and designing organic seed treatments. Important for the commitment of both seed companies and organic growers are strict EU regulations no longer allowing derogation for the use of conventional seeds after 2003 for those crops with sufficient assortment, quantity and quality of seed or planting material available. The expectation is that by 2004 for most crops there will be sufficient quantities of adequate quality organic seed and planting material. However, ongoing optimisation of organic seed production management will be required to enlarge the cultivar assortment and to control the quality of organic seed and planting material.

Keywords: organic agriculture, organic seed production, threshold values, seed-borne diseases

Introduction

Organic agriculture is in development and at this moment depends on conventionally bred cultivars and conventionally produced seed and planting material. The EU regulations 2092/91 on organic farming state that organic farmers shall use organically produced seed and planting material (Anonymous, 1991). Within this EU regulation a (frequently extended) derogation to use chemically untreated, conventionally produced seed is possible, when organically propagated material is not available. This derogation was most recently and finally extended until the end of 2003. Now that there is a clear increase in the organic sector and several governments of EU countries strive for an increase of organic farming up to 10% (or even more) of the total agricultural area in 2010, several seed companies have started to pick up the organic propagation of varieties (Van Roekel, 2000).
In the EU regulation seed is regarded as organic seed, when it is produced by a crop that is planted and raised organically for at least one generation for annual crops, and for at least two growing seasons for biennial and perennial crops. That means that conventionally produced basic seed, provided they are chemically untreated, can be used to produce organic commercial seed. Organically propagated material has to fulfil the requirements of the EU regulation concerning organic farming and also the conventional regulations on quality aspects of propagated material. The main quality criteria of propagated materials are: genetic quality (varietal trueness; true-to-type), physical quality (varietal purity, absence of seeds of other species and other types of impurities), health quality (absence of diseases and pests) and physiological quality (e.g. germination percentage and vigour).
In this chapter the problems and challenges for arriving at sufficient quantities and quality of organic seeds and to a sufficient diversity of varieties for the organic sector, will be discussed. Problems and challenges associated with organic seed production can be categorised into: a) market aspects, b) technical aspects, and c) aspects relating to quality standards. The three problem areas, their interconnection, and the role of the different actors will be discussed to develop a long-term strategy for organic production of seeds and planting material.

Materials and methods

Data presented are from own research conducted at the Louis Bolk Institute including a survey and variety trials in the period between 1993-2002 (Lammerts van Bueren, 1994; Lammerts van Bueren & Hulscher, 1999; Lammerts van Bueren et al., 2000, 2001a, b, c, 2002a, b, c; Lammerts van Bueren & Van den Broek, 2002; Osman & Lammerts van Bueren, 2002) or derived from experiences of Dutch seed companies, and are completed with data from literature. The fact that the amount of peer reviewed articles and other documentation on organic seed production is very limited shows that we are dealing with a relatively new research area. At the same time the pressure to make rapid progress is enormous. A lot of information is therefore extracted from secondary literature and empirical information.

Market: limited assortment and quantities

The first step for obtaining an adequate assortment of varieties for the organic sector, before starting long-term breeding programmes for new varieties, is to select the best suitable existing (conventional) varieties for organic propagation. There is already a long history, although on a small scale, of organic production of seed and planting material. Until the mid 1990s small (farmer) enterprises in Switzerland, Germany, the Netherlands and the UK organically produced vegetable seeds, mainly for small farmers and hobby gardeners. They were dependent on free (i.e. with expired breeders' rights) and thus somewhat older and open pollinated varieties (Henatsch, 2000; Seyfang & Frech-Emmelmann, 2000). Those varieties are usually acceptable for smaller farms with their own market outlets. In 1994, Dutch organic farmers' co-operatives organised enough propagation of organic seeds and planting material for cereals, dry pea and beans, mustard, and potato for Dutch producers. But at that time none of the commercial, conventional seed companies were organically producing seeds of modern varieties commonly used by the larger, commercial organic farms producing for export or supermarkets demanding highly productive, uniform and thus modern varieties (Leenen, 1990; Lammerts van Bueren, 1994; Cook, 2000; Jongerden et al., 2002).

The number of organically propagated, modern open pollinated and hybrid varieties from the conventional seed companies is still very limited. Several surveys have been made to identify barriers and problems for the seed companies wishing to enter the organic market (Lammerts van Bueren, 1994; Bloksma & Jansonius, 1999; Anonymous, 2000; Cook, 2000; Groot, 2002). From a survey in 1993/94 it became clear that the main obstacle for conventional seed companies producing for the organic sector was an economic one: the area of organic farming per country is limited and therefore areas per crop are relatively small (Lammerts van Bueren, 1994). Next to a limited area per crop there is also an expected limited area per variety because of a stronger genotype x environment interaction in the organic sector than in the conventional sector, possibly requiring a greater diversity of varieties and therefore resulting, in some cases, in a smaller market per variety. The overall conclusion at that time was that there are no major technical barriers for most of the crops: the Dutch vegetable seed companies, interviewed in 1994, were convinced that after some years of experience organic seed production should be

technically feasible, although lower yield levels of seeds were to be excepted. Next to the aspect of limited areas, the second main concern was the uncertainty about yield stability and controlling seed-borne diseases.
The interest from seed companies in investing in organic seed production and entering the market for organic seed has grown recently and this was triggered by two factors. First of all it was important that the EU regulations 2092/91 clearly stated in 1999, that organic agriculture will not allow genetic modification, and therefore demands varieties bred without genetic modification. Secondly most European governments decided to strive for (at least) 10% organic area of the total agricultural area (LNV, 2000).

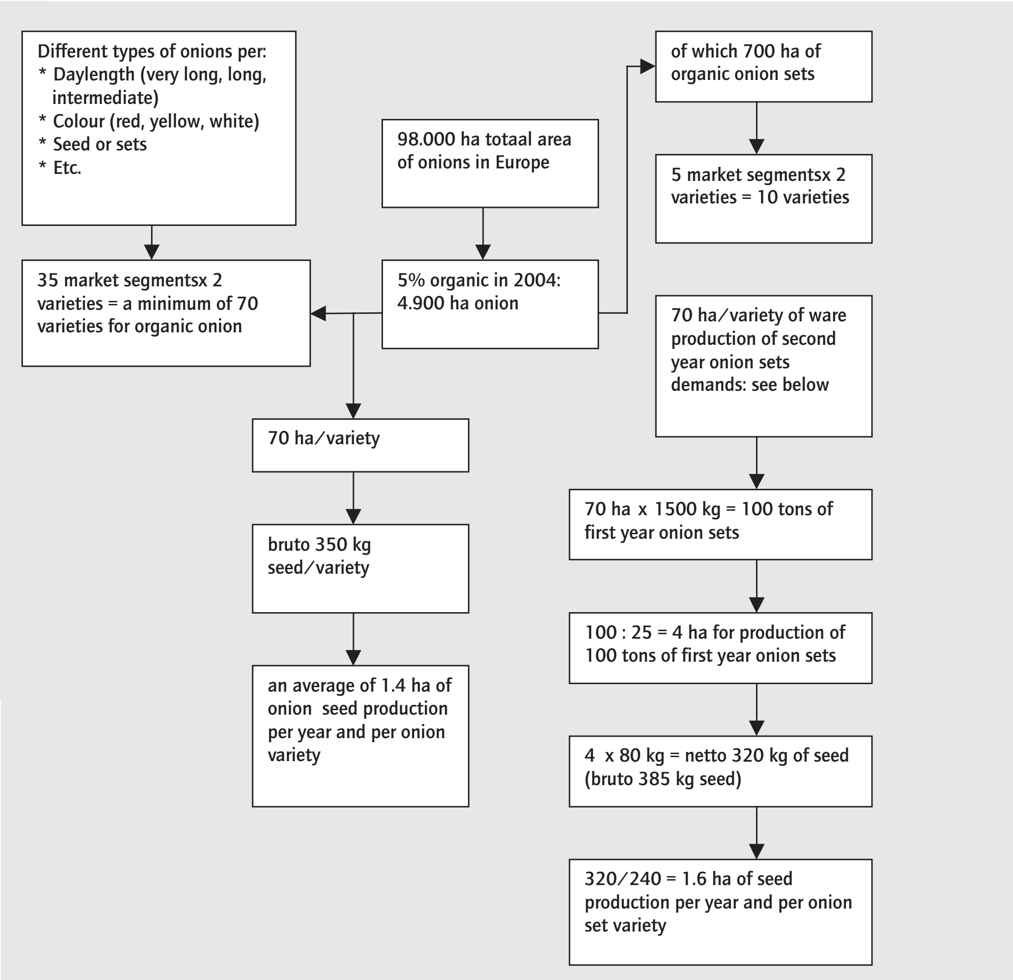
Yet this potentially larger area does not mean that the economic barriers are taken away. Cook (2000) mentioned that in the light of the expected higher seed costs some seed companies have expressed their concern that their efforts in this limited market might be frustrated by organic farmers saving their own seeds in order to keep the production costs low. Cook argues that seed saving is a more important issue for agricultural and annual crops, like cereals, than for horticultural and biennial crops, and that seed saving also takes place in the conventional sector, thus should not be viewed by the seed companies as an argument against taking part in organic seed production. Most organic farmers realise that producing good quality seeds is a skill in itself, and they rather rely on professional seed producers. But some farmers regard it as a challenge to integrate seed production of one or more crops in their farm organisation to close the cycle as part of a quality control strategy in organic farming (Sattler, 1989; Spiess, 1990, 1996).

For most crops seed companies focus on the international market, which usually demands different varieties adapted to agro-ecological and cultural differences. That implies that providing the relative small organic market with a sufficient diversity of varieties is economically and technically challenging. An example for onion is given in Box 4.
With the limited areas of organic agriculture and therefore the relatively higher cost compared to conventional seed production, the organic assortment of varieties per crop will be limited.
It is not easy to get an overview of the bottlenecks, such as shortage of seed of certain crops, which will arise by January 2004. Several seed companies are developing a sufficient assortment of varieties for 2004, but because of the higher price, will only start to sell these varieties by the end of 2003, when the derogation ends for such crops (Bloksma & Jansonius, 1999; Brakeboer, 1999). Table 5 shows the number of organic varieties per crop already available for the Dutch market in 2001 and 2002.

Box 4. An estimation of the area required for organic seed production of onion in Europe in 2004.

Onion is a crop sensitive to daylength. Europe has three different types of daylengths during the growing season: very long day, long day, and intermediate daylength. Moreover, cultural differences in preference for skin colour (red, yellow or white) exist, and different types have different dominant propagules (either seed or onion set) and therefore require different varieties. Finally there are also types that ripen in different seasons. If these factors are combined there are roughly 35 market segments for onion planting material. Not all types are important for all regions (e.g., white onions are not marketed in the Netherlands). Assuming that it is required to have at least two distinct varieties per segment that cannot be grown for other market segments, 70 onion varieties will be needed in Europe. Some varieties are more commonly used than others; seed companies know from experience that 80% of the total onion area is cropped to 20% of the variety assortment. In Europe 98,000 ha are cropped to onions. If in 2004 5% is grown organically, the organic onion area will be 4,900 ha. This means approximately 70 ha per variety with an average of 280 kg seed per variety, and 1 ha of seed production per year per variety, see box figure. In this figure the estimation is also specified for onion sets.

To attune further development of an adequate assortment for different groups of farmers and markets, communication is very important between seed companies and farmers, including variety trials under organic conditions to screen existing varieties on their suitability for organic farming. A general list of desirable variety characteristics to suit the organic farming system where no artificial fertilisers and chemical inputs are applied, has already been discussed by Lammerts van Bueren et al. (2002c), see Chapter 3. These authors indicated that varieties should give a reliable and stable yield and quality, be able to cope with low nitrogen levels from organic manure, have sufficient weed suppressive ability, and adequate disease and pest resistance or tolerance. This general list has to be specified for each crop and market segment. The Louis Bolk Institute has several projects on the way to 2004 to build up a network among seed companies and farmers, to conduct variety trials and attune the assortment of a few model crops: wheat, onion, carrot, cabbage, and beetroot (Lammerts van Bueren & Hulscher, 1999; Osman & Ter Berg, 2000; Osman et al., 2000; Lammerts van Bueren et al., 2001a, 2002b; Lammerts van Bueren & Van den Broek, 2002b; Osman & Van den Brink, 2002). A principal tool for assessing the suitability of varieties for organic farming and attuning the right assortment are the field meetings where



farmers and breeders assess and discuss together the variety trials under organic farm conditions. The conventional breeders who are not (yet) familiar with the organic way of farming get a more complete picture of the demands per crop. This includes more than a set of resistances, and also includes a different plant morphology and crop architecture to get, for example, a better root system, an earlier canopy closure, or a longer peduncle to let the cereal ear ripen further above the moist leaf canopy. In this way more suitable ideotypes for each crop and market sector can be developed as a guide to identify the most adequate varieties among existing varieties for

Table 5. Available number of organically propagated varieties in the Netherlands in 2001 and 2002 (after Lammerts van Bueren et al., 2000; 2001a, 2002a).

Crops	Number of varieties in 2001	Number of varieties in 2002	Numbers of varieties in 2003
Arable crops			
Potato	14	15	14
Cereals	13	14	16
Maize	0	7	6
Sugar beet	1	1	2
Dry bean and pea	9	13	11
Oil-seed crops	0	2	0
Grass	5	14	18
Green manure and fodder crops	4	19	10
Horticultural crops			
Lettuce	138	105*	116
Cabbage	41	40	40
Other leafy vegetables	88	100	101
Onion, garlic, shallots	13	18	18
Root crops	67	72	72
Bean, sweet pea	53	39*	32
Pumpkin/squash	12	24	12
Strawberry	10	10	10
Herbs	62	66	75
Greenhouse crops			
Tomato, cucumber, sweet pepper, etc.	56	96	112

*** The fact that the number of varieties of this category of crops has decreased in 2002 has to do with an adjustment in distinction between varieties for amateur and professional growers by some seed producers. The list of 2001 also contained some varieties for amateur growers; the list of 2002 and 2003 only contains varieties for professional organic farmers.**

propagating organically, and for further development of new varieties (Lammerts van Bueren et al., 2001c; Lammerts van Bueren & Osman, 2002; Osman & Lammerts van Bueren, 2002).

The fact that the number of varieties of this category of crops has decreased in 2002 has to do with an adjustment in distinction between varieties for amateur and professional growers by some seed producers. The list of 2001 also contained some varieties for amateur growers; the list of 2002 and 2003 only contains varieties for professional organic farmers.

The assortment is not only determined by its suitability for organic ware production, but also the ability of a variety to produce healthy seeds under organic conditions without chemical crop protectants. This will in some cases cause a shift in the assortment. Of several well-known varieties currently used by organic farmers for ware production it is difficult to produce seed under organic conditions in good quality or/and economic quantities because they are not vital enough and/or are too susceptible for specific diseases without the protection of fungicides. One of the examples is the carrot hybrid Nerac, which has been one of the main varieties among organic and conventional growers during the last few years, but of which the seed company has decided not to propagate it organically because the seed production is too difficult under organic conditions. Here we meet the technical limits of organic seed production compared to conventional seed production including chemical disease management, which is greater than most seed companies had initially realised. This requires not only suitable varieties but also a sound cultural practice of organic seed production.

Development of a sound cultural practice of organic seed production

As the use of chemical inputs is not permitted in organic farming, it is of great importance that seed and planting material for organic farming is of high quality. Organic seed production therefore makes high demands upon expertise, location and varieties.
For many decades there has been organic seed production of nearly every crop in different countries carried out by small enterprises together with organic farmers (e.g. Henatsch, 2000). But the expertise needed to produce organic seeds on a larger scale by conventional seed companies is still limited. This lack of experience causes initial problems and failures. Next to (regular) basic and technical expert knowledge on seed production additional knowledge and expertise needs to be built up to upscale and optimise organic seed production without the use of chemical protectants and easy-release nitrogen fertilisers. The main problems are: nutrient management, disease and pest management, and weed control. Among the diseases the seed-borne diseases require special attention. These problems mean that climatic factors during seed formation and ripening are even more important in organic farming than in conventional seed production, demanding concentration of the seed production in regions with the most suitable climate conditions and the lowest pressure of pests and diseases (Dornbusch et al., 1993), thus usually outside the areas of origin and destination. However, optimising organic seed production not only requires adapted management practices, but also more attention to variety traits

allowing a healthy organic seed production. Without the use of chemical protectants such traits are more crucial than in conventional seed production and should be included in the organic crop ideotype.
In the following text the state of the art of organic production of seeds and planting material of some important crop(s) (types) will be discussed: cereals, potato, grass/clover, vegetables and fruits. Those are the crops (or crop types) included in several research projects of the Louis Bolk Institute concerning variety trials or improvements of organic production of seeds or planting material. They also represent a wide diversity of seed-borne diseases and of traits related to physiological performance.

Cereal seed
Most experience in organic seed production is collected and documented for cereals. Due to variation in weather and (partly site-specific, partly farmer-specific) cropping conditions, the quality of cereal seed can differ very much from year to year and from seed lot to seed lot. Experience with organic cereal seed production so far has taught that seed lots are most frequently discarded because of contamination with *Tilletia caries.* Other reasons are insufficient seed calibration, low germinability, and presence of the seed-borne pathogens *Fusarium* spp. and *Septoria nodorum* (Rüegger et al., 1998; Hartl et al., 1999; Dornbusch et al., 1992, 1993; Borgen & Kristensen, 2000). In the case of cereal seed, we will focus on the seed-borne diseases.

Special attention is needed for common bunt (causal agent: the fungus *Tilletia caries*) causing serious problems for organic seed producers because of the rapid, easy spread of spores of the fungus. An extra complication is that *Tilletia caries* is not only seed-borne but also soil-borne, and thus a wide rotation is required to suppress the fungus population in the soil (Johnsson, 1990; Borgen, 2000). The problem may occur when untreated seed that is also not tested, is used. The problem is often associated with the use of farm saved seeds frequently multiplied by the farmer himself. In Denmark, approximately 15% of the winter cereal crops is sown with farm saved seeds (Kristensen & Borgen, 2001). This practice can cause problems in two ways: through the use of contaminated seed and through the spread of the disease by harvesting equipment. Common bunt can be controlled by strict hygienic measurements and the use of resistant varieties. Resistant varieties are not always the most suitable varieties concerning other properties desired for organic farming, so both breeding and alternative treatments are necessary (Heyden, 2002).
A second important cereal fungus is *Fusarium* spp. which reduces the size of the grain in the ear. Both reduced seed size and the presence of the seed-borne fungus reduce vigour and emergence rate to a great extent (Hulscher & Lammerts van Bueren, 2001). No resistant varieties are available, which is one of the reasons why organic farmers prefer wheat varieties with a long

stem (1.00-1.10 m). They are less susceptible to ear diseases because the ear ripens further above the humid microclimate of the canopy (Lammerts van Bueren et al., 2001c). Grading (> 2.5 mm) can be a way to limit the adverse effects of *Fusarium* spp. and similar kinds of fungi, like *Septoria nodorum,* on cereal seeds (Prior, 1991). More research is needed to organically optimise the control of *Fusarium* spp. during seed production.

In cases where the disease level is hard to control by cultural practices and resistant varieties are not yet available, development of post-harvest treatments are an important complementary measure. During the past 10 years many studies have been conducted on alternative, post-harvest seed treatments to control common bunt and other cereal fungal diseases in organic farming (Spiess, 1986; Spiess & Dutschke, 1991; Becker & Weltzien, 1993; Winter et al., 1997, 1998; Heyden, 1999; Borgen & Davanlou, 2000; Borgen & Kristensen, 2000; Kristensen and Forsberg, 2000; Schachermayer et al., 2000; Plakolm & Söllinger, 2000; Spiess, 2000). These authors mention several alternatives that are effective (i.e., > 95% control) with limited side-effects on seed germination. Alternatives include several different ways of using warm or hot water treatments, seed dressing with mustard flour or milk powder, acetic acid, etc. The warm or hot water treatments are very labour intensive and therefore relatively expensive in the case of cereals, and are only feasible in exceptional situations.

For some organic farmers farm-saving of cereal seeds is a measure to keep control of the seed quality. They have successfully propagated wheat varieties for more than 20 years or longer, without significant compromises in yield or quality, applying mass selection to avoid excessive heterogeneity or degeneration of the variety (Sattler, 1989; Prior, 1993; Heyden & Lammerts van Bueren, 2000). Producing organic seed on farm requires a professional grower's approach, with additional attention to managing seed-borne disease problems, using appropriate varieties, adequate seed cleaning and storage, and seed analysis to monitor the level of infection (Spiess, 1996; Kristensen & Borgen, 2001; Thomas & Wyartt, 2002).

Seed potato

In organic seed potato production the main problems are caused by soil-borne and air-borne fungi. Nematode and virus problems are rare in organic potato seed production.

As in organic cereal seed production there is already long experience in organic seed potato production by individual organic farmers or organic organisations (a.o. Bioselect in the Netherlands since 1989), and also in the context of organic farmers joining conventional farmers' co-operatives, like Agrico in the late 1980s.

In a three-year survey among 15 Dutch organic farms producing seed potatoes the most important problems appeared to be caused by *Rhizoctonia solani* (soil-borne and seed-borne) and late blight (*Phytophthora infestans)* (seed-borne, air-borne, and in some cases also soil-

borne) (Hospers, 1996a, 1996b). The quality of the seed potatoes can clearly differ among farms of origin with relation to size, number and vitality of *Rhizoctonia sclerotia* on infected tubers, which not only influence the yield but also the quality of the ware production (Karalus, 1999). Many organic farmers prefer to produce their own seed potatoes for reasons of farm hygiene and control of diseases (Hospers, 1996a; Hoekman, 1998). Whether this is a result of natural site-adapted soil-borne antagonists or not, is not yet known. Several harvesting methods (root cutting, green crop harvesting, haulm pulling or stripping) and the use of biological control of Rhizoctonia with a natural antagonist *Verticillium biguttatum* have been investigated under organic conditions (Hospers, 1996a). Although the use of *Verticillium biguttatum* has not yet been admitted officially and the production of this antagonist is expensive, the effect in organic trials with *Verticillium* reducing the vitality or number of sclerotia of Rhizoctonia on the seed tubers is positive (Hospers, 1996a).
Compared to the ware production of potato, late blight is a smaller problem in seed potato production in the Netherlands due to the fact that usually before late blight appears the haulm of a seed potato crop has to be destroyed in order to conform with the official regulations/ advice with respect to aphid flights. In organic agriculture late blight is not expected to be a soil-borne problem because its oospores are inactivated after 4 years (Turkensteen et al., 2000), and organic farming systems in most cases have a 6-7 years of rotation. For the same reason nematodes do not occur as a problem in organic (seed) potato production.
Virus infection is a minor problem in organic agriculture, because of the combination of lower organic nitrogen use (and therefore less lush growth and tougher leaf surface), use of chitted seed potatoes, and virus resistant varieties. In organic potato seed production a lower density of aphids is often experienced, so that some viruses will spread less rapidly through these vectors (Kölsch & Stöppler, 1990; Hospers, 1996a).

Grass and clover seed
Growing seed of perennial ryegrass fits well in an organic farming system with cattle. Access to slurry is essential for the harvest year. Some problems with weeds and diseases need addressing. Attention is paid to enhancement of the seed crop's competitiveness against weeds and enabling mechanical weed control with minor crop damage through a larger row distance, or by intercropping with green manure crops (Boelt et al., 2002; Deleuran & Boelt, 2002).
Due to favourable climatic conditions, long tradition and expertise, Denmark holds a considerable proportion of the production of perennial ryegrass seed (*Lolium perenne* L.), as one of the main constituents of forage mixtures, and white clover (*Trifolium repens* L.) seed production, 40% and 80% respectively of the total EU grass and white clover seed production. The demand for organic grass seed in Denmark (1100 ton in 2000) is fulfilled, but as yet not the

demand for white clover (Boelt et al., 2002). There is also grass seed production by Dutch seed companies (Karsdorp, 1999). Borm (2001) did research on the possibilities for improving the organic grass seed production in the Netherlands by enlarging the row distances (50 cm) for better mechanical weed control while maintaining yield. Adequate nitrogen supply through animal manure needs further research for optimisation. That is why grass-seed companies in the Netherlands and Denmark switched from monoculture to undersow in a cover crop of a cereal. After the harvest of the cereal crop, the grass vegetation can be used for grazing and control of weeds, and after that one can allow the grass to set seed in the second year. Yields and seed purity in Danish seed production are now satisfactory (Lund-Kristensen et al., 2000). Because of lower nitrogen level used in organic grassland some diseases are less important in Dutch organic grassland than in conventional grass seed production, such as black rust (*Puccinia graminis*). But black rust does occur during seed production and reduces the organic seed production so much that one has to look for varieties with more resistance to this fungus, like some of the French varieties (M. Nas, pers. comm., 2002). Because of standard chemical protection in conventional grass seed production breeders have not focussed on such a trait for seed production of Dutch grass varieties until now. Furthermore, the choice for grass varieties in the organic sector largely depends on the ability to grow grass in a mixture with clover, and thus to allow clover to establish and persist in the grassland, and to maximise the use of nitrogen fixed by the clover in the grass (Van Eekeren, 2001).
More problematic is the production of white clover without great yield losses because of *Apion* spp. damage and weeds, differently from year to year and farm to farm (Boelt et al., 2002; Lund-Kristensen et al., 2001). Further research on organic white clover seed production is urgently needed.

Vegetable seed

The diversity of vegetable crops and varieties is enormous. Because there is limited experience with large-scale organic production of vegetable seed, it is not easy to identify the most severe problems. The experience from conventional seed production can give some direction, but problems need not necessarily be the same for the organic seed production system, as is known from comparisons of organic and conventional ware production of crops (a.o. Van Bruggen, 1995). However, a great concern is gaining experience in managing seed-borne diseases in several crops. Table 6 summarises the current experience of several Dutch seed companies with organic vegetable seed production. Seed companies experience most seed-borne diseases as severe as in the conventional system; only some occur being less severely, like *Fusarium* spp. in carrot, and some as even more problematic, such as *Xanthomonas campestris* in carrot, because lack of experience and lack of possible treatments. Research on alternative seed treatments is

Table 6. The importance of seed-borne diseases of several vegetable crops in conventional (Conv) and organic (Org) seed production systems, after a format for conventional seed production by Groot (2002).

Crop	Disease	Level of damage, problem or economic interest etc., in conventional and organic seed production, and the phase in which it occurs					
		Seed production		Germination, emergence		Ware production	
		Conv	Org	Conv	Org	Conv	Org
Brassica spp.	*Xanthomonas campestris*	++	++	± ph,ss	± ph	++	++
	Phoma lingam	± s	±/+	+ ss	+ ph	++	+/++
	Alternaria brassiciola	++ s	++	± s	± ph	+ s	++
Onion	*Botrytis aclada*	++ ss	++	± ss	± ph	++	+/++
	Botrytis spp.	++ s	++	+	± ph	+	±
	Fusarium oxysporum	±	±	±	-	+	-
	Stemphylium spp.	±	±	+ ph	± ph	+ s	±
Carrot	*Alternaria radicina* (tox)	++ s	++	++ s, ph	++ ph	++	++
	Alternaria alternata (tox)	±	±	±	-	+	±
	Alternaria dauci	++ ss	++	+ s, ph	+ ph	++ s	++
	Fusarium spp.	+	±	± s	-	±	-/±
	Xanthomonas campestris	±	++	± ph	± ph	++	+/++
Beans	*Ascochyta* spp./ *Phoma* spp.	+	-/±	+ ss	±/+	++	±
	Pseudomona syringae	++	-	+	-	++	-
	Fusarium solani	±	-/±	++ s	-	±	-
Lettuce	Mosaic virus (LMV)	+	+	-	-	+	+

± = importance is not (yet) known/clear, - = not important, + = important, ++ = very important
s = standard chemical treatment, ss = chemical treatment very essential
ph = physical treatment important (incl. warm or hot water, steam)
tox = possibility of toxic compounds in end product

necessary. Warm water treatment can be effective for some seed-borne diseases and is already used by seed companies, although further optimisation of the method is needed. Several companies develop the application of natural antagonists as alternative treatment (Van Vliet, 1997; Van den Bulk & Bino, 1998).

Extra attention is needed for the organic seed production of biennial crops, such as *Brassica* spp., onion and carrot, with respect to the development of diseases in the first year and a continued increase of the disease pressure in the second year.

Another complicating aspect is that of hybrid production. It is known from conventional experience that seed production of hybrids can be more difficult than that of open pollinated varieties, because of the need to synchronise the flowering of both parental lines in separate rows, and because of less growth vigour of the parental lines in some cases. This can be more complicated under organic conditions where the growth is less easy to control. Also weather conditions can influence the pollination process, the availability of bees or other pollinating insects, and the development of one parent in relation to the other. Some seed companies conclude that it will not be possible to produce F1-hybrid seed of vegetable crops in the UK for instance for climatic reasons (Cook, 2000). As mentioned before, it can mean that in some cases seed of certain varieties cannot be produced organically, even if the production of seed is moved to more suitable climates.

Nursery stock for fruit cultivation
In a survey on the situation for the fruit sector and their necessary nursery stock, it became clear that several aspects make organic propagation complex (Bloksma & Jansonius, 1999). There is limited experience with the organic production of fruit tree nursery stock in the Netherlands and other EU-countries, and the current experience is primarily based on apple. Bloksma & Jansonius (1999) concluded that it is in principle possible to propagate fruit tree nursery stock in the Netherlands for a slightly higher price per tree, based on organically grown root stock and conventionally grown scions. The expectation is that scions will not be available organically for such a small market, because of the sanitary demands for keeping material virus-free. There is more experience and nursery stock available in Germany and Italy, but this does not include varieties common in the Netherlands. In 2001 for the first time a reasonable amount and quality (tree shape) of organic planting material was available from Dutch nurseries, of both common and new, scab-tolerant varieties. There are still a number of gaps in the current knowledge with respect to cultivation techniques, especially relating to the risk of canker (*Nectria galligena*) and to good branching. Where the conventional nursery uses hormones to stimulate the young tree to branch in an early stage, an organic nursery has to realise growth enhancing conditions risking higher canker susceptibility or choose for less lush growth and therefore less canker susceptibility but with an extra growth year before first delivery. Through lack of experience it is not yet clear what the best and most economically feasible nursery strategy is, and how many losses can be expected (Bloksma & Jansonius, 1999; Bloksma et al., 2002).

Seed quality

From the above described examples of propagation of cereals, potato, grasses, clovers, vegetables and fruits it is clear that seed-borne diseases are an important bottleneck in producing optimal seed quality. Good quality of seed and planting material is essential for organic agriculture, because there are fewer possibilities for protecting seeds in the vulnerable germination phase. Good quality of organic seeds starts with providing optimal growing and ripening conditions during seed production, applying all measures to avoid contamination with diseases, including the use of resistant varieties. Even if in due time more technical experience and adjustments have been gained to enable the optimisation of organic seed production, still minimum standards for seed quality should exist to guarantee the buyer a sufficient level of seed quality. Apart from the existing criteria for physical purity, genetic purity, absence of obnoxious weed seeds, and a minimum level of germination, aspects such as in particular, seed treatments against seed-borne pests and diseases, vigour, and seed standards need more attention or adjustments for organic farming.

Seed selection, grading and treatment

Although the organic strategy is primarily focussed on systemic[15] solutions and prevention at the level of pre-harvest cultural practices rather than symptomatic and technical solutions for seed treatment, it is clear also that the organic seed sector needs post-harvest seed treatment options for specific crops to be able to sell enough quantities of seeds free of or with an acceptably low level of seed-borne diseases.

There are several methods to grade and to separate infected seeds from healthy seeds to keep the contamination low in marketed seeds. This can be done by selecting on seed weight or size, as is known for reducing *Fusarium* on cereal seeds. New techniques are in development capable of separating ripe and less ripened seeds on the basis of their chlorophyll fluorescence (CF) with a CF-analyser (Jalink et al., 1998).

Another method is to disinfect the contaminated seed either with physical treatments, like hot or warm water, or steam. Some seed companies already have positive experiences with the use of warm or hot water treatments, but these methods still need to be further elaborated in order not to reduce physiological seed quality.

Next to the disinfecting coatings, like mustard powder for cereal seed, there are developments in growth-promoting seed coatings ('biologicals') using microorganisms, or priming methods to promote rapid and even emergence. More research is needed to determine under which organic farming conditions such costly solutions will provide cost-effective benefits in terms of higher level or rate of germination that may help to overcome problems with crop establishment or

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[15] **Organic agricultural research requires a whole system oriented approach. Alrøe & Kristensen (2002) define such science as a systemic science based on complex, dynamic socio-ecological systems, and involved in the development of its own subject area: agriculture.**

weed competition (Groot, 2002).
The number of alternative seed protection techniques (either antagonists, coatings or physical methods) that are permitted according to the positive list in Annex IIb of the EU regulation 2092/91 for organic agriculture is still very low.

Physiological seed quality
Seed quality implies more than absence of seed-borne diseases that also can be reached by seed treatments. For instance, not properly ripened seeds, possibly due to disease pressure during seed production, are more susceptible to stress during storage and sub-optimal field conditions after planting. Particularly for those crops that risk adverse germination conditions under non-chemically protected, organic conditions, like wheat in early spring, or beans and maize, it might be important to test seed lots on vigour. The vigour of the seed is more than just the germination rate and is defined as the total sum of those properties of the seed which determine the potential level of activity and performance of the seed or seed lot during germination and seedling emergence (ISTA, 1995). High vigour seed lots are more likely to be able to withstand stresses than low vigour seed lots, so that vigour is positively related to the ability of a seed population to establish an optimum plant stand, in both optimum and suboptimum soil environments (Dornbos Jr, 1995; Tekrony & Egli, 1991). Optimal emergence and plant stand is important for the organic management of weeds, but also for avoiding diseases due to suboptimal growth. The best test for vigour is the cold-test which cannot only be used for testing seeds before trading, but is also known as a tool to select vigorous, cold-tolerant inbred lines of maize (Martin et al., 1988).

Seed standards and testing
Seed treatments do not need to be applied in a standard way if seed health tests are used to ascertain the necessity, and accurate information on threshold values is available. Official sanitary regulations for the seed-borne diseases in the seed production system differ per crop. For some arable crops maximum levels of contamination of certain diseases are given. For most horticultural crops no exact levels are given, but ‘good quality’ is required. Untreated seeds of cereals can only be recommended if every seed lot has been tested and the contamination rate by pathogens is below certain threshold values. The official threshold values are not adapted to organic farming conditions, and insufficient for trading of undressed seeds, and urgently need adjusting. This is confirmed by the Dutch seed control organisation NAK, which is concerned about the expected seed health. A clear example is given for cereal seed. In case of conventional cereals NAK has stopped research on Fusarium and Septoria because standard seed treatments have taken care of these problems (Anonymous, 2000; NAK, pers. comm., 2002). According to

the official Dutch regulations for certified cereal seed, seed lots with a Fusarium contamination rate above 25% have to be treated or discarded. Treatment is advised and mentioned on the certification when the seed lot is contaminated with a rate between 10 and 25%, but treatment is not compulsory. This is not an acceptable situation to guarantee good quality organic seed. Thus in some countries action has already been undertaken to revise such threshold values for organic agriculture. Austria has adapted the threshold values for organic cereal seed on the basis of research and years of experience (Hartl et al., 1999). For diseases such as *Septoria nodorum, Fusarium* spp., and *Helminthosporium* spp. the conventional threshold in Austria lies at a total value of 20% contamination; for organic seed production there is a special value for *Fusarium nivale* of 10%, and when this value is surpassed adequate treatment is required. For *S. nodorum* the value is raised from 10 to 20%. Also in seed potato production the threshold has been adapted on the basis of experience. In the Netherlands, the official threshold of 25% contamination of Rhizoctonia on seed potatoes is lowered to a maximum of 10% for a better control of this disease (Hospers, 1996a). More systematic research is needed to adjust the threshold values for marketing good quality organic seed and planting material.

The role of different actors

Seed production for the organic sector is largely new and requires adequate attuning of activities by the different actors in this field to get development moving in the right direction (Lammerts van Bueren et al., 1999, 2001c). The most important actors are organic farmers as users and producers of seed, seed companies as breeders and producers of seeds, traders distributing the end products and communicating with the consumers, and the governments organising the regulations of seed production and marketing. The specific role in the network of the different actors will be distinguished briefly below.

The role of organic farmers includes

- integrating seed crops in their rotation on the basis of contracts with seed companies;
- organising crop study groups and participating in regional variety testing to identify varieties required on the basis of crop ideotypes adapted to optimise the organic farming system and products;
- communicating with traders and breeders about varietal characteristics required;
- considering seed saving only if conditions are fulfilled to produce seed of good quality;
- developing new organisational forms of co-operatives among farmers to diversify the seed production to enlarge the diversity of varieties next to the input of commercial seed companies.

The role of seed companies/breeders includes
- keeping in contact with farmers for better understanding of the possibilities and limitations of organic farming, and to learn how the varieties should look;
- using the crop ideotypes described by farmers to select best suitable existing varieties to propagate organically and to integrate organic traits in breeding programmes for future variety improvements;
- contracting well-established organic farms for propagation.

The role of traders includes
- showing commitment and communicating with farmers and breeders about the (limited) assortment suitable for organic seed production, ware production and trading;
- integrating not only trade (storage, transport and performance) traits but also quality traits, like taste, to better distinguish between conventional and (more expensive) organic products;
- translating higher seed costs into higher farmers' price.

The role of the national and international governments includes
- conducting clear regulation on the use of organic seeds and plant stock;
- developing an adequate certification system for organic seed production and marketing, where the control bodies for organic production co-operate with the (regular) specialised official seed control agencies;
- regulating international trade of organic seed with standardisation of (adapted) threshold values for seed-borne diseases on organic seeds;
- stimulating research programmes to improve the organic seed production system.

The role of international co-operation includes
- communication between the Organic Commission of the European Seed Association (ESA), the International Seed Testing Association (ISTA), and European Consortium for Organic Plant breeding (ECO-PB) to stimulate exchange of knowledge and attuning mutual interests.

Discussion and conclusions

The organic sector is heading for further improvement of organic farming systems by developing organic seed and planting material. It can contribute to a more closed organic production chain and therefore will gain more credibility from the consumer by being less dependent on the conventional agricultural sector and thus on chemical inputs. From a conventional point of view organic seed production without chemical application and with few permitted natural treatments is hardly thinkable, and many problems for an economically sound development of organic propagation are emphasised. Opposing that view the organic sector tends to conceive many problems as merely perceived and not actual, which can be overcome by education, training and discussion. Problems regarding soil fertility, weeds, pest and diseases can be adequately controlled in organic systems, although further work for optimisation has to be done on those issues.

To look at it more precisely, it is clear that merely relying on 'alternative' seed treatment is expensive and does not guarantee high quality of seed. Seeds that are contaminated with fungi risk less vigour and can be disastrous for organic farmers. Because the breeding industry could in many cases rely on chemical protection during seed production not all existing varieties are suitable for organic seed production. In some cases, as discussed with black rust in Dutch grass varieties, there are replacement varieties available, but these are not always optimal for other desired traits. The ability to produce healthy seed without chemical protection is the first aspect that needs reconsideration. This addition to the organic crop ideotype requires more attention in future breeding programmes.

The second aspect which needs attention is improving a sound cultural practice for organic production of seed and planting material and to keep the disease pressure as low as possible. In some cases there are good arguments for using intercropping systems like in grass seed production or to optimise the system by further understanding interactions between for instance natural beneficial organisms in the system and the crop, as discussed with Rhizoctonia on potato and the expected interactions with certain soil antagonists. In some cases the climate is the bottleneck for producing healthy seed on an economic basis and is so crucial for a low disease pressure that moving the seed production to warmer and dryer climates, like in the south of France or Italy, can be the best solution. This is the case for the seed production of onion and carrot, which require a long ripening season. But this is not the solution for all crops. For a bulk crop like cereal, it is important that each European country can produce sufficient quantity and quality of seed. Absolutely Fusarium-resistant varieties are not available and are maybe not even the first option for a sustainable solution for organic agriculture. More benefit is to be expected from an integrated approach of further understanding the epidemiology of the fungus in order to

be able to design adequate cultivation measurements and to be able to look for such morphology (longer peduncle, leaf angle, etc.) that varieties can produce more tolerance to such a disease.
Our conclusion overlooking the state of the art as discussed in this chapter is that organic seed production can be realistic when the following aspects are taken into account as part of an optimising strategy for the organic propagation of seed and planting material:

- Selecting and developing varieties with sufficient tolerance or resistance against diseases during organic seed production is crucial.
- Further practical and research work is needed to improve and adapt cultural practices for sound organic seed and plant stock production.
- Seed producers should identify the best locations with low disease pressure.
- Adjusted threshold values for marketing organic seed should be developed.
- Practical seed health tests and standards should be developed for crops with a high risk of seed-borne diseases.
- Adequate, alternative seed treatments need to be developed, and permitted.
- For successful development of organic seed production good communication and mutual commitment from farmers, traders, breeders and governments are necessary.
- The EU regulation can stimulate the development of organic seed production by allowing only derogation for the use of conventional, untreated seeds of crops where there is not yet a sufficient quantity of seeds and varieties available, and to yearly update the positive list where derogation is no longer needed.

Important for the commitment of both seed companies and organic growers are strict EU-regulations no longer allowing derogation for the use of conventional seeds after 2003 for those crops with sufficient assortment, quantity and quality of seed or planting material. As for future perspectives it is good to realise that the EU regulation 2092/91 now agrees on the condition of organic seed as seeds being produced by a crop that is planted and raised organically for at least one generation concerning annual crops, and at least for two growing seasons for biennial and perennial crops. That means that untreated, conventionally produced basic seed can be used to produce organic market seed. But as the sector keeps on growing and improving its system, further closing of the organic production chain should be discussed by also demanding organic maintenance of varieties suitable for organic farming systems, as a step towards organic plant breeding.

6

The concepts of intrinsic value and integrity of plants in organic plant breeding and propagation

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Abstract

A central characteristic of organic agriculture is its 'naturalness', which includes a non-chemical and agro-ecological approach in farming and appreciation for the 'integrity of living entities'. Integrity is the ethically relevant element of naturalness, determined by a biocentric framework of action. Integrity of cultivated plants refers to the inherent, characteristic nature of plants, their wholeness, completeness, their species-specific characteristics and their being in balance with the organic environment. This concept of the nature of plants can be made operational by deriving principles from the relevant characteristics at four different levels of the nature of plants: integrity of life, planttypic integrity, genotypic integrity and phenotypic integrity. Criteria derived from those principles are used to assess whether existing breeding and propagation techniques respect the integrity of plants. Techniques at whole plant or crop level are in line with the principles of organic farming, respecting the self-reproductive ability and the reproductive barriers. *In-vitro* techniques and techniques at DNA level are not compatible with the integrity of plants, except for the use of DNA markers. In the selection process the so-called 'breeder's eye' can be developed as a more consciously applied instrument to perceive aspects of the wholeness or phenotypic integrity of a plant. By introducing the concept of integrity of plants the organic sector challenges the plant breeders to develop additional and new approaches for organic plant breeding and propagation. This implies further development of scientific concepts and the systematic development of the respectful and 'artful' eye of the individual breeder.

Keywords: intrinsic value, integrity of plants, organic farming, breeding techniques, ethical evaluation

Introduction

Modern varieties of field-grown crops do not satisfy all the requirements and demands of organic agriculture. Therefore, more emphasis is needed on the breeding of cultivars adapted to conditions prevailing in organic farming and complying with the special nature of organic agriculture. Organic agriculture is often characterised as a natural way of farming, mostly referring to the absence of chemical-synthetic inputs, such as chemical fertilisers, herbicides and pesticides (IFOAM, 2002; Anonymous, 1991). To avoid the use of chemical fertilisers and pesticides in organic agriculture, agro-ecological principles are to be applied to enhance the self-regulatory capacity of the agro-ecosystem. An important tool is stimulating functional diversity at different levels of management: farm level, cropping system level, crop species level, and variety level. Organic farmers require varieties adapted to the organic farming system to contribute to the resilience of the agro-ecosystem, both in organic ware production and in seed production. The approach for improvement of varieties for organic farming systems developed from a non-chemical and agro-ecological point of view is discussed in Lammerts van Bueren et al. (2002c, d, e). However, Verhoog et al. (2002b) pointed out that the concept of 'naturalness' as used in the context of organic agriculture, not only refers to the avoidance of inorganic, chemical inputs, and to the application of organic, agro-ecological principles, but also implies the acknowledgement of the 'integrity of life', see Chapter 2. Integrity is the ethically relevant element of naturalness, which is determined by a biocentric framework of action. Verhoog et al. (2002) concluded that only if all three approaches are taken together, can the concept of naturalness be used to distinguish organic agriculture from conventional agriculture. The concept can also be used as a guideline for future developments in organic plant breeding and propagation.

Box 5. Concepts on intrinsic value, integrity, and naturalness in organic agriculture.

Naturalness
Naturalness, as used in the context of organic agriculture, refers to the avoidance of inorganic, chemical inputs, to the application of organic, agro-ecological principles and to the respect for the 'integrity of life'.

Intrinsic value of plants
Intrinsic value of plants indicates that something is ethically relevant, and has a value of its own, independent of the instrumental value for humans. Ethically relevant means that humans take the intrinsic value into account in their decisions for action, out of respect for the intrinsic value. What is assessed as ethically relevant depends on the choice of a basic attitude towards nature and the bio-ethical framework of action, see Box 6. In that context plants also, cultivated or wild, have an intrinsic value based on respect for their integrity and autonomy.

Integrity of plants
The integrity of plants refers to taking into account the characteristic nature or way of being of living entities, their wholeness, completeness, their species-specific characteristics and their being in balance with the species-specific environment. Taking the integrity seriously does not imply that man cannot interfere with the plant object. In organic agriculture respect for the integrity of (cultivated) plants implies that the characteristic nature and wholeness of such plants (see Box 7) are to be taken into account and given weight next to the non-chemical and agro-ecological arguments, when interfering with nature, as is normal in agriculture and is very pronounced in breeding and propagation.

This chapter will concentrate on the meaning of the third element of naturalness, the 'integrity' of plants and will discuss the implications of this concept of integrity for organic propagation and breeding schemes. In the literature the concept of integrity is closely linked to the more embracing concept of intrinsic value. Both are usually only applied to the animal kingdom. We will evaluate how these two concepts are used for animal life forms and then apply and translate them to plant life. This analysis will result in an assessment of the 'naturalness' of the various plant breeding and propagation techniques and thus of their acceptability for use in organic breeding programmes.
The concepts of intrinsic value, integrity and naturalness are briefly summarised in Box 5.

Materials and methods

This chapter is partly the result of an extensive literature research. The main body of information and ideas, however, has been collected during several research and discussion projects conducted in the period 1997-1999 (for details, see: Lammerts van Bueren et al., 1998; 1999) and in 2001 (for details, see: Lammerts van Bueren & Luttikholt, 2001; Lammerts van Bueren et al., 2001d) by order of the Dutch Ministry of Agriculture, Nature Conservation and Fisheries. In those projects all together more than 30 national and international workshops were held with farmers, breeders, seed producers and traders, researchers and policy makers, defining ecological criteria for assessment of the suitability of breeding and propagation techniques for organic plant breeding. The concept of integrity had at that time not yet been developed for plants, and could not be included in these assessments. The results of a project conducted from 1999-2001 to define the concept of naturalness for organic agriculture, including the concept of integrity of life (Verhoog et al., 2002b), formed the basis for further development of the concept of integrity of plants as a criterion to assess breeding and propagation techniques for organic agriculture as will be done in this chapter.

Ecological criteria to assess breeding and propagation techniques for organic agriculture

In the organic sector the discussion about the acceptability of certain breeding techniques started in the 1990s around genetic modification. Genetic modification was not accepted in the standards of the International Federation of Organic Agricultural Movements (IFOAM) in 1993 and in the EC-directive 2092/91 in 1999 (stating that in the organic production method no genetically modified organisms and/or derived parts may be used). Bullard et al. (1994)[16] described the underlying arguments of the IFOAM: they were mainly ecological (e.g., further industrialisation of agriculture, new level of risks, threatening of biodiversity) and a first indication of an ethical argument (no respect for the inherent nature of (cultivated) plants), although not further conceptualised; the implications of genetic engineering are not in compliance with the fundamental principles of organic agriculture. In 1997, the Dutch government asked the Louis Bolk Institute to elaborate the viewpoints on all modern plant breeding techniques and to outline criteria for future development of organic plant breeding (Lammerts van Bueren et al., 1998; 1999). This assignment resulted in a number of position papers leading the discussion not only in the Netherlands but also at the international level. In these papers a concept was developed to draw up a framework for assessing the existing breeding and propagation techniques. The position papers were based on three ecological key-principles, i.e. 1) closed production cycles, 2) natural self-regulation, and 3) agrobiodiversity. These principles are relevant at the farming system level and have been subsequently converted to the level of the plant/crop (a biological system at a lower level of aggregation) and to the socio-economic level (a socio-economic system at a higher level of aggregation), see Table 7.

Table 7. The ecological key-criteria for organic farming systems converted to the plant and socio-economic levels (based on Lammerts van Bueren et al., 1999).

Plant/crop level		Farming system level		Socio-economic level
self-reproductive ability	←	closed production cycles	→	Close interaction between farmers,
ability to adapt to environment	←	natural self-regulation	→	regulations incorporating organic principles
genetic diversity with respect for reproductive barriers	←	agrobiodiversity	→	cultural diversity represented by many different breeding programmes

[16] In Bullard et al. (1994) the arguments are given why the International Federation for Organic Agriculturual Movements (IFOAM) concluded that genetic engineering is not compatible with organic farming and is in conflict with the fundamental principles of organic agriculture. The arguments are mainly based on a non-chemical and agro-ecological approach. But there was also one ethical consideration stating that "[...]genetic engineering inherently reduces the integrity of organisms. [..]", motivated by the statement: "Genetic engineering does not respect the inherent nature of plants since it treats livings things as mere factors of production, to be reconstructed as if they were machines."

This means that from an ecological point of view a more or less closed production cycle at farm level has its equivalent at plant level: the ability to fulfil its own life cycle from seed to seed without artificial environmental (lab)conditions (*in-vitro* techniques). Natural self-regulation at farm level is translated at plant/crop level to the ability of adaptation to and interaction with the environment independent of chemical protection. Functional genetic diversity with respect for reproductive barriers at plant level is the translation of agrobiodiversity at farm level. All these criteria were to ensure a sustainable, ecologically efficient use and development of plants with benefits to a sound, agro-ecological farming system.

As for the conversion of the ecological key-principles from farm level to the socio-economic level, a successful plant breeding programme is not only based on a close plant x environment interaction, but also on a close co-operation between farmers and breeders (participatory approach), optimising the use of the mutual specialist knowledge and experience (Jongerden et al., 2002). In modern plant breeding, regulations play an important role, but current legislation for instance on the authorisation of new varieties is in some cases a bottleneck in the marketing of varieties suitable for organic farming (Lammerts van Bueren et al., 2001c). Further steps and research are needed to adapt the regulations to organic agriculture, like adapting the protocol for Value for Cultivation Use testing of varieties in organic agriculture (Lammerts van Bueren et al., 2001c; Lammerts van Bueren & Osman, 2002) and adapting threshold values for contamination with diseases on marketable seeds (Lammerts van Bueren et al., 2002e).

The third criterion mentioned in Table 7 concerns cultural diversity. Cultural diversity represented by many different breeding programs in different regions is a value on its own, but also a condition for genetic diversity. In that context organic agriculture respects the breeders' exemption in breeders' right, but opposes patents on (parts of) plants/varieties. The so-called breeders' exemption which gives breeders the possibility to use germplasm of other breeders even if protected by a plant variety right, should not be frustrated by a restrictive interpretation of the research exemption as defined in the biotech directive in relation to patented plant material (Kiewiet, 2000). Patents threaten genetic and cultural diversity, and are therefore not in line with a sustainable organic breeding concept from an ecological point of view.

In the report on the evaluation of modern breeding techniques (Lammerts van Bueren et al., 1999) no explicit reference was made to the terms intrinsic value and integrity of plants, as they were at that time politically sensitive and not yet conceptualised for the field of plant production. Lammerts van Bueren & Luttikholt (2001) reported that in the organic sector the same criteria mentioned in Table 7 at plant/crop level were associated with the term integrity of plants, although they were not further elaborated. It underlines the idea that these criteria represent more than just the ecological principles in the organic sector, and that ethical elements also play an important role in the assessment of the acceptability of breeding and propagation techniques among specialised organic breeders and farmers.

Up to now we have given a short overview of the steps already made in the discussions on assessing the acceptability of current breeding and propagation techniques for organic agriculture which took place in the Netherlands and other European countries in the period of 1997-2001. To clearly unravel the ethical and ecological elements in the discussion and thereby make the future discussion and assessment more transparent and communicable, it is necessary to further elaborate the meaning and possible instrumentalisation of the concept of integrity of plants. This is the aim of this chapter. Therefore we will first describe the way this concept of integrity has developed in the field of animal production, and subsequently how we can apply this to the field of plant production.

The concepts of intrinsic value and integrity of animals

The concept of intrinsic value indicates that some natural entity is ethically relevant. Whether and in which way intrinsic value can be ascribed to natural entities or not, depends on two factors (see also Verhoog et al., 2002b):

1. The basic attitude towards nature (man as a ruler, man as a steward, man as a partner of nature or man as a participant in nature (Zweers, 1989, 2000; Kockelkoren, 1993, 1995);
2. The normative bio-ethical framework (anthropocentric, zoocentric, etc.), see Box 6.
   The basic attitude of man as a ruler or steward is man-centered. It emphasises nature as producer of raw material functionally related to human aims, although the steward because of the duty to leave natural resources for next generations restrains the drive for expansion of mankind. The basic attitude of partnership implies that humans have to take into account the needs and interests of living beings because they have intrinsic value. For the participant in nature it is important to identify himself with nature, because all life is one. All beings in nature depend on each other (interdependency). These basic attitudes towards nature are reflected in different normative, bio-ethical frameworks of action. In the anthropocentric theory only human beings are ethically relevant, which means humans have no direct ethical responsibilities towards nature. In a zoocentric theory only human beings and sentient animals are ethically relevant, whereas in the biocentric theory all living entities are considered ethically relevant, which means that the intrinsic value is taken into account in decisions on the exploitation of nature. In an ecocentric, bio-ethical framework not only individual organisms, but also species and ecosystems have ethical relevance.

Long before the concept of 'intrinsic value' emerged in plant production it was first recognised in animal ethics and introduced to counterbalance the (then) increasing 'instrumentalisation' of animals in agriculture and medical research. The Netherlands was the first country to adopt it in an official government statement in 1981 (Anonymous, 1981). When animals are instrumentalised they are considered to merely have an instrumental value (extrinsic value), but not a value or worth of their own (intrinsic value) (Verhoog, 1992). The concept of the intrinsic value of animals refers to the inherent, non-instrumental value of animals, indicating that animals are ethically relevant. The intrinsic value is ascribed to animals independent of their utility for humans, out of respect for their otherness and their being more or less autonomous. Once the intrinsic value of animals was acknowledged, this value of animals became ethically relevant in decisions on human exploitation of animals. Until 1992, the concept of intrinsic value was only used for sentient (vertebrate) animals, and was made operational in terms of animal health and welfare. In the Dutch 'Animal Health and Welfare Act' of 1992 it refers to all animals, and the concept of integrity was included. The emphasis is no longer on what an animal experiences but also on its characteristic nature. Here we see a shift from a zoocentric to a biocentric bio-ethical framework of action.

The concept of integrity can be seen as an extra operational dimension of the concept of intrinsic value, next to animal health and animal welfare (De Cock Buning, 1999). Integrity refers to respect for the characteristic nature or way of being of animals, their wholeness, completeness,

Box 6. Different bio-ethical frameworks of action.

Anthropocentric	Zoocentric	Biocentric	Ecocentric
Humans are ethically relevant, out of respect for their freedom, autonomy, and individuality.	Not only humans, but also sentient animals are ethically relevant, out of respect for their feelings and ability to suffer pain. This means that animal welfare and animal health will be taken into account.	Not only humans and sentient animals, but also all living organisms are ethically relevant, out of respect for their integrity or naturalness. This means that their inherent nature, wholeness and independence will be taken into account.	Not only humans, and all other living organisms, but also species and eco-systems are ethically relevant out of respect for their integrity. This means that their inherent nature, wholeness and independence will be taken into account.

their species-specific characteristics and their being in balance with the species-specific environment (Rutgers & Heeger, 1999). The concept of animal integrity was introduced in the ethical evaluation of transgenic animals, to deal with those moral aspects, which go beyond animal health and animal welfare. Crossing barriers between animal species was interpreted as a violation of their integrity. An overview of the European discussion on ethical questions around animal biotechnology leads one to conclude that the Netherlands played an important and leading role in defining underlying concepts of intrinsic value and integrity of animals for ethical evaluation (Brom & Schroten, 1993; Brom, 1999).

The intrinsic value and integrity of plants

As mentioned above the concept of intrinsic value was first recognised in animal ethics and was usually not applied to plant production. It was at that time recognised that animals can suffer and that their well being can be at risk, but one could not speak about the well being of plants in similar terms. Therefore, the concept of intrinsic value seemed at that time not suitable for plants. The integrity of plants did not seem to be an important issue either. Reflection on the impact of intervention on the integrity of plants first occurred when genetic engineering with plants became an issue in the public debate. Kockelkoren (1993, 1995) was the first to challenge the hierarchy present at that time in the Netherlands:

Life form	Genetic modification allowed
Humans	No
Animals	No, unless
Plants	Yes, but
Bacteria	Yes

This hierarchy meant that genetic modification of humans was not allowed, and in the case of animals meant that genetic modification of animals was forbidden, unless it could be proven that it was done for a significant goal, that there were no alternatives, and the 'no, unless' policy meant that no unacceptable violation of animal well-being and animal integrity was implied. The 'yes, but' with respect to plants meant that genetic modification was allowed, but only if there were no environmental and human health risks, whereas no restrictions were seen for genetic modification with bacteria in this hierarchy. Kockelkoren tried to go beyond the view that genetic modification of plants was allowed if there were no environmental or human health risks and he suggested that for plants also the intrinsic value of nature should be taken into account. He referred to the earlier described basic human attitudes of man as a ruler, as a steward, as a partner with nature and as a participant in nature, when evaluating several applications of the genetic modification of plants. However, the results of his report did not influence Dutch policy at that time, due also to the fact that at that time even the concept of integrity of animals was not yet fully elaborated and accepted. Thus genetic modification of plants was not considered a moral problem.

It is only very recently that this attitude is beginning to change. In several recent reports about consumer concerns related to plant biotechnology the question of respect for the naturalness and intrinsic value of plants is explicitly mentioned as a consumer concern (Meyer-Abbich, 1997; Hofmeister, 1999; Anonymous, 1999; Heaf & Wirz, 2001; Verhoog, 2002). These authors describe that there is an increasing awareness in society that all living creatures, including plants, are to be respected on the basis of their otherness. It implies that not only the consequences of human exploitation of plants should be taken into account, but also the nature of the intervention itself. This can be seen as the first step towards the acceptance of biocentric ethics in which the intrinsic value of living entities refers to the idea that all organisms have a value of their own.

The concepts of intrinsic value and integrity of plants were explicitly elaborated in an international workshop on 'Intrinsic value and integrity of plants in the context of genetic engineering' in Switzerland spring 2001, co-organised by the first author of this chapter. This workshop was a multidisciplinary orientation on the question whether, in which way and to what extent plants possess intrinsic values and integrity (Heaf & Wirz, 2001; Lammerts van Bueren, 2001). No consensus on a definition of the concept of integrity was reached during this workshop, due to a pluriformity of position and perception. There were some common elements: the relation to wholeness (specific harmonious relations between all parts of the plant), to otherness (autonomy) and to the importance of the ecological environment of the plants. One of the conclusions was that further conceptualisation was needed.

Different levels of the nature of plants

In ethics, the ethical relevance of plants is not the same as that of animals or human life. To identify the meaning of the nature of plants, as the operationalisation of intrinsic value in a biocentric framework, we have chosen to follow the systematic and practical approach of Visser & Verhoog (1999) and Verhoog (2000) who distinguished four levels to operationalise the concept of the nature or naturalness of animals. In their study about the normative meaning of the concept of 'naturalness' in relation to the genetic modification of animals they distinguished: the level of life, the level of animality, the level of species-specific nature, and the level of the nature of the individual. The reformulation of these levels in general terms allows for an adaptation to plants:

- the level of the nature of life;
- the level of the specific realm of nature;
- the level of species-specific characteristics;
- the level of individual characteristics.

Level of the nature of life (integrity of life)
A general characteristic of a living organism in contrast to that of the mineral realm is that it has the ability to grow, develop and reproduce itself as a more or less autonomous entity. Its parts show coherence with the whole of the organism. This means that it is more than merely the sum of different (non-living) elements, such as chemical compounds or genes. Living organisms can maintain themselves through a self-regulatory and self-ordering ability and an urge to survive and continue the existence of the species by adapting to changing environmental conditions. This is the level that plants and animals have in common.

Level of the plant-being and plant-worthiness (planttypic integrity)
The realm of plants distinguishes itself from the realm of animals because a plant depends more on its environment and therefore has a greater need and ability to cope with the environmental conditions in order to survive, to grow and develop, and to reproduce. Plants have the ability to actively interact with the rhizosphere and to live in symbiosis with beneficial soil microorganisms. Similarly, plants need to live in an optimal association with the organisms in the phyllosphere (e.g., nitrogen fixing phyllospheric bacteria) and the internal spheres (e.g. endophytes) as well as with their abiotic environment (including physical and chemical factors affecting its functioning). In interaction with the environment plants show more phenotypic variation than animals, due to a greater plasticity associated with their lack of mobility within one generation.

Level of species-specific characteristics of plants/crops (genotypic integrity)
Being alive (showing a characteristic metabolism and growth and development) is a general characteristic of all living organisms. Being a plant refers to a specific realm of nature, as most plants only require elements from the mineral realm to satisfy all their metabolic needs. Within the realm of plants, plants manifest themselves in a species-specific way. Therefore, belonging to a particular species is part of a plant's nature. In relation to this level for animals Verhoog (2000) defines genotypic integrity as the species-specific genome being left intact. This integrity can be affected by bringing in genes from other species (in case of non-related species for plants or animals) or by crossing reproductive barriers (between plants). Nevertheless, within the species

populations strive to maintain genetic variation. The boundaries of plant species are less strict compared to those of animal species, that is why we only speak here of reproductive barriers.

Level of individual characteristics of plants/crops (phenotypic integrity)
In the description of the level of individual characteristics of an animal Verhoog (2000) refers to three criteria: individual health, welfare or well being and integrity. At plant level one cannot speak of well being, at least not in the same way as with animal behaviour and its potential to suffer pain. Plants are also less individualised than animals. Depending on the agricultural sector the focus of individuality lies either on the crop or on the individual plant. In arable and vegetable cropping the focus is less pronouncedly shifted towards individual plants as it is in the case of fruit trees and ornamental trees or ornamental plants.
Compared to animals, a plant's appearance is, within the boundaries of its species, more plastic. The boundaries of plant production and thus the way plants can perform, can be challenged by altering the plant's environment and its genome.

Consequences of respecting the integrity of plants in organic plant breeding and propagation

From a biocentric framework of action (see Box 6) organic agriculture acknowledges the intrinsic value and therefore also the different levels of integrity of plants as described above. However, some specifications and remarks should be made applying these characteristics of plants to the field of organic agriculture.
From an organic point of view plants do not lose their naturalness or their intrinsic value once they are domesticated. Even if plants are domesticated, in the organic context, respect for planttypic integrity implies cultivation in soil (either in the field or greenhouse). *In-vitro* culture or culture on hydroponics is not responding to the plant's worthiness in the organic sense, because these systems depend on artificial fertilisers and media. Our cultivated plants are not only selected by humans but also in their cultivation dependent on humans, so part of the wholeness or planttypic integrity of the cultivated plants includes the interaction with the ecological environment as well as with the socio-economic context.
As to the concepts of species and acknowledging species-specific characteristics, it should be noted that the principles of organic agriculture respect reproductive barriers (see Box 7), and strive for the maintenance of the cultural inheritance of wild and cultivated species diversity.

Specifying the meaning of the criterion of plant health from an organic agricultural point of view implies cultivating and developing plants/crops in such a way that they can maintain themselves and potentially can complete their life cycle in an organic farming system (without chemical crop protection). The interaction of a plant with its environment is stronger than that of animals. In organic agriculture this is recognised and valued by stimulating recognisable, regional varieties and plant product qualities.

Box 7. The concept of species of plants in organic agriculture.

There are competing taxonomic schools, using different species concepts (Rosenberg, 1985). In the context of the discussion about the crossing of the boundaries between species organic agriculture uses the biological species concept. This implies that belonging to a certain species means belonging to a group or 'natural' entity of individuals that can exchange genetic information among themselves, but are genetically separated from other species by reproductive barriers. The boundaries of plant species are less strict than those of animal species. Therefore the use of crosses among closely related species as a tool in the selection process is possible in organic breeding provided the crossing is possible without *in-vitro* conditions.

The consequence of acknowledging the intrinsic value of plants and respecting their integrity in organic agriculture implies that the breeder takes the integrity of plants into account in his decisions in choosing for a breeding and propagation strategy. It implies that one not merely evaluates the result and consequences of an intervention, but in the first place questions whether the intervention itself affects the integrity of plants. From the above-described levels of the nature of plants and its characteristics a number of criteria, characteristics and principles for organic plant breeding and propagation techniques can be listed. They are summarised in Table 8.`

Assessing whether plant breeding and propagation techniques respect integrity of plants

Below the consequences of assessing the existing breeding and propagation techniques in light of the criteria of integrity of plants will be discussed more in general at plant/crop level, (organised) cell level and DNA-level. This results in Table 9 providing the consequences of an assessment on the suitability of the various breeding and propagation techniques for organic agriculture.

Table 8. Levels and characteristics of the nature of plants and the resulting main principles and criteria for plant breeding and propagation methods derived from the integrity approach in organic agriculture.

The level of the nature of plants	Characteristics of the nature of plants	Principles	The main criteria respecting the integrity of plants in organic plant breeding and propagation
Level of the nature of life	Self-regulation, self-ordering, autonomy	Integrity of life	The autonomy and the self-regulatory ability of living entities should be respected.
Level of plant being and plant worthiness	Adaptation to and active interaction with environment; soil-bound; independent reproduction	Planttypic integrity	Breeding should improve and not reduce the ability to adapt and actively interact with the environment. The breeding process should occur under organic soil conditions. Techniques should not affect the plant's potential for natural reproduction.
Level of species-specific characteristics	Species-specific genetic variation, reproductive barriers	Genotypic integrity	The volume of genetic variation should be in correspondence with the species. Reproductive barriers should be respected.
Level of individual characteristics	Plant wholeness, plant/crop health	Phenotypic integrity	Crossing techniques should allow pollination, fertilisation, embryo growth and seed formation on the (whole) plant. Selection should focus on plant types that can maintain themselves and potentially can complete their life cycle in an organic farming system.

Techniques at plant and crop level

Techniques at plant/crop level as mentioned in Table 9 can be considered as 'plant-worthy' breeding and propagation techniques, in line with all levels of integrity. All these techniques at plant level do not affect the wholeness of the plant (phenotypic integrity) when the pollination, fertilisation and seed formation can occur on the whole plant itself. They also do not interfere with the plant's natural interaction with the (organically cultivated) soil (planttypic integrity) or with reproductive barriers (genotypic integrity). This also applies to all kinds of field selection methods, and all those kinds of multiplication and propagation techniques that allow the plant (or parts of plants) to grow in (organically cultivated) soil. These techniques can be used to maintain parental lines and to select and propagate progeny under and adapted to organic growing conditions. The maintenance of parental lines *in vitro*, as is done for some modern hybrids such as leek hybrids, is not in line with planttypic integrity.

Table 9. The consequences of acknowledging the integrity of plants for the compatibility of the different kinds of techniques with organic plant breeding and propagation.1

Level / assessments	Variation induction techniques	Selection techniques	Maintenance and propagation
Plant/crop level: Compatible with the integrity of plants	combination breeding crossing varieties bridge crossing back crossing hybrids with fertile F1 temperature treatment grafting style cutting style untreated mentor pollen	mass selection pedigree selection site-determined selection change in surroundings change in sowing time test crosses indirect selection DNA diagnostic methods marker-assisted breeding	generative propagation vegetative propagation: - cut tubers - scales, husks, chipped bulbs - brood buds, bulbils - offset bulbs, etc. - layer, cut and graft shoots - rhizomes
(Organised) cell level: Not compatible with the integrity of plants	embryo culture ovary culture *in-vitro* pollination somatic variation	*in-vitro* selection	meristem culture anther culture microspore culture micropropagation somatic embryogenesis
DNA level: Not compatible with the integrity of plants	genetic modification protoplast fusion		

[1] The outcome of a similar table, composed on the basis of ecological criteria, was published in the reports by Lammerts van Bueren et al. (1998, 1999) and has provided the basis for a draft by the International Federation of Organic Agricultural Movements for the Basic Standards on organic breeding and propagation (IFOAM, 2002).

Taking the planttypic integrity of plants into account also includes the avoidance of techniques that reduce a plant's natural reproductive ability (planttypic integrity). Using cytoplasmic male sterility (cms) in hybrids without restorer genes is not in line with the level of planttypic integrity. The use of cms in modern hybrids is growing, partly to simplify the procedure of hybridisation and to reduce the percentage of undesired inbred plants (deviants). Although cms occurs naturally in some species, such as carrots and onions, breeders use protoplast fusion to transfer the cms characteristic to other species as well, for instance from radish to cauliflower. The use of cms hybrids without restorer genes reduces the free access to the complete functional gene pool by other breeders. They can pass on their genes used as a female parent, but a breeder cannot introduce a desired trait from cms hybrids into his own breeding plant material separately from the cms trait, as the cms trait is transferred to the next generation through the cytoplasmatic DNA of the female parent. The progenies of cms hybrids without restorer genes stay male sterile.

This blocking of the free exchange of the gene pool is not in line with the organic principles of sustainable breeding (genotypic integrity). These ethical objections do not apply to seedless fruits, such as the bitter-free cucumber cultivars. In this case it concerns female flowering cultivars, that can nevertheless bear fruit by parthenocarpy. Such cultivars can pass on their genes if a breeder crosses the cultivar with a monoecious or a male flowering cucumber cultivar.

Techniques at organised cell level

Techniques at organised cell level or *in-vitro* techniques, such as embryo culture and ovary culture, concern crossings, which in principle could occur under natural circumstances when a large number of plants is involved, large enough to allow the odd chance of success. Such crossings do not affect the genotypic integrity because the reproductive barriers are not crossed. But when such crossings occur under *in-vitro* conditions they are not in compliance with the planttypic integrity or with the phenotypic integrity. In the case of embryo culture the embryos resulting from pollination and fertilisation on the plant are extracted and grafted on an artificial substrate where they are allowed to grow to maturity. The reproduction in the next generation can in principle occur naturally, on the plant. These techniques have already been standard techniques in conventional plant breeding for many decades. They are applied to enlarge the success rate of certain crosses between related species and to speed up breeding programs, for example for the introduction of disease resistance from wild relatives, as it is now usually performed in breeding tomatoes. From a biological perspective, for some life forms the cell is the smallest living, coherent entity with a more or less independent self-regulatory ability, but this does not apply to higher plants. With the cultivation of cell and tissue cultures the plant is reduced to its potential in the cell and the natural environment is reduced to artificial nutritional and growing conditions of a lab. This is very different from what the whole plant requires with respect to its physical, chemical and biological environment from the perspective of organic agriculture. By using (omnipotent) organised cell cultures the differentiation processes of a plant in relation to time and to its natural (or organic) environment, which are so characteristic for the development of plants, are temporarily eliminated, and thus impair the described level of plant-worthiness.

Techniques at DNA level

Techniques like protoplast fusion and genetic modification go a step further than the above-mentioned techniques. These techniques are applied when two species differ so much that a successful cross cannot or will hardly ever be achieved under natural circumstances, so that one can speak of natural (species) crossing barriers. The techniques go beyond the level of the organised cell as the smallest living entity in a living context and affect the cell coherence and

organisation. A protoplast is not even an integral cell, because the cell wall is dissolved, and cells are separated from the living context of the plant or tissue. Genetic engineering of higher plants is the process in which the genotype of the plant cell is altered by the introduction of an (often alien) gene or genes into the genome other than by sexual crossing. This definition includes the technique of protoplast fusion. With protoplast fusion and with genetic modification genes are dissociated from the outer context of the natural plant-environment relation and also from the inner context of a living coherent cell or plant.
These techniques violate all levels of the nature of plants. They exceed the reproductive barriers (genotypic integrity) and they go beyond the level of maintaining the integral, living cell, and are thus associated with the non-living level of nature (violating the integrity of life, plant integrity and phenotypic integrity). Out of respect for the autonomy of life it is not compatible with the intrinsic value of plants to 'own' living organisms and put patents on (parts of) plants. Domesticated plants and cultivars are not man-made but obtained through human selection.

DNA diagnostic techniques
DNA diagnostic techniques, which enable selection at DNA level, do not involve genetic modification of crop plant DNA. The techniques, which are usually based on biochemical and molecular markers, could therefore be used in organic breeding programmes to supplement trait selection methods in the field, but their potential for organic agriculture has yet to be proven. Genotype x environment interaction is of primary importance in organic plant breeding, and markers can, in addition to field selection, contribute to the assessment of environment-specific performance of genotypes traits. However, a point worth paying attention to is the techniques used with DNA-diagnostics, as some of them include the use of radioactive idiotypes and (cancer-inducing) chemicals, which are not used in organic agriculture.

Evaluating the breeding and propagation techniques on the basis of the criteria derived from the principles of integrity of plants does not lead to the same list of techniques acceptable in organic agriculture as the earlier assessment based on ecological criteria in Lammerts van Bueren et al. (1998, 1999). The main difference is the arguments behind the assessment of the *in-vitro* techniques, as discussed above and also shown in Table 10. Based on the ecological criteria one may consider the *in-vitro* techniques not compatible because of the use of inorganic nutrients and artificial media. The application of these techniques is an ecological detour, yet one still operates within the level of life, albeit the lowest integration level (i.e., of organised cells). That is why the discussion got stuck and why these techniques are still 'under review'. From the principles of integrity of plants there are much clearer arguments against *in-vitro* techniques, as they affect the planttypic and phenotypic integrity of plants. It is up to the organisations responsible for the standards in organic agriculture to weigh the different arguments, including economic ones.

The breeder's eye

Another aspect of breeding that needs to be addressed in the context of integrity of plants is the way plants are observed and assessed in the selection process. Plant breeding looks for equilibrium between plasticity and stability of the plant and its species-specific potential. Plants, in general, show a wide range of potential of performances within the boundaries of the (closely related) species. Considered from a biocentric point of view breeders can in principle affect the integrity of plants by applying breeding techniques that are not 'plant-worthy', and also by selection at all aspects of plant performance: plant morphology, developmental ability, reproduction capacity, ability to adapt to the environment, etc., when a breeder selects plants that cannot maintain themselves in organic farming systems without chemical protectants. The breeder's attitude towards nature determines how he proceeds, selects and in which direction

Box 8. Examples of integration of an image of a plant ideotype as reference or 'Leitmotiv' for the development of new cultivars for organic plant breeding.

The working hypothesis of organic grower and breeder D. Bauer of the Dottenfelderhof (Germany) states that such a harmonious species-specific development of a cultivated plant is reflected in the ability to develop quality aspects, like taste, in an optimal way, and is also associated with ecological benefits like weed suppression. In the case of his organic breeding programme of cabbage, his selection criteria for optimal and balanced growth yield types that show their specific morphological forms in all developmental stages (juvenile, head forming, seed production, etc.) (Heyden & Lammerts van Bueren, 2000). He selects those cabbage types that show a clear juvenile phase with the juvenile leaves first spreading horizontally in a rosette and covering the ground completely, before the more erectophile leaves start to grow to cover and fill the head of the cabbage (see Picture A). This balance between the more outspoken differences of the juvenile and more mature growing phase and between the outer, planophile leaves and inner, erectophile leaves, results in a cabbage plant of which the head is 'carried' by the crown of outer leaves. Many modern, productive cabbage cultivars are rapid growers and do not show a clear separation between the specific morphological forms and characteristics of the different development stages as mentioned above. As a result, such cultivars hardly show a metamorphosis in the leaf forms, all being erectophile from the start, see Picture B. Bauer experiences that such cultivars are poor weed suppressers and have, in many cases, a modest quality in taste.

Another example can be found in organic wheat breeding (Kunz, 1983; Kunz & Karutz, 1991), see also Lammerts van Bueren & Osman (2002). Kunz' selection is focussed on wheat varieties with such a balance between guides the evolution of cultivated plants.

Next to the observations of quantitative traits (plant height, mass, dry weight, disease infection, etc.) as important aspects of selection or assessing the breeding progress, breeders usually also perceive and assess the total impression of plants, and that can be seen as an aspect of the integrity of plants. Breeders develop such a way of perceiving on the basis of a personal relationship with their plant object, based on their former and recent experiences and observations of plant performances in the field. Perceiving a specific kind of 'wholeness' indicates that plants are more than the sum of isolated characteristics that can be registered by computers. The appreciation of the perception of wholeness of a plant depends on the breeder's individualised inner view of plants and on a personal, basic attitude towards nature. It comprises more than merely aesthetic characteristics or agronomic value. It can lead to extra parameters on the basis of experiential knowledge. These extra parameters may be related to the spread in quality, disease tolerance, etc. It has to do with what breeders call 'the breeder's eye' after years of personal dedication to and relationship with his breeding object/crop, constantly comparing

Picture A – Variety A shows a red cabbage type with a more outspoken difference between the outer, older, planophile leaves with a strong weed-suppressive ability and the inner, younger erectophile leaves.

Picture B – Variety B shows a red cabbage type with no clear difference between the outer, less weed-suppressive leaves and inner leaves, all being more or less erectophile from the start.

vegetative, mass building and ripening processes that they can attain optimal ripening qualities. He found that plant types with a clear distinction between the vegetative development in the juvenile phase and the reproductive development after booting could best attain the ripening quality, which he could more easily find among taller wheat types than among the modern dwarf types. Such selection criteria result in plants with a longer peduncle with the ear ripening further above the wet leaf canopy in light and wind. This also results in an ecological advance of less pressure of ear diseases under organic conditions.

populations and 'knowing' whether a plant deviates from or is in harmony with a certain dynamic, inner reference of a plant ideotype. This recognition of a certain kind of pattern[17] more or less explicitly results in an inner reference, built upon his knowledge of and experience with the broad spectrum of potential appearances of progenies after crossings. On the basis of this knowledge the 'breeder's eye' experiences and perceives what is a more or less balanced or harmonious appearance of a plant in relation to its environment in the broadest sense (J. Velema, personal communication). It makes breeding, despite the scientific influences, always something of a skill or even an art, with a breeder trying to mould or create living material to conform to an image or an ideal in his mind (Briggs & Knowles, 1967; Duvick, 2002).

When the instrument of the breeder's eye is applied more or less consciously and this experiential knowledge is more systematised, it can on the one hand lead to inspiration to take extra parameters into account and on the other hand can lead to a different evaluation of the performances (Baars, 2002). In this context authors like Holdrege (1996) and Hofmeister (1999) indicated the importance of a more holistic, creation-specific assessment on the basis of whole plant performances (in German: 'Schöpfungsadäquates Erkenntnisweise') next to the increasing emphasis of the mathematical nature of observation. There are examples of organic breeders who, by applying the principles of the integrity of plants, consciously try to develop and integrate such an image of a plant ideotype as reference or 'Leitmotiv' for the further development of new cultivars, see Box 8. They aim at finding the right balance between intended mass production and quality from a utility point of view (extrinsic value), and the intrinsic value and integrity of the plant. This implies the ability of a plant/cultivar to grow in an optimal, crop-species specific balance between the extremes of starving and luxurious growth under the given growing conditions, expressed by a more or less species-specific balance between growth, differentiation and ripening processes in relation to its environment (Bockemühl, 1983). This is not a fixed image of a species-specific plant performance, but refers to a certain balance in growth dynamics that can be expressed in the different development phases of a plant from germination to ripening. With respect for integrity of plants as a prerequisite an organic breeder can make his personal selection within the often wide range of plant performances aiming to serve the continuously evolving climatic, agricultural and nutritional requires for improvement of the varieties.

[17] Kiene (2001) and De Vries (1999) described the ability of pattern awareness in other professions, and distinguished three levels of pattern awareness: pattern recognition based on correspondence in space, and in time, and pattern recognition based on inner expectations. The reality of the expectation functions as the control for the outcomes and as a guide for judgement and further action, see also Baars (2002).

Consequences of the concept of naturalness for plant breeding and propagation in organic agriculture

In Table 10, the consequences of the appreciation of the intrinsic value of plants in plant breeding and propagation in organic agriculture are summarised in the light of the three organic approaches of naturalness, including the non-chemical, agro-ecological and integrity approach. The assessment of the breeding and propagation techniques for organic agriculture on the basis of the ecological criteria (comparable with the non-chemical and agro-ecological approach) was discussed in Lammerts van Bueren et al. (1999). Other aspects of organic breeding and propagation like desired variety traits are extracted from Lammerts van Bueren et al. (2002c, d, e), see Chapters 3, 4 and 5. To elucidate and to specify these consequences three components of the process of moral evaluation are also distinguished (cognitive, emotive, and normative) (Verhoog et al., 2002b).

Table 10. Consequences of the appreciation of the organic concept of naturalness, including the non-chemical, agro-ecological and integrity approaches, for organic breeding and propagation (adapted from Verhoog et al., 2002a).

Approaches of naturalness	Cognitive dimension (view)	Emotive dimension (attitude)	Normative dimension (do's and don'ts)
• Non-chemical approach	• Intervention with chemical substances is not accepted, and crop nutrition and crop protection should be carried out with organic substances and conditions • Breeding is a genetic improvement of cultivated plants to obtain desirable traits for human use to maximise product quality and production within the accepted boundaries • Breeding should be as efficient as possible; modern strategies like quantitative genetics and DNA-markers can be important instruments	• Mankind has the right to cultivate plants as long as one does not use artificial substances • Cultivated plants are experienced as (living) production units to which one can add useful traits • Fear for chemicals • Organic seeds should be untreated and should have a natural resistance 'by themselves' • Genetic modification is unnatural	• Organic seeds are conventionally bred seeds but are at least propagated organically • Propagation in other regions/countries with better climates is no problem • Seed treatment is permitted if non-chemical • *In-vitro* techniques are not suitable because of the artificial growing conditions • Genetic modification is not accepted because chemicals and artificial growing media are used • DNA markers can be used

Table 10. Continued

Approaches of naturalness	Cognitive dimension (view)	Emotive dimension (attitude)	Normative dimension (do's and don'ts)
• Agro-ecological approach	• Breeding is genetic adaptation of cultivated plants to the agro-ecological conditions in the farm system, with ecological variety traits, like: - Ability to perform under low input of organic fertilisers - Efficient in uptake of minerals and water - Deeply rooting - Ability to associate with beneficial soil microorganisms - Weed suppressing - Disease resistant or tolerant - Stable in yield and quality - Ability to produce healthy seeds • Plant diseases can in many cases be considered as an expression of an unbalance between plant and environment, and solutions need interdisciplinary approach • Functional genetic diversity is important to stimulate the self-regulatory ability • Genotype x environment interaction has to be taken into account • Farmer x breeder interaction has to be taken into account • Regulations need adaptation	• Respect for nature and the complexity of living entities, including agro-ecosystems • Responsibility for maintenance and development of genetic diversity as cultural inheritance of mankind. • Robust cultivars are needed • Cultural diversity is to be respected	• Organic adapted cultivars are not only organically propagated but also have ecological traits • Selection, maintenance and propagation should occur under organic conditions • Selection in the region for ecological adaptation • No *in-vitro* techniques because they represent an ecological detour • Genetic modification is rejected because it is a product of reductionistic science with possible environmental and health risks • No patents on life because it threatens cultural and genetic diversity • Participatory approach • Adapted regulation for variety testing protocol and threshold values for seed-borne diseases

Table 10. Continued

Approaches of naturalness	Cognitive dimension (view)	Emotive dimension (attitude)	Normative dimension (do's and don'ts)
• Integrity approach	• Organic plant breeding and propagation aim at a plant-worthy development of our cultivated plants departing from the insight in the meaningful interdependence of the plant and its ecological, and socio-economic environment • Development of an art- and respectful breeder's eye as an important instrument to perceive the phenotypic integrity of plants. • Organic plant breeding and propagation aim at optimal expression of species-specific potential of self-regulatory/adaptive ability and quality characteristics • Organic plant breeding and propagation aim at genetic diversity in and between varieties to stimulate the self-regulatory capacity and the specific regional and cultural qualities • Organic breeding techniques should aim at a sustainable use of cultivars (among different breeders or farmers)	• Respect for breeding as an art • Respect for the autonomy and wholeness of plants; consequently, breeding refrains from forcing/manipulating plants, but elicits the plant's potentials (respect for integrity of life and plant integrity) • Respect for the reproductive barriers (respect for genotypic integrity) • Respect for the coherence of a plant appearance, growth dynamics, species-specific balance between quantitative and qualitative aspects (respect for phenotypic integrity). • Farmers want to be involved in the total life cycle and development of cultivated plants • One does not 'make' plants and can thus not 'own' plants	• Organic varieties are bred, maintained and propagated under organic conditions. • Only techniques that allow pollination, fertilisation and seed formation on the (whole) plant itself are acceptable • A plant's potential for natural reproduction should not be affected, thus no cytoplasmic male sterility-hybridisation without restorer genes • *In-vitro* techniques are not accepted out of respect for plant integrity • Genetic modification is not accepted because it violates all levels of the integrity of plants • Stimulation of participatory plant breeding strategies • No patents on life, out of respect for autonomy of life

Discussion and conclusions

Without doubt breeders respect and are dedicated to their plants as objects. But taking the intrinsic value of plants seriously in the sense that one links it with restrictive consequences is still a sensitive issue in public but even more so in scientific debates. While the conceptualisation of the intrinsic value and integrity of animals has already resulted in governmental regulations, with regard to plants the discussion is still in its incipient stage. Kockelkoren (1993, 1995) opened the debate by linking different attitudes towards genetic modification in society to the different basic attitudes towards nature. Other authors, like Hofmeister (1999), recently pointed out that increasingly the attitude in society shifts towards a biocentric framework of action anticipating that not only the intrinsic value of animals but also that of plants should be taken into account. Such authors describe several inherent characteristics of the nature of plants that should respected, such as their autonomy, their otherness, their ability for self-reproduction, etc. This contribution, however, is the first attempt to systematically conceptualise intrinsic value and integrity of plants, and to derive criteria for assessment.

Also in the discussions on the assessment of breeding and propagation techniques for organic agriculture in the period from 1997-2001 it became increasingly clear that not only ecological criteria were at stake but also that ethical elements (implicitly) played a role. Ethical criteria, however, were lacking. Because organic agriculture consciously develops its farming system from a biocentric point of view, the urge to define a complying breeding and propagation concept is felt. In this contribution we have applied bio-ethical principles to the field of organic agriculture by translating the more or less established concepts of intrinsic value of animals to the area of plants.

Distinguishing different levels of integrity of plants opened the possibility to instrumentalise the concept of integrity and derive criteria to assess whether breeding and propagation techniques comply with the organic principles of respecting integrity of plants.

Comparing the outcome of the assessment based on ecological criteria with the assessment including criteria of integrity subtle differences in the outcome of sorting out the suitability of breeding and propagation techniques for organic agriculture appear concerning the *in-vitro* techniques. From ecological arguments one can argue whether these techniques can or cannot be used, but from the principles of integrity the *in-vitro* techniques are clearly not compatible with organic agriculture. The arguments behind the assessment can give more clarity on the ethical aspects in the societal and political discussion in the organic sector, as also in the case of not allowing genetic modification in organic agriculture even when there are no environmental or health risks at stake because it is not compatible with all levels of the integrity of plants.

Another example may be the arguments opposing patents that can be derived either from the agro-ecological approach out of concern for blocking the free exchange of germplasm and threatening genetic diversity, or from the integrity approach. In the latter context one considers patents as being not in keeping with respect for the autonomy of plants arguing that mankind can only alter plants but cannot own plants.

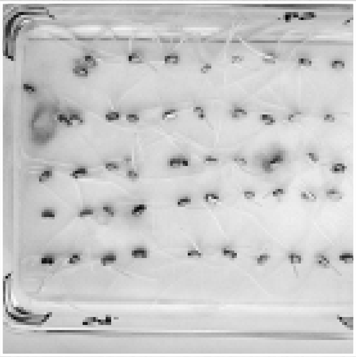
The practical consequences of the concept of integrity are not immediate as organic agriculture is a constantly developing agriculture in which breeding and seed production activities specifically for organic agriculture (even those merely based on the principles of the non-chemical and agro-ecological approaches) are still in their infancy. Making the criteria of intrinsic value and integrity of plants more explicit and adding these approaches to the non-chemical and agro-ecological approaches will assist breeders willing to participate in organic plant breeding, to develop adequate breeding strategies for organic varieties.
Distinguishing the three different approaches of naturalness in organic agriculture, and the consequences for the breeding and propagation strategies as presented in Table 10, can also be helpful to distinguish short term and long term steps for the practical, future development of organic plant breeding and seed production. Some breeding companies start with the non-chemical approach, others include the agro-ecological or even the challenge to include the integrity approach in breeding.

Taking all three approaches of naturalness into account the aim of organic plant breeding can be summarised as follows:

Plant breeding for organic agriculture is a kind of plant breeding that produces varieties with a good nutritional value and taste, which enhance the potentials of a sound organic seed production and farming system, and enhances biodiversity. Organic plant breeding follows the concept of naturalness avoiding the use of chemical inputs, stimulating the agro-ecological, self-regulatory ability of organic farming systems and respecting the integrity of plants based on their natural reproductive ability and barriers, and their viable relationship with the living soil.

From a conventional point of view, these aims merely restrict the tools for breeders. From an organic point of view, however, they challenge the life sciences to develop alternative strategies for varieties with sufficient levels of disease resistance or tolerance without using some of these tools (Den Nijs & Lammerts van Bueren, 1999). Therefore other, new approaches and scientific concepts are needed from a broader perspective on plant health. Most of all, however, organic plant breeding needs the 'artful' creativity of the expert and the respectful eye of the individual

breeder.
It took more than 10 years to define and implement the concept of intrinsic value and integrity of animals. It can therefore be expected that the concept of integrity of plants will also need time to further develop into a concept and guideline for further practical development in organic agriculture, including organic plant breeding and seed production. The necessary biocentric framework of action is already one of the principles of organic agriculture in the context of naturalness.

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Organic breeding and seed production: the case of spring wheat in the Netherlands

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Abstract

To further improve the organic farming system, varieties are required that are adapted to this type of management and allow an organic production of high quality seed or planting material. This contribution describes the position and role of spring wheat in Dutch organic farming, and discusses the needs with a short-term, middle-long and long-term outlook to improve spring wheat based on approaches that comply with the non-chemical, agro-ecological and ethical principles of organic agriculture. Progress has been enhanced by developing a participatory approach in which the farmers' eye can guide the focus of conventional breeders (including their breeders' eye) on the organic sector. Designing an ideotype for organic spring wheat is an important tool for that purpose and an ideotype is proposed. Most modern, conventional varieties do not match the proposed ideotype as they lack the plant architectural characteristics that contribute to weed suppressiveness and disease tolerance.

As a next step an adapted protocol for Value for Cultivation and Use (VCU) testing has been developed and applied in official VCU trials for organic spring wheat in the Netherlands, from 2001 onwards. The obstacles in organic seed production of spring wheat are not so much the availability of quantities but more of seed quality. This requires more effort in developing strategies to avoid seed-borne diseases, seed treatments and threshold values for contamination on organically produced wheat seed.

The ethical principles in organic agriculture are based on the acknowledgement of the intrinsic value and integrity of plants. These principles can be used to assess breeding and propagation techniques for organic spring wheat. Acknowledging the intrinsic value and integrity of plants can also have a meaning in the perception of spring wheat as a cultivated plant in the selection process focussing not only on traits referring to extrinsic values but also taking the intrinsic value of wheat into account. This integrity approach has to be further elaborated in practice and our description is therefore indicative.

In the long run the organic sector can only benefit from breeding programmes specifically focussed on the requirements of organic farmers and processors, users and consumers.

Keywords: spring wheat, organic breeding, organic seed production, intrinsic value of plants, ideotype, participatory breeding, value for cultivation and use

Introduction

Currently, Dutch organic farmers largely depend on varieties supplied by conventional plant breeders and developed for farming systems in which artificial fertilisers and agro-chemicals are widely used. Instead of external regulation through chemical protectants, organic farmers aim at managing the resilience and buffering capacity of their farm-ecosystem by stimulating internal self-regulation through functional agro-biodiversity in and above the soil. As a result of this non-chemical and agro-ecological approach organic farming systems differ fundamentally from conventional systems in management of soil fertility, weeds, diseases and pests. The organic sector needs varieties which are adapted to this type of management. Lammerts van Bueren et al. (2002c) elaborated a general organic ideotype with desired traits to support the realisation of the principles of organic farming systems, see Chapters 3, 4, 5. The desired traits include adaptation to organic soil fertility management based on low(er) and organic inputs; better root system and ability to interact with beneficial soil micro-organisms; weed suppressiveness; contributing to soil, crop and seed health; high product quality; high yield level; and high yield stability, see also Table 11.
Such a non-chemical and agro-ecological focus on traits is not the only relevant principle in organic agriculture. Verhoog et al. (2002b) concluded that the concept of 'naturalness' in organic agriculture includes not only a non-chemical and an agro-ecological approach, but also includes the ethical aspect of the acknowledgement of the integrity of life, see Chapter 2. Since the use of gene technology in breeding the organic sector has become more and more aware of the ethical aspects of organic principles that have an impact on the approaches in organic propagation and plant breeding. This awareness is reflected in the notion of the intrinsic value of plants (Bullard et al., 1994). Although the above-described non-chemical and agro-ecological approaches already express respect for nature and the nature of life, these approaches are mainly driven by or based on an instrumental (functional) point of view to benefit an ecologically and economically sound production system. Organic agriculture, however, also acknowledges an inherent, non-instrumental value of living organisms, thus independent of their utility for humans, out of respect for their 'otherness' and their being more or less 'autonomous'. This indicates that in organic agriculture plants and animals are also ethically relevant in decisions on human exploitation of such organisms. The integrity of living organisms can be considered as a dimension of the concept of intrinsic value (De Cock Buning, 1999). Integrity refers to the characteristic nature or way of being of living organisms, their wholeness, completeness, their species-specific characteristics and their being in balance with the species-specific environment, as Rutgers & Heeger (1999) have defined for animals. The consequences of applying the concept of intrinsic value, including respect for integrity of plants, for organic plant breeding and

propagation was elaborated by Lammerts van Bueren et al. (2002f), see Chapter 6. It concerns criteria for the assessment of breeding and propagation techniques, but can also give direction to the perception of plants in the selection process. For the assessment of breeding and propagation techniques suitable for organic agriculture four principles are formulated on the basis of four distinguished levels of the nature of plants: the integrity of life, the planttypic integrity, the genotypic integrity and the phenotypic integrity, see Table 12.
Organic plant breeding and propagation aim at a 'plant-worthy' development of our cultivated plants taking its starting point from insight into the meaningful interdependence of the plant and its ecological and socio-economic environment. The assessment of breeding and propagation techniques implies that techniques that allow pollination, fertilisation and seed formation on the (whole) plant itself are most in line with the principles of organic farming, respecting the autonomy (integrity of life), self-reproductive ability (planttypic integrity) and the reproductive barriers (genotypic integrity). Next to this category of techniques at plant level, more and more *in-vitro* techniques are applied in plant breeding, but these impair the plant integrity and are therefore not suitable in organic agriculture. Techniques at DNA level are not compatible with the principles of organic agriculture either (Anonymous, 1991). This does not mean that DNA markers, which do not involve genetic modification, cannot be of value in assisting in trait selection.
Taking the phenotypic integrity into account in the selection process implies that the organic plant breeder perceives with his 'breeder's eye' the specific kind of 'wholeness' of his plant object, constantly comparing populations and knowing from experience whether a plant deviates from or is in harmony with a certain dynamic, inner reference of a balanced or harmonious plant ideotype. Such an inner reference of a plant ideotype is an aspect the breeder develops in recognising certain patterns in the plants' species-specific performances after years of personal dedication to and relationship with his breeding object of plants (Lammerts van Bueren et al., 2002f). Respecting and taking the integrity of plants into account indicates that one perceives plants as more than merely the sum of isolated characteristics.

In this chapter the implications of the above-mentioned general principles for organic breeding and propagation strategies will be specified for the case of spring wheat. The most direct way to obtain varieties better adapted to the organic system is to develop a special organic breeding programme. This approach is not only costly, but would also neglect existing resources (knowledge and material) in the conventional plant-breeding sector. Diverting some of the existing conventional breeding resources towards the organic sector would in the short term be a more effective approach for obtaining varieties with improved adaptation. We will, therefore, first describe the approach we developed in stimulating conventional breeders to pay more attention to organic spring wheat from a non-chemical and agro-ecological point of view. After that, we will discuss the possible consequences of including the integrity approach in organic spring wheat breeding. Compared to the non-chemical and agro-ecological approach, this integrity approach concerning organic plant breeding and propagation is less elaborated in practice. Our description is therefore more indicative as this aspect needs more discussion in the organic sector. Finally we will discuss the future challenges of organic plant breeding and propagation following the concept of naturalness.

Materials and methods

The criteria derived from the concept of naturalness, including the non-chemical, the agro-ecological and integrity approach as described above, to assess future perspectives for an organic plant breeding and propagation of spring wheat in the Netherlands, are summarised in Tables 11 and 12.
Data for this contribution are from projects concerning development of concepts and strategies for organic plant breeding and propagation, including variety trials with spring wheat under Dutch organic farming conditions in the period between 1997-2002 (see Lammerts van Bueren et al., 1999; Heyden & Lammerts van Bueren, 2000; Hulscher & Lammerts van Bueren, 2001; Lammerts van Bueren et al., 2001a, b, c; 2002a, b, c, d, e; Osman & Van den Brink, 2002; Osman

Table 11. Criteria for organic plant breeding and propagation strategies derived from the non-chemical and agro-ecological approach (based on Lammerts van Bueren et al., 2002c).

Criteria	Desirable variety characteristics
Adaptation to organic soil fertility management	Adaptation to low(er), organic inputs and fluctuating nutrient dynamics, efficient in capturing water and nutrients, their uptake and their use; deep, intensive root architecture; ability to interact with beneficial soil microorganisms
Weed suppressiveness	Plant architecture for early soil cover and more light-competitiveness
Crop health	Durable resistance, field tolerance, plant morphology, combining ability for crop or variety mixtures, capable of interaction with beneficial microorganisms
Seed health	Resistance/tolerance against diseases during seed production, germination and crop establishment
Crop quality	High processing/baking quality, good taste, high storage potential
Yield and yield stability	Maximum yield level and yield stability under low, organic input

Table 12. Criteria for organic plant breeding and propagation strategies derived from the integrity approach (after Lammerts van Bueren et al., 2002f).

The level of the nature of plants	Characteristics of the nature of plants	Principles	The main criteria regarding respect for the integrity of plants
Nature of life	Self-regulation, self-ordering, autonomy	Integrity of life	The autonomy and the self-regulatory ability of living entities should be respected.
Plant worthiness	Adaptation to and active interaction with environment; soil-bound; independent reproduction	Planttypic integrity	Breeding should improve the ability to adapt and actively interact with the environment. Breeding process under organic conditions. Techniques should not affect the plantês potential for natural reproduction.
Species-specific characteristics	Species-specific genetic variation, reproductive barriers	Genotypic integrity	The volume of genetic variation should be in correspondence with the species. Reproductive barriers should be respected.
Individual characteristics	Plant wholeness, plant/crop health	Phenotypic integrity	Crossing techniques should allow natural reproduction on the whole plant. Selection should focus on plant types that can complete their life cycle in an organic farming system.

& Schaap, 2002; Osman et al., 2002; Verhoog et al., 2002). Other results used are based on contacts with Dutch organic farmers and seed companies, including international contacts. The information is completed by literature research.
In several sections of this contribution specific materials and methods used to arrive at the data presented will be described in more detail.

The position of wheat in organic farming in the Netherlands

To get an understanding of the context of organic wheat production the position and role of spring wheat in Dutch organic agriculture will first be described. Wheat is the main crop in organic cereal production in the Netherlands and Europe. In the Netherlands more than 40% of all the organic cereals produced in 2001 is wheat (Table 13) of which roughly 50% finds its destination in human consumption and the other 50% as feed (Overbeeke, 2002). Such a high percentage of Dutch organic wheat for human consumption is in contrast with the percentage of conventional wheat used for human consumption and is associated with a good market and price for home-grown baking wheat. Traders pay higher premium prices for good quality baking

Table 13. Organic cereal area (ha) in the Netherlands from 1996-2001 compared to the conventional cereal area in 2000 and 2001 (source: Centraal Bureau voor de Statistiek).

Crop	1998 org.	1999 org.	2000 org.	2000 conv.	2001 org.	2001 conv.
Winter wheat	654	332	539	120,510	479	95,791
Spring wheat	629	705	707	16,176	1,306*	28,931
Winter barley	133	108	116	3,635	66	3,236
Spring barley	491	536	387	43,537	979	63,525
Rye	516	232	286	5,961	303	3,568
Oats	189	170	352	2,404	443	2,556
Triticale	346	136	484	6,646	402	4,808
Total cereal area	2,959	2,217	2,871	198,869	3,979	202,415
% wheat of total cereal area	43.4	46.8	43.4	68.7	44.9	61.6
Total arable area	7,022	6,617	8,150	806,169	9,686	797,542
% cereals of total arable area	42.1	33.5	35.2	24.7	41.1	25.4

*** Increase partly due to a newly converted state farm of 2,600 ha.**

wheat to organic farmers compared to prices of conventional produce, stimulating farmers to grow baking wheat and to choose varieties that can meet the milling and baking quality standards as much as possible. Prices, though, will be under more pressure because of increasing (cheap) imports of organic wheat from Eastern Europe. Because there is a strong societal demand on reliability and controllability of adherence to organic standards, there may remain a market for home-grown, Dutch organic cereals in the future because of the greater transparency of the production chain (Overbeeke, 2002).

The role of wheat in Dutch organic farming systems

Cereals in organic farming systems are not only grown for their grains for feed and human consumption, they are also very important for their contribution to the soil fertility as the basis of a sound organic farming system. Cereals in general play a special role in the organic rotation system by contributing strongly to restoring and improving the soil structure through their deep and intensive root system, recycling of nutrients from deeper soil layers and building up the organic matter content with a large proportion of crop residues. The importance in maintaining soil fertility can be even higher when clover is undersown. The important position of cereals in organic rotations is illustrated by the fact that the percentage of cereals in Dutch organic arable

farming systems (35%) is 10% higher than on conventional farms (25%) (Anonymous, 2002b). Organic farms typically manage six year long and diverse rotation schemes with one or two cereal crops within one cycle.
Cereals are also important for straw production, which is a vital product for composting stable manure. For reasons of animal welfare and manure quality large amounts of straw are needed for deep litter barn systems (Raupp, 1999; Van der Burgt & Baars, 2001). Because there is a shortage of organic straw such stable systems cannot expand to such an extent as organic farmers would wish to (Hendriks & Oomen, 2000).
Another important aspect for farmers is that cereals are not labour intensive and therefore fit nicely in the labour scheme of an organic farm. Special attention is needed to control weeds, not so much for the wheat itself but to avoid the development of a seed bank for the following crops in the rotation. Next to the argument of a higher baking quality of spring wheat, the poor competitiveness of the current winter wheat varieties in an early growth stage under organic farm conditions, and the limited possibilities for mechanical control of weeds in the often relatively wet late autumn and early spring, are important arguments for organic farmers in the Netherlands to switch more and more from winter wheat to spring wheat (Lotz et al., 1990; Lammerts van Bueren et al., 2001c). In the Netherlands, the organic spring wheat area is more than 57% of the total organic wheat area, compared to 17% spring wheat of the conventional wheat area, see Table 13. This is very different from the organic spring wheat position in other European countries, where winter wheat is still more important than spring wheat (Herrmann & Plakolm, 1993).

Steps towards better suited spring wheat varieties for organic farming systems from a non-chemical and agro-ecological point of view

A starting point of aiming for better suited spring wheat varieties for organic farming systems was one of the conclusions of a workshop organised by the Technology & Agricultural Development Group of Wageningen University, in which the first author participated together with the seed sector (Ruivenkamp & Jongerden, 1999). The workshop showed the need for the organic sector to communicate their desired characteristics in the form of an ideotype. It was also concluded that the current protocol for the official Value for Cultivation and Use (VCU) testing for release of new varieties for conventional agriculture could be a bottleneck for the release of varieties with characteristics which serve the needs of the organic sector (see below). There is a real chance that among the rejected varieties material could be present that would be suitable for organic agriculture. As a first step in our approach to stimulate the focus of conventional breeders on the organic sector we therefore developed an ideotype of organic spring wheat. This was done in a participatory approach, involving farmers, traders and breeders. As a second step we designed a research protocol for Organic VCU testing, which was approved by the Commission for the List of Recommended Varieties of Arable Crops. The following (third) step will be executing this organic VCU testing. These steps will be described in more detail in the following sections.

Development of an organic ideotype of spring wheat

The core of the participatory approach to arrive at better suited varieties for organic farming systems is developing descriptions of ideotypes for each individual crop, see Box 9. These descriptions consist of lists of the characteristics, which farmers and traders desire in their ideal variety. To develop such ideotypes we organised field visits to variety trials with farmers and traders, and asked them to discuss and evaluate the varieties on positive and negative characteristics. We asked them to do this first individually and afterwards discussed the results with the whole group. The field sessions resulted in a list of desired and undesired characteristics. During subsequent off-season sessions the ideotype was completed and desirable traits were prioritised. In the next step we invited breeders to send in varieties which fitted the first draft ideotype for on-farm variety trials. The characteristics in the ideotype were translated into parameters that could be quantified, to give breeders a more precise and objective description of the characteristics, which would enable them to better screen their collection. These variety trials were evaluated by farmers, traders and breeders just before the ripening phase started, to coincide with the time when the largest differences were expected. These field sessions in different regions triggered further discussions, fine-tuning and sharpening of the desirable characteristics of the ideotype and their priorities. This resulted in the ideotype of spring wheat in Table 14.
One of the conclusions of the discussions during field assessment of the variety trials and the off-season meetings together with farmers and breeders, was that the above-mentioned procedure helps the breeders to get a better understanding of the possibilities, limitations and obstacles in the organic farming system, and of the kind of varieties that are needed to optimise the organic sector (Lammerts van Bueren et al., 2001c; Osman & Lammerts van Bueren, 2002).

Box 9. Participatory approach developing an ideotype for organic varieties (adapted from Osman & Lammerts van Bueren, 2002).

The steps towards an ideotype:

- Developing an ideotype
  During field visits farmers and traders are invited to evaluate existing varieties. Discussion on the evaluations leads to a list of desired plant traits. In a second meeting the characteristics are further elaborated and priorities are set.
- Feeding the ideotype back to breeders
  The ideotype is presented to seed companies with a request to send in seeds for a variety trial. The latter is important because it shifts the discussions from a paper list to real seeds and plants.
- Setting up variety trials in farmers' fields
  The varieties which - according to breeders - fit the ideotype are evaluated in the field.
- Inviting farmers, traders and breeders to evaluate the trials and results in off-season meetings
  These visits and meetings form a lively platform for discussions as breeders are confronted with the performance of their own varieties and seeds of their colleagues.

Below we will discuss the background of the different characteristics mentioned in the ideotype description (Table 14). The ideotype was developed for a wheat crop grown on clay soil without clover undersow. In the Netherlands hardly any organic wheat is grown on sandy soils. Wheat with an undersow of clover is usually a crop aimed first at improving soil fertility and not in the first place at producing baking quality and high yields. A variety that satisfies the ideotype of bread-making spring wheat can still be undersown with clover by sowing wheat at lower seed rate. This organic wheat ideotype may not differ in all characteristics from the conventional farmers' ideotype, but it clearly differs in priorities set for the different characteristics. High priority to e.g. baking quality and weed suppressiveness are an expression of how organic wheat production differs in production objectives and problems from conventional farming.

Baking quality

Baking quality is important in organic wheat production. To achieve high baking quality Agrifirm, the largest trader of Dutch organic wheat, pays farmers a premium according to the protein content, zeleny sedimentation value, hagberg falling number and specific weight. The discussions with farmers and traders showed that a satisfactory method for assessment of baking quality is

Table 14. The ideotype of Dutch organic spring wheat from a non-chemical and agro-ecological point of view (adapted from Lammerts van Bueren et al., 2001c).

Characteristics	Minimum	Ideal	Priority
Good Baking Quality			
Hagberg Falling Number	260 s[1]	Optimum profit. This is yield (in kg) times the premium price for baking quality as high as possible	++
Zeleny Value	35 ml[1]		++
Protein Content	11.5 %[1]		++
Specific Weight	76 kg/hl[1]		++
Good Grain Yield	Lavett = 100 (± 6500 kg/ha)		++
Efficient use of (organic) manure	... [2]	Desired profit to be gained with as low manuring level as possible	++
Reducing Risk of Diseases			
Long stem	± 100 cm (Lavett)	± 100 cm (Lavett)	+
Ear high above flag leaf	± 20 cm	...	++
Ear not too compact	... [2]	... [2]	+
Last leaves green for the longest time possible (# days before harvest) = stay green index	... [2]	... [2]	++
Resistance against			
Yellow Rust *(Puccinia striiformis)*	6[3]	8	++
Brown Rust *(Puccinia recondita)*	7[3]	8	++
Leaf spot *(Septoria* spp.*)*	6[3]	8	+
Fusarium spp.	... [2]	... [2]	++
Mildew *(Erysiphe graminis)*	8[3]	8	
Supporting Weed Management			
Good recovery from mechanical harrowing	... [2]	... [2]	+
Good tillering	... [2]	... [2]	++
Rapid closing of canopy	Like Lavett	Better than Lavett	++
Dense crop canopy	Like Lavett	Better than Lavett	++
Reducing risks at harvest			
Stiff stem	7	8	++
Early ripening	Mid August	First week of August	++
Resistance against sprouting	7	7	++

[1] Based on the bonus system of Agrifirm (trader of +/- 75% of the Dutch organic wheat production).

[2] No values were given, because there was no quantitative information available on the item.

[3] Based on the values for the variety Lavett in the Dutch Recommended List of Varieties of 2000 (Ebskamp & Bonthuis, 1999).

still lacking. Farmers argued that results of these laboratory assessments do not correlate well with the results of real bread baking by the processors. Sometimes lots that do meet the standards do not bake well, whereas sometimes grain lots around the minimum levels give better results than those with better levels (Vaessen, 1990; Lammerts van Bueren et al., 2001c). In depth interviews with millers and bakers confirmed this (unpublished data). Although each miller or baker has their own way of assessing baking quality, they all agree that the only truly valid assessment is by baking bread. The criteria of the traders are used by most of the bakers to decide whether a grain lot is interesting enough to test it for baking quality. The end product is usually a whole wheat bread. Ideally organic bakers do not use bread additives in the baking process, so test baking should be done accordingly. Currently criteria and specifications are based on conventional experience with white bread with the use of additives. That means that the organic sector might require parameters and specifications adapted to its way of processing the wheat. This still requires more research effort because the processes are not exactly the same as the conventional test baking process (Kunz et al., 2000).

Yield and yield stability

Yield of wheat is not expressed in kg/ha but in financial return; which is – for organic farmers – the optimal combination of grain production and the premium price for high grain quality. The yield level in kg/ha of winter and spring wheat is usually 20-30% lower compared to that in conventional systems (Spiertz, 1989; Mäder et al., 2002; Lammerts van Bueren et al., 2002c). Organic farmers prefer yield stability to higher yield. They need a ‘reliable’ variety, which means a variety that can cope with the fluctuations in weather conditions and disease pressure without large fluctuations of yield and quality of both grain and straw. Straw yield is also relevant, but has not been included by the farmers as a separate criterion in the ideotype description, because good straw yield is achieved when varieties meet the criteria of dense canopy and long stem.

Nutrients

As a low yielding crop, organic wheat receives half as much (organically applied) nitrogen (80-100 kg N ha^{-1}) as in the conventional farming systems (Tamis & Van den Brink, 1999). In the Netherlands there is a shortage of organic manure for arable farms. In 2002, the regulations demand that 20% of the manure must be derived from organic origin; this demand will rise up to 100% within a few years, by then allowing no more additional supply with conventional manure (Hendriks & Oomen, 2000). With this development fewer nutrients will be available for the relatively low value wheat crops. This implies that farmers will have increasingly higher demands on the efficiency of the nutrient uptake and on nutrient use efficiency of the wheat varieties under organic farm conditions. It is important to realise that adaptation to organic farming systems not only implies adaptation to low(er) inputs but also to the organic character of the slow-releasing nutrient inputs. It means that spring wheat varieties should be able to cope with a low mineralisation rate in the early spring under low temperature conditions, with more fluctuating N-dynamics and with the form in which nitrogen is available (NH_4^+/NO_3^-).

In organic agriculture soil microorganisms play a decisive role in making nutrients available. The ability to establish relationships with microorganisms would be an advantage for organic varieties.

Diseases and pests

Not so much pests such as aphids or nematodes, but mainly air- and seed-borne fungi cause problems in Dutch organic wheat production. Yellow and brown rust, Septoria, Fusarium, and mildew are important. Infection by fungi differs from year to year due to variation in weather, and there is also variation among individual farms. The disease pressure in organic wheat production is in most years lower than in conventional systems, but in some years the disease pressure can be larger than in conventional production systems (Tamis & Van den Brink, 1999). In most cases the incidence of mildew in particularly is lower in organic wheat production than in conventional systems. Our own observation is that in most seasons most of the fungi appear later in the season under organic conditions (unpublished data). Organic farmers not only look for genetic resistances; they also want to reduce the risk of disease incidence by selecting for additional morphological traits and thus look for a more robust plant architecture not conducive to disease contamination and/or development. Examples are a longer stem allowing the ear to ripen above the moist canopy, more vertical distance between the leaves, and a less compact ear. An important field criterion for organic farmers is a long stay green index of the upper leaves, expressing the ability to use all available nutrients and light efficiently and to express sufficient disease tolerance.

Mycotoxins by Fusarium

In the ideotype description Fusarium was first ranked as a minor problem by the farmers, but after discussions they ranked it higher because of the risks of mycotoxin contamination. They assessed this risk as small, but were aware of the detrimental effects of negative publicity even if it was encountered in only a few grain lots.

The FAO stated recently in a report on food safety as affected by organic production techniques, that on the basis of several studies it cannot be concluded that organic farming leads to an increased risk of mycotoxin contamination (FAO, 2000). However, organic agriculture has the responsibility to further control and reduce the risk of mycotoxins for instance produced as secondary metabolites by ear fungi of wheat, like deoxynivalenol (DON) predominantly by

Fusarium culmorum and *Fusarium graminearum* (Lammerts van Bueren, 2001; Lammerts van Bueren et al., 2001b), but this requires more research.
Until now Fusarium resistance has not been an important criterion for admittance to the Dutch variety list for spring wheat in contrast to winter wheat (Bonthuis & Donner, 2001). In variety trials differences in susceptibility among existing spring wheat varieties have been observed, but exact information on the level of resistance among varieties is not known (Anonymous, 2001b). There seems to be good scope for breeding for resistance, but the correlation between the resistance traits and mycotoxin content are moderate and highly dependent on the environment (Miedenar, 1997; Rückenbauer et al., 2001). This underlines the approach of organic farmers not only to rely on genetic resistance traits and for most diseases to look for broader field tolerance in the plant by requiring varieties with different plant architecture including traits like a longer peduncle, greater distance between the leaves, less compactness of the ear, but also a shorter flowering time (Eisele & Köpke, 1997; Schütze et al., 1997). Mycotoxins can also be produced by *Fusarium* spp*.* after harvest time if the moisture content of the kernels is high enough. To reduce the risk of Fusarium development during storage, traders demand that Dutch organic farmers dry the kernels to 15% moisture content as a HACCP measure (Agrifirm, personal communication, 2001).

Weeds
Another important point in cereal production is weed control. It is not only important that wheat itself does not suffer so much from competition from weeds but the aim is also to avoid creating a seed bank for the following crops in the rotation. Early and repetitive mechanical weeding is of great importance, and gives good results if managed well in time. Farmers have experienced variety differences in the ability to recover from mechanical harrowing and therefore demand varieties allowing and resisting mechanical control.
But particularly under wet weather conditions, mechanical weed management cannot be done in time or is not effective enough. Thus from an organic point of view farmers demand a crop that grows rapidly in the juvenile phase with a good tillering ability, many leaves and a long stem to be able to cover or shade the soil in an early stage of crop development outcompeting weeds for light. Van Delden (2001) concluded that for spring wheat it is not merely a matter of more nitrogen in the early growth phase, because that can also support a more advanced growth of certain weeds. It underlines the need for varieties that are adapted to low(er) N input and are still capable of covering the soil to a larger extent (Kunz & Karutz, 1991; Eisele & Köpke, 1997; Müller, 1998). Van Delden (2001), however, pointed out that in the case of breeding for organic agriculture it is also important to have insight into trade-offs between crop traits such as those between an improved weed suppressing capacity and improved N uptake efficiency. Increasing N

uptake by increasing the root : shoot ratio may lead to a smaller weed suppressive ability due to a smaller proportion of shoot biomass.

Adapting the Dutch protocol for VCU research for organic spring wheat

With the ideotype available, breeders were invited to screen their collections for lines that would match the ideotype. This exercise would only result in new varieties on the market if the material passed official Value for Cultivation and Use (VCU) testing. To pass official VCU testing the material should be better than the existing varieties.

Table 15. Comparison of the approved organic protocol for VCU testing for spring wheat with the conventional protocol (Lammerts van Bueren et al., 2001c).

	Organic Protocol	Conventional Protocol
Research site	• managed organically, in accordance with EU regulation 2092/91, for at least three years	• managed conventionally with mineral fertilisers; chemical pest and disease control
Seed	• not chemically treated	• chemically treated
Crop husbandry	• according to organic farm management practice	• according to conventional management practice; part of the trial is conducted without chemical protectants
Plant characteristics, which are not observed in conventional spring wheat VCU *	• recovery from mechanical harrowing • tillering • speed of closing the crop canopy • canopy density • stay green index • distance of ear to flag leaf • compactness of the ear • resistance against sprouting • black molds in the ear	• not observed • not observed • not observed • not observed • not observed • not observed • not observed • not observed • not observed
Evaluation baking quality	• evaluation on whole wheat bread without artificial bread additives	• evaluation on white bread with addition of ascorbic acid

*** Other aspects that are observed and listed in the conventional protocol as well as in the organic protocol are not mentioned.**

A review of the conventional research protocol for VCU testing showed that this research could not identify better varieties for organic agriculture. Not only because testing is done in conventional fields instead of under organic conditions, but also because important characteristics such as canopy characteristics and soil coverage are not observed, see Table 15. It was agreed with the Dutch Commission for the List of Recommended Varieties that the protocol should be adapted for special testing for organic agriculture. The EU regulation 70/457/EU allows such adaptation, because the condition for admittance to a National Variety List requires at least for a certain region a clear improvement, either for the production or the valorisation of the harvest or of the derived products. A poorer performance with regard to certain characteristics can be compensated by other positive traits.
A protocol for testing spring wheat varieties for organic agriculture was elaborated and discussed with organic farmers, researchers and breeders. A Working Group for Organic Wheat was formed to finalise the VCU protocol and supervise its execution. The final version was accepted by the Dutch Commission for the List of Recommended Varieties in 2001 (Lammerts van Bueren et al., 2001c).

In 2001, the Louis Bolk Institute and PPO-AGV (Lelystad, The Netherlands) started a three year project in which VCU executed according to the organic protocol was compared with a variety trial with the same accessions grown under the conventional VCU regime without chemical protectants. Preliminary results of the first year showed that differences between varieties for vegetative traits such as canopy density and ground cover were better observed under organic growing conditions. In the first year in the conventional trial differences between varieties were small, while the same varieties grown under organic conditions showed clear differences for these traits. On the other hand, differences in levels of susceptibility for diseases were more clearly shown under conventional circumstances. In the organic trials diseases appeared later and reached lower levels than in the conventional field. Varieties in the conventional field trials also showed severe lodging, including the organic standard variety Lavett, while lodging did not occur under growing conditions in organic farming. Finally the use of chemical seed treatment had an effect on the outcome of the trial. Some varieties showed better emergence in the conventional fields with treated seed than with untreated seed in the organic fields. These preliminary findings underline the importance of doing VCU testing under organic conditions (unpublished data).

Do current varieties match the organic crop ideotype?

On the basis of the first results of the official organic VCU trials on three organic locations with spring wheat in 2001 (Osman & Van den Brink, 2002) we can give an estimation of the

Table 16. Comparison of the current spring wheat varieties for baking of the Dutch National List of 2002 (Bonthuis & Donner, 2001) with the organic ideotype. Comparison based on the organic VCU trails in 2001.

	Anemos	Baldus	Lavett	Minaret	Pasteur	Sunnan [1]
Good Baking Quality						
Protein content	[3]	+	+	+	++	++
Zeleny value	[3]	+	+	– – –	+	+
Hagberg falling number	[3]	+	+	+	+	+
Specific weight	[3]	++	+	+	++	+
Good Grain Yield	[3]	–	+	–	+	–
Efficient use of organic manure [3]						
Reducing Risks of Diseases						
Long straw	–	– –	+	–	– –	+/– [2]
Ear high above flag leaf	–	–	+	+	–	++
Ear not too compact	– –	– – –	+	–	– – –	– – – – –
Last leaves green for the longest time possible[3]						
Resistance against:						
Brown Leaf Rust (*Puccinia recondita*)	+	++	++	– – – –	+++	++
Yellow Rust (*Puccinia striiformis*)	++	+++	+++	– – –	+++	+++
Leaf spot (*Septoria* spp.) [3]						
Fusarium spp. [3]						
Mildew (*Erysiphe graminis*) [3]						
Supporting weed management						
Good recovery from mechanical harrowing[3]						
Good tillering capacity[3]						
Rapid closing of crop canopy	[3]	+	+	+	–	[3]
Canopy density	+	–	+	+	–	+
Reducing Risks at harvest						
Stiff straw	++	++	++	+	+	+
Early ripe	– – – –	++	+	+	– –	– – –
Resistance against sprouting	++	++	+	++	+	–

1 Sunnan is not on the Recommended List of Varieties but on the National List.

2 +/- Organic farmers consider this variety too long instead of too short.

3 Boxes left blank means that no information on the characteristic is available yet.

matching of the varieties, listed in the Dutch National Variety List of 2002, with the organic ideotype, see Table 16. For the development of the ideotype farmers used the variety Lavett as their reference variety. Most organic farmers grow this variety and are satisfied with its characteristics. Therefore it has positive scores for all characteristics. The other varieties lack high scores for one or more traits to make them suitable for organic farming. What is especially noteworthy in the table is that all varieties scored lower than Lavett for those plant morphological characteristics, that may create an unfavourable growing environment for fungal diseases (tall plant, long peduncle (distance from flag leave to ear), compact ear). This illustrates that breeders are highly focussed on resistance genes, and pay less attention to crop architecture that can support tolerance against diseases. From an organic point of view one would like to rely on as many defence mechanisms as possible, so combining resistance genes with morphological characteristics, in order to make the system less vulnerable to possible breakdowns of one of these defence mechanisms. In addition, organic farmers do not want to rely on just one good variety, because varieties usually have a short lifetime due to breakdown of vertical resistances. As the Recommended List only contains one suitable variety (Lavett) there is an urgent need for more varieties. Lavett was included in the list in 1998, and has only recently been followed by Pasteur in 2002. This new variety scores well for yield, quality characteristics and resistances, but is poor in soil cover. This illustrates how urgently the organic sector needs to pay special attention to the characteristics adapted to organic farming systems.

Organic seed production of wheat

During the last few years organic farmers have experienced disappointing seed emergence rates, especially in cold and wet springs. In the first year of VCU testing this was confirmed with some varieties showing problems in the organic fields, while emergence was normal with chemically treated seeds in the conventional fields. Seeds used in organic farming have to fulfil the requirements of the EU regulation concerning organic farming and also the conventional regulations on quality aspects of propagated material. The EU regulation 2092/91 for organic agriculture states that organically propagated seeds should be used. If not available derogation for the use of conventional untreated seed is possible until the end of December 2003. For annual crops seed is regarded as organic seed, when it is produced by a crop that is planted and raised organically for at least one generation. That implies that in principle conventionally produced basic seed, though as seed chemically untreated, can be used to produce organic commercial seed before it is sold to organic farmers for wheat production. This is largely the practice in the Netherlands. In many other European countries often conventionally propagated basic cereal seed is no longer used, but repeatedly organically produced cereal seed is. Because of the EU regulation 2092/91 more and more organically produced seed will be used that has been untreated during seed production, and risks of contamination with seed-borne diseases like Fusarium and Septoria, will therefore require more attention in the future. This requires more attention to strategies which avoid seed-borne diseases and to seed treatments and threshold values for contamination on organically produced wheat seed, see below.

Fusarium

After contamination with Fusarium in recent years, organic farmers are becoming more and more aware of this problem. Contamination by *Fusarium* spp. can be air and seed borne. Fusarium reduces the size of the grain in the ear, and also reduces emergence rate to a great extent. It is therefore even more important for organic farmers that the soil conditions during the time of emergence of spring wheat should be as optimal as possible. It may mean not sowing too early in springtime (Dornbusch et al., 1993; Thomas & Wyartt, 2002). This problem was confirmed by a one year pilot pot trial with 14 different conventionally and organically managed soils and seed lots of the spring wheat variety Lavett with different levels of contamination (Hulscher & Lammerts van Bueren, 2001). The differences in emergence were not related to differences between conventionally and organically managed soils, but to the physical characteristics of the soil. In this study the emergence of seeds lots with 25% contamination of *Fusarium* spp. on heavy, compact clay soils was 40%, whereas on lighter sandy soils 60-70% emerged.
Because *Fusarium* spp. and also *Septoria nodorum* reduce emergence and vigour, it is important to avoid the marketing and use of seed with too high levels of contamination. In most European countries rejections of seed lots in organic seed production of winter wheat were due to contamination with common bunt (*Tilletia caries),* because repeatedly organically propagated seed is used. Other reasons were insufficient seed calibration, low germinability, and presence of the seed borne pathogens *Fusarium* spp. and *Septoria nodorum* (Dornbusch et al., 1993; Rüegger et al., 1998; Borgen & Kristensen, 2000). Latterly in the Netherlands, common bunt has rarely occurred. An explanation could be that conventional wheat seed lots are standardly chemically treated, and most organic wheat seed usually originates from crops that are produced organically during one year out of untreated, conventionally produced seed (G. van den Bovenkamp, NAK, personal communication 2002).

Seed treatments

In cases where the disease level is hard to control by cultural practices and resistant varieties are not yet available, development of post-harvest treatments are an important complementary measure. During the past 10 years many studies have been conducted in different European countries on alternative, post-harvest seed treatments to control common bunt and other cereal

fungal diseases in organic farming with good perspectives (Spiess, 1986; Spiess & Dutschke, 1991; Becker & Weltzien, 1993; Winter et al., 1997; Winter et al., 1998; Heyden, 1999; Borgen & Davanlou, 2000; Borgen & Kristensen, 2000; Kristensen & Forsberg, 2000; Plakolm & Söllinger, 2000; Schachermayer et al., 2000). These authors mention several alternatives that have been effective (> 95% control) with limited side-effects on seed germination in trials on common bunt control, such as several different ways of using warm or hot water treatments, seed dressing with mustard flour or milk powder, acetic acid, etc. The warm or hot water treatments are very labour intensive and therefore expensive, and are only realistic in exceptional situations.
Grading can also be a way of limiting the adverse effects of certain kinds of fungi on cereal seeds by selecting wheat seeds larger than 2.5 mm in diameter (Hare et al., 1999). Prior (1991) found that wheat seeds greater than 2.5 mm were less likely to succumb to fungal attack from diseases such as *Septoria nodorum* and *Fusarium* spp. under organic conditions than smaller sized grains.

Threshold values for seed-borne diseases
In some countries research is ongoing to adapt official seed health regulations for marketing organic cereal seed, because they are insufficient for the trading of undressed seeds. This is also confirmed by the Dutch seed control organisation NAK which is concerned about the expected seed health, because conventional cereal seeds are treated in a standard way and they have therefore stopped routine research on Fusarium and Septorium (Anonymous, 2000; G. van den Bovenkamp, personal communication, 2002). According to the official Dutch regulations for certified cereals, seed lots with a Fusarium contamination rate above 25% have to be (chemically) treated or discarded. Treatment is advised and mentioned on the certification label when the seed lot is contaminated with a rate between 10 and 25%, but treatment is not compulsory. In the Netherlands no experience is available with organic treatment of wheat seed. Usually farmers are advised to use a higher seed rate, like 170-200 kg ha^{-1} for spring wheat with contamination by fungi.

Consequences for further improvement of organic wheat production from a non-chemical and agro-ecological point of view

Considering the results of the above-described non-chemical and agro-ecological approach aimed at gaining progress in the improvement of spring wheat varieties for organic farming systems the main constraints in improving organic spring wheat production in the Netherlands are:
- the limited availability of soil nutrients;
- insufficient competitiveness against weeds;

- susceptibility to Fusarium and Septoria;
- low yield stability;
- limited choice of suitable varieties;
- the need for adapted organic baking quality standards;
- seed quality and the need for adapted organic standards for threshold value of seed-borne diseases;
- high demand for safe food and controlling of mycotoxin production by ear fungi.

In most cases, these constraints also apply to winter wheat and to the organic practices in other European countries, although the priority order can differ per region (Osman et al., 2002). Next to agronomic research an important contribution to these afore-mentioned problems can be made by improvement of varieties. This requires more attention from breeders to the ecological demands on breeding for organic farming systems. Therefore several strategies can be developed. Without elaborating this issue extensively in this contribution three aspects should be mentioned. One way of improving adaptation to the different soil fertility, manuring and nutrient uptake system is by following regular breeding and selection schemes but under organic field conditions, with or without a participatory approach. In addition to this strategy more attention should be given to selecting varieties that can profit from an optimal relationship between crop (roots) and beneficial soil microorganisms (Lammerts van Bueren et al., 2002c).
Another approach is to develop a different strategy for disease resistance and yield stability by broadening the genetic basis and thus by enlarging functional biodiversity, e.g. through variety mixtures (Lammerts van Bueren et al., 2002d). Variety mixture is an option for keeping the disease pressure as low as possible. Varieties should then have the ability to grow in combination with other varieties (Wolfe, 1985). Variety mixtures do not have priority in the Dutch organic farming systems at this moment, because Dutch organic farmers fear low yields and baking quality, such as they experienced in the 1980s. Recent results of trials with mixtures of currently available varieties look promising on both yield and baking quality (Osman & Schaap, 2002).

Including the concept of integrity of plants in organic seed production and breeding strategies of spring wheat

Up to now we have discussed the role of the non-chemical and agro-ecological approach for organic plant breeding and seed production for further improvement of organic wheat production. As described in the introduction the organic sector intends to take the integrity of plants into account too, as part of the concept of naturalness (Verhoog et al., 2002b). The concept of integrity of plants refers to respect for the characteristic nature of plants, their wholeness, completeness, their species-specific characteristics and their being in balance with the species-specific environment (Lammerts van Bueren et al., 2002f), see Chapter 6. Such ethical aspects are becoming more and more of an issue for consideration in organic agriculture. Although, there is already more experience in the animal husbandry sector in dealing with the concept of integrity of organisms, in many cases the practical and agricultural implications of integrity of plants still have to be elaborated by the organic sector. In this section, we will give an indication in which direction the implications of such a concept for organic seed production and plant breeding of spring wheat could develop on the basis of the four criteria for integrity of plants mentioned earlier (see Table 12): integrity of life, planttypic integrity, genotypic integrity and phenotypic integrity. The focus in this section will mainly be on the perception of plants and the suitability of techniques for propagating and breeding of wheat.

Acknowledging and taking the integrity of plants into account does not mean that one cannot interfere with the plant's development. Unquestionably, cultivated plants are in many ways dependent on human cultivation, but from an organic and bio-ethical framework of action[18] one wants to restrict that dependency to a certain extent. From an organic point of view it is the duty of mankind to integrate the development of our cultural heritage of cultivated plants into the ongoing development of agriculture and mankind. So plant breeding is considered as a respectful and important part of the development of organic agriculture to produce and further develop productive and healthy, nutritional plants and varieties. The aim is to develop a 'plant-worthy' way of breeding and seed production of wheat to gain further improvement of spring wheat, well adapted to organic farming systems and producing good processing and nutritional quality.

Perception of wheat as a cultivated plant

In the search for a 'plant-worthy' and species-specific plant breeding (in German: art-gerechte Pflanzenzüchtung) and to more consciously develop an eye for the genotypic and phenotypic integrity of wheat, some organic wheat breeders have investigated the basic characteristic of wheat and its potential spectrum of appearances by studying different gene bank accessions in relation to their region of origin (a.o. Kunz, 1983; Kunz & Karutz, 1991; Müller, 1998; Heyden,

[18] In ethics usually four different normative bio-ethical frameworks of action are distinguished: anthropocentric, zoocentric, biocentric and ecocentric (a.o. Taylor, 1986). In an anthropocentric theory only human beings are ethically relevant, which means humans have no direct ethical responsibilities towards nature. In a zoocentric theory only human beings and sentient animals are ethically relevant, whereas in the biocentric theory all living entities are considered ethically relevant, which means that the intrinsic value is taken into account in decisions on the exploitation of nature. In an ecocentric, bio-ethical framework not only individual organisms, but also species and ecosystems have ethical relevance. In Verhoog et al. (2002) it is concluded that to fully describe the ethos of organic agriculture the bio-ethical framework of action can better be described as holocentric.

1997; Heyden & Lammerts van Bueren, 2000; Müller, 2000). One of the typical questions one can ask in relation to the integrity of wheat is: what is typical of cereals as cultivated plants compared to their wild relatives, such as grasses. Another relevant question is: what are characteristic elements in the growth dynamics and morphology of wheat compared to other cereals such as barley? Below is an example of how several organic cereal breeders elaborate such questions in search of a way of studying and taking the intrinsic value and integrity of the cereal plant into account.
Typical in the growth pattern of wheat or cereals in general, which they have in common with their wild relatives, are the different development phases: germination, root formation, early leaf formation and tillering giving the juvenile plant a short-grass appearance. Once the plant shifts from vegetative to reproductive growth the stems and their ears elongate followed by flowering and seed formation. The ability to build up a fruit with more and refined substances for human nutrition (and not merely a germ in a seed to produce the next generation) by keeping its fruit in balance with growth (mass building) and senescence, distinguishes the cultivated cereals from its wild relatives (Kunz, 1999). The ripening process can be delayed because of too much vegetative growth and negatively influenced by a too large susceptibility to fungi or even by lodging. But it may also happen that the grains cannot grow out well because of too poor (soil) conditions. Well-ripened grain does not only comply with the quality specifications such as protein content and specific weight, but also with bread quality criteria such as smell and taste (Kunz, 2000). In search for those plant types that can optimally use their ripening ability under organic conditions, Kunz compared the growth dynamics of old and modern wheat varieties. One can see that through the breeding activities of the past hundred years that not only the peduncle length but also the way in which the fruit forms and ripens have fundamentally changed. The modern short straw varieties build up their yield by being much more dependent on a steady supply of nutrients from the soil and prolonged synthesis of proteins and carbohydrates, whereas the old varieties with long straw accumulate their grain yield to a larger extent through translocation of nitrogenous compounds and carbohydrates from the straw to the kernels. It is clear that going back to the old varieties is not the solution for modern organic agriculture (Stöppler et al., 1989), but the question is more a matter of striving for a certain balance or harmony in the plant's growth dynamics which cannot be considered independent of its environment. Kunz (1983) found that under organic and thus low(er) input farming conditions, plants with a clear distinction between the vegetative development in the juvenile phase and reproductive development after booting were most capable of developing their potential of optimal ripening. He could more easily find such plant types among taller wheat types than among the modern dwarf types. Such selection criteria result in plants with a longer peduncle, so that the ear ripens further above the wet leaf canopy by sun and wind demanding varieties with a plant architecture

that contributes to more tolerance against fungi in the ear. Such a plant type with an extended juvenile phase has more ability to cover the soil and is therefore more weed suppressive.
This way of perceiving the species specific growth dynamics of wheat does not result in one static image of wheat performance. Wheat should be able to adapt to different, regional growing and climate conditions. This means practically that a breeder includes a dynamic image of what he considers to be a balanced plant performance in relation to the purpose and regional specific conditions he is aiming for.
More research is needed and pilot studies are ongoing to develop a method for assessing the relationship between differences in growth dynamics and the adaptation to ecological environmental and quality aspects, such as baking quality including sensory criteria of bread, and to find corresponding field selection criteria (Karutz, 2000; Kunz, 2000; Arncken, 2001).

Techniques
Another consequence of respecting plant worthiness is considering the breeding and propagation techniques. For mainly self-pollinating wheat, techniques applied for breeding include combination crossings, bridge crossings, backcrossings, mass or pedigree selection; and for multiplication and seed production mostly the 'normal' generative propagation techniques are applied. Following the concept of integrity these techniques at whole plant level respect the plant worthiness (planttypic integrity). These mentioned techniques leave the wholeness of the plant (in the sense of the whole life cycle in a continuous interaction between plant and organic environment) intact throughout the whole process of crossing, selection and seed production.
In the past many crosses have been made in wheat breeding programmes with closely related or wild relatives, and therefore in some cases embryos have been cultured to gain successful crosses. 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 microspore culture followed by induced (colchicine) or spontaneous chromosome doubling and a few varieties are already available that are based on these techniques. It concerns crosses that in principle can occur in nature and therefore do not impair genotypic integrity. Another approach is to obtain doubled haploids through interspecies hybridisation with maize causing chromosome elimination, followed by induced or spontaneous chromosome doubling. All these mentioned techniques are developed to speed up breeding programmes. Following the concept of integrity would imply that such *in-vitro* techniques are not in compliance with the planttypic and phenotypic integrity, because the processes of fertilisation, embryo growth and seed formation do not occur on the whole plant, see Table 12 (Lammerts van Bueren et al., 2002f). From a non-chemical point of view one can argue that these processes still remain at the level of life (of organised cells) but the fact that these processes occur under laboratory conditions with artificial media and nutrients is not in

line with organic principles (Müller, 1996; Lammerts van Bueren & Luttikholt, 2001). The consequence of leaving out these techniques is that organic breeding programmes will take more time compared to the current way of breeding.
Most of the crossings with wild relatives, which require laboratory techniques, are aimed at incorporating resistance genes. As an alternative, searching for a more sustainable way of wheat breeding, Kunz (2002) is not so much focussed on single specific resistance traits, but searches for those plant types within the range of longer straw types (1.10-1.30 m) that can cope with fungi. His selection criterion is not a specific level of resistance but the ability of a plant to build up sufficient yield level and baking quality under organic farming conditions despite a certain level of presence of fungi (Kunz, 2002). This approach is similar to the durable resistance approach of Parlevliet (1975) and can also be found in the system of partial resistance, allowing the fungi to survive at a lower level of population density and preventing the re-adaptation of the fungal physiology breaking through the resistance. Resistance mechanisms such as field tolerance would fit the organic farming system because of the available lower disease pressure at lower nitrogen levels.

Discussion and conclusions

In this chapter we have elaborated the consequences of applying the organic concept of naturalness, which includes the non-chemical, the agro-ecological and integrity approaches, to see how such a concept can be a leading principle for the further developments of organic seed production and breeding of spring wheat varieties. Within these approaches short-term, middle-long and long-term options can be distinguished.

Non-chemical and agro-ecological approach
The non-chemical and agro-ecological approach is well established in organic agriculture and has not only resulted in standards given by the International Federation of Organic Agricultural Movements, but also in Europe by official governmental EU regulations 2092/91. Nevertheless we defined several obstacles for further development of organic spring wheat production from a non-chemical and agro-ecological point of view. Next to agronomic research an important contribution for solving these problems can be given by improvement of varieties.
So far breeding efforts and variety testing have almost only targeted conventional agriculture. As most of the above-mentioned constraints are not so much an issue in conventional agriculture, current varieties are not selected to cope with these constraints and hence considerable advances are to be expected with breeding efforts and variety evaluation for organic growing conditions. A major constraint from the breeders' side however are the costs, with regard to the fact that

organic agriculture in the Netherlands is still limited to 1.9% of the total area, although the Dutch government strives for 10% in 2010.
Therefore it is important to discuss the different perspectives of breeding for organic spring wheat which can be distinguished into short-, middle- and long-term approaches.

We have described the short-term approach that has been started in the Netherlands in order to stimulate conventional seed companies to look for better-adapted varieties among their existing material. An important first step was the participatory approach involving organic farmers in the development of a crop ideotype for organic spring wheat and the discussion with the seed companies on this ideotype. Such a participatory approach bringing farmers and breeders into direct contact helped the breeders to get a better understanding of organic farming systems. Here the farmer's eye can sharpen the breeder's eye. The results also showed that at this moment the choice among suitable spring wheat varieties on the Dutch Recommended List or National Variety List is limited. More and other types of varieties are urgently needed.
As an important next step an adapted protocol for Value for Cultivation and Use (VCU) testing was developed and applied in official VCU trials for organic spring wheat in the Netherlands, from 2001 onwards. This can enhance the possibility that new varieties with suitable traits for organic farming systems may pass the variety testing.

Socio-economic factors
An important issue that we have not elaborated in this chapter is the socio-economic 'environment' of organic plant breeding and propagation. If the above-mentioned short-term approach renders varieties which are only attractive for the organic sector, the maintenance of such new varieties will be costly. Seed companies are not prepared to maintain a variety only for the organic sector, let alone to finance a special breeding programme for organic varieties (Ruivenkamp & Jongerden, 1999; Lammerts van Bueren et al., 2001c). Another point is that to date all wheat breeding companies in the Netherlands have joined the organic VCU trials for organic spring wheat without considerable costs because it is an externally funded pilot project. The question is how such trials can be financed in the future. Both problems demand searching for alternative options for socio-economic conditions which maintain such varieties and organise variety trials for instance by organic farmers co-operatives.
In Lammerts van Bueren et al. (2002c) a participatory approach has been discussed involving close co-operation between breeders and farmers, and also involving farmers in the choice of parental lines for crossings: for them to undertake the selection for several generations on their own farms and return the most promising lines for further testing by the breeding company. Such co-operation makes it possible to screen large numbers of lines at lower costs and to complete

each others knowledge and skills, such as is known in the existing Dutch potato farmer breeders system (Van der Zaag, 1999). There are other pioneering examples searching for new organisational forms in other European countries supporting organic seed production by farmers and financing organic breeding programmes (Jongerden et al., 2002).

Variety concept

The step to special breeding programmes for organic spring wheat varieties is a real long-term approach and is very costly, but in the long run necessary to improve the spring wheat yield stability in organic farming systems. Although organic farmers are convinced that the modern wheat varieties bred for conventional agriculture, compared to older varieties, have improved the yield potential also in organic farming systems (Stöppler et al., 1989), we showed that they are still not optimally adapted to the demands of organic farming systems. In the organic sector, several specialised organic plant breeders in Switzerland and Germany have established breeding programmes for winter wheat varieties adapted to organic farming systems, but little attention has been given to spring wheat varieties. The problem is that spring wheat has great importance to the organic sector in the Netherlands but is of little importance in other European countries. Improvements in the short-term management of specific fungal diseases are to be expected with the further development and application of variety mixtures (Finckh et al., 2000b; Lammerts van Bueren et al., 2002d). This requires research to sort out the most effective combination of varieties in the mixtures. In the long run an organic variety concept requires a broader genetic basis for further improvement of yield stability, as is discussed in Lammerts van Bueren et al. (2002d), see Chapter 4. In that chapter it is suggested that a start is made with composite crosses between a large number of selected varieties. Out of this population, grown under organic conditions for several generations, further selection for adapted lines can follow for either new single varieties or for line mixture varieties.

Perspectives for organic seed production of spring wheat from a non-chemical and agro-ecological point of view are more positive, but need further optimisation. In most years the total need for spring wheat seed in the Netherlands is covered (Lammerts van Bueren et al., 2002e). The general conclusion from experience in the past is that organic seed production of spring wheat is possible, but that the percentage of marketable seed of sufficient quality largely fluctuates from year to year and from one seed lot to another, due to variation in weather conditions and the risk of contamination with seed-borne fungi, such as Fusarium. Optimisation of cultural practices of seed production includes actions regarding development of resistant or tolerant varieties, seed testing on all seed-borne diseases and adapted standards for organic cereal seed health quality. Further development of adapted testing and threshold values for seed-borne diseases is necessary to protect organic farmers from using seed with too high a level of contamination of seed-borne fungi and therefore too low seed quality.

The integrity approach
The consequences of the integrity approach do not constrain the seed production methods of organic spring wheat, but concern mostly organic breeding techniques. The EU regulations 2092/91 have excluded the use of genetic modification in organic agriculture, but the international discussion on assessment of all other available breeding techniques only began a few years ago and needs more time to settle all the arguments and assess the practical consequences for regulations on breeding techniques. The IFOAM has recently proposed draft standards for organic breeding to give direction to future policy heading for considering whole plant techniques as the most obvious breeding and propagation techniques for organic agriculture. This requires in the future specific organic breeding programmes.

General conclusions
To optimise the organic spring wheat production, new varieties are required complying with a new variety concept. It should be a challenge for the breeding sector not merely to interpret the principles for organic breeding and propagation as restrictions to 'leave out' certain techniques, but also to develop new approaches within the framework of the organic principles of naturalness to gain the desired progress for organic wheat production with new or additional breeding concepts. This includes multidisciplinary approaches from a non-chemical, agro-ecological and an integrity approach in which variety improvement can play an important role for organic spring wheat. Further elaboration of the concept of integrity including the perception of plants must show in which way it can complete the non-chemical and agro-ecological approach in developing a broader variety and breeding concept for the optimisation of organic spring wheat production.
Not only the ecological environment but also the socio-economic environment of organic plant breeding and propagation should be further studied. It is not likely that conventional seed companies will start special breeding programmes for organic spring wheat, unless the needs in conventional agriculture are also simultaneously served. This will only be the case if the government's policy with regard to fungicides and herbicides becomes more strict in the future. Even if conventional farmers would appreciate more disease resistance and the ability to suppress weeds in wheat varieties, the problem still exists in respect of better adaptation to low(er) input of organic fertilisers. In the long run the organic sector can only benefit from special breeding programmes focussed on the requirements of organic farmers and processors. Such

organic breeding programmes will not be possible without an adapted socio-economic environment: developing suitable organisational forms involving the participation of farmers.