Organic plant breeding and propagation:

concepts and strategies

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Abstract

The organic farming system differs fundamentally from conventionally agriculture in the management of soil fertility, weeds, diseases and pests. Organic farmers depend greatly on conventionally bred and produced varieties, but require varieties better adapted to organic farming systems for further optimisation of organic agriculture. This includes a greater need for 'reliable' varieties contributing to higher yield stability.

In this thesis the concept of 'naturalness' as applied in organic agriculture is elaborated and used as a guide to develop concepts and strategies for organic plant breeding and propagation. It refers to ecological and ethical principles, including the non-chemical and agro-ecological approach, and also taking the integrity of life into account.

Based on these approaches the organic farming system is described and a general crop ideotype is defined. In the long run organic agriculture can only gain further progress when the genetic basis is renewed and broadened, and when the selection process is conducted under organic farming conditions. For self-fertilisers the concept of (isophenic) line mixture varieties seems most promising, being composed of lines which are phenotypically uniform but genetically heterogeneous. The ability to produce healthy seed under organic conditions should also be included in the variety ideotype. Further research is needed to develop protocols for seed health testing, to assess threshold values for seed-borne diseases and to design organic seed treatments.

To improve transparency in the discussions on the ethical aspects of organic agriculture concerning the assessment of the suitability of the breeding and propagation techniques, the concept of the intrinsic value and integrity of plants has been elaborated and operationalised. Therefore principles are derived from the relevant characteristics of the nature of plants at four different levels: integrity of life, planttypic integrity, genotypic integrity and phenotypic integrity. Techniques at whole plant or crop level are most in line with these principles, respecting the self-reproductive ability and the reproductive barriers. The concept of integrity of plants can also give direction to the perception of plants in the selection process by the so-called breeder's eye.

The consequences of the ecological and ethical principles for the concepts and strategies for organic plant breeding and propagation are demonstrated for the case of spring wheat in the Netherlands, including the adaptation and application of the protocol for Value for Cultivation and Use (VCU) testing. The participation of organic farmers with their experiential knowledge and farmer's eye was essential in the development of the spring wheat ideotype, but can also contribute to the selection process of new varieties. The proposed organic crop ideotype and variety concept may benefit not only organic farming systems, but in future also conventional systems moving away from high inputs of nutrients and chemical pesticides.

Keywords: crop ideotype, genetic diversity, integrity of plants, intrinsic value, isophenic line, mixture varieties, organic plant breeding, organic farming, organic propagation, participatory plant breeding, variety characteristics, seed-borne diseases, seed quality, spring wheat, threshold values, variety concept, variety mixtures.

Preface

This thesis not only marks an important milestone in my personal search for and dedication to the issue of organic plant breeding, varieties and seeds. It also marks an important point in the development and research policy of the Louis Bolk Institute (LBI, Driebergen, The Netherlands), a research institute specialised in organic agriculture, health care and nutrition. At the present time we are stimulating several researchers to pick up the challenge not only to show the results of our work to the organic sector itself, but also to publish them in scientific articles or as a PhD thesis. This gives us the opportunity to present the contribution of our LBI-research work and methodology to the international scientific community.

The idea of writing a thesis myself might never have arisen if Evert Jacobsen, professor in Plant Breeding at Wageningen University, had not been pointing me in this direction for quite some time. Our paths have crossed on many occasions and it may have appeared that we were representing opposite fields (gene technology versus organic breeding). But Evert always supported me in clearly putting forward the approach of the organic agricultural sector. The final stimulus came from Paul Struik, professor in Crop Physiology at Wageningen University, and experienced in propagation and agrobiodiversity issues. He presented me with the opportunity to provide a basis for my orientation in organic plant breeding and propagation from an agronomic, farm and crop system based approach. The respect that both my promotors Paul and Evert have shown for the field of organic plant breeding and propagation, and their commitment and support in writing this thesis, made them without any doubt the best promotors I could have wished. With endless patience, enthusiasm and inspiration they helped me to bring structure into the research results and practical experience. They also challenged me to elaborate further some of my less developed topics, such as the role of genetic variation in an organic variety concept and the concept of integrity of plants. I am very grateful to Paul and Evert for challenging me to the utmost while staying close to the main issues.

I could never have withdrawn myself from the daily running of the institute for such a long time without the encouragement of my colleagues and team. I am very grateful to the Louis Bolk Institute and the Iona Foundation (Amsterdam) for allowing me this opportunity and funding the study for this PhD thesis, based on my research since 1993. I owe thanks to many colleagues at the Louis Bolk Institutes, especially Ton Baars, Erik Baars, Joke Bloksma, Monique Hospers, Chris Koopmans, Aart Osman, Eugène Thijssen, Marjolein Tiemens-Hulscher, Henk Verhoog, for the

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From other institutes I would like to thank Christine Arncken, Jos van Damme, Pat Heaf, Gon van Laar, Susanne Lijmbach, Piet Stam, Jan Velema, Klaus Peter Wilbois, Johannes Wirz and Martin Wolfe for their critical and fruitful comments on earlier drafts. For extra information I am grateful for the help several seed companies were prepared to give me, and I also thank Coen ter Berg, Louise Luttikholt, Jan Parlevliet and Piet Stam for the time they spent in answering my questions and commenting on my viewpoints. Thanks are also due to Arjen Dekking (PPO-Lelystad, The Netherlands) for sharing unpublished data of crop yields in the DFS-project (Nagele, The Netherlands) to elaborate the issue of yield stability.

The fundamental work behind this thesis is the research work that could not have been done without the ongoing requests and commitment of many organic farmers. They were prepared to conduct variety trials on their farms, and allow us, many other farmers, breeders and other involved participants in their fields to assess the suitability of many varieties between 1999-2002. I therefore especially thank Tineke Bakker, Hans Bals, René Groenen, Frans Haverbeke, Riet Heurkens, Jos Jeuken, Jan Jonkman, Wim Keuper, Gert Jan Kos, Cees Kristelijn, Lex Kruit, Mindert Meindertsma, Jan Nijmeijer, Henk Oosterhuis, Anna van Oostwaard, Paula Peters, Hans Risseeuw, Dignie van der Dries, Jan de Veer, Thieu Verdonschot, Niek Vos, Henk Wansink, Jan de Winter, and Jan van Woerden.

In this period of writing many dear friends kept me on my feet, of whom I especially thank Anna Schwerdtfeger, Martijn and Laurence Niemeijer, Priscilla van Leeuwen, Jeroen en Juna de Vries, John and Georgine Lammerts van Bueren, Jaap van de Weg, René Alofs, Oscar van den Boezem, Brigitte Langner, Volkert Engelsman, Jaap van der Haar, Carlien Erlings, Kim Geerlings, Myra van Bladel, Susanne Vlijm, and not to forget my parents, and my sons Florian and Michiel.
Last, but not least, I am grateful to the plant world itself for revealing some of its secrets, from which I have learned the beauty and diversity of their appearance. I am especially indebted to my 'mate' the carrot (*Daucus carota* L.) who inspired me in showing how in a cultivated plant the influence of (the realm of) light above the soil works into the realm of darkness in the roots, by bringing taste, scent and colour into the carrot.

Edith Lammerts van Bueren
Driebergen, September 2002.

Contents

1

General introduction

This thesis is written in the context of an organic agriculture[1], which is increasingly gaining more societal, political and scientific recognition for its contribution to a sustainable agriculture, and which is continuously searching for further optimisation and the development of new areas such as organic plant breeding and organic propagation.

Background

Although organic farmers also profit from the improvements of modern breeding activities, the fact that most organic farmers in north-western Europe use modern varieties does not imply that those are the best varieties for optimising organic agriculture (Stöppler et al., 1989; Jongerden & Ruivenkamp, 1996). Varieties supplied by conventional seed companies are developed for farming systems in which artificial fertilisers and agro-chemicals are widely used. Organic farming, however, aims at a 'natural' way of farming, refraining from agro-chemical inputs and applying agro-ecological strategies (Lampkin, 1990). Therefore organic farmers require varieties with characteristics that are better adapted to this kind of farming system. While first developing other areas of their farming systems organic farmers have long accepted their dependence on conventional varieties, perhaps with the exception of some pioneering farmers and breeders in organic plant breeding and propagating. This situation changed when genetic modification[2] became important in plant breeding. Organic farmers realised that they are not only concerned about the variety traits but also about how varieties are bred and propagated, and thus comply with ethical principles in organic agriculture. The dependence on conventional varieties is no longer a desirable situation if the organic sector wished to design its own future without the application of genetic modification (Anonymous, 1991; Bullard et al., 1994).

In order to put more pressure on closing the chain, EU regulation 2092/91 demands the ending of the general derogation allowing the use of conventional propagated seed and planting material for organic agriculture. From 2004 onwards only the application of organically propagated varieties will be permitted. Because organic agriculture is not just product oriented,

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[1] One can find the origin of organic agriculture long before the agro-chemical revolution made environment into an issue, at the beginning of the 20th century in several countries (Woodward et al., 1996). Organic agriculture is nowadays defined by the International Federation of Organic Agricultural Movements as follows (IFOAM, 2002): "Organic agriculture is a whole system approach based upon a set of processes resulting in a sustainable ecosystem, safe food, good nutrition, animal welfare and social justice. Organic production is therefore more than a system of production that excludes certain inputs". Organic agriculture is understood to be that section of the agribusiness which operates in accordance with the standards of the International Federation of Organic Agricultural Movements (IFOAM, 2002) and in the European Union according the EU regulation 2092/91 (Anonymous, 1991).

[2] Genetic engineering of higher plants is defined in this thesis as 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.

but mainly a production controlled agricultural production system, not only are the ecological characteristics of varieties important, but also the way in which these varieties are bred and propagated in compatibility with the principles of organic agriculture. In that context the world umbrella organisation for organic agriculture IFOAM (International Federation for Organic Agricultural Movements) has very recently (August 2002) given direction to future developments with respect to organic plant breeding by presenting draft standards for organic plant breeding definition and techniques to be used (IFOAM, 2002).

Involving farmers and seed companies

Given the above-described developments the discussions in the past few years on the possible consequences of demanding and developing organic breeding and propagation no longer remain free. Complying with the EU regulations on organic farming entails a great effort for the seed sector, initially in developing adequate organic propagation strategies to supply the organic market with sufficient quantities and quality of seed. At the moment, only a few of the seed companies also consider breeding for organic agriculture. With the step of producing organic seed on a larger scale the commercial seed sector has now become economically involved and needs support, not only by the organic sector defining their desired variety characteristics, but also from research in order to remove several obstacles in this new area. This would enable the further improvement of organic propagation and breeding strategies.

Since 1993, the author of this thesis, being affiliated to the Louis Bolk Institute (Driebergen, The Netherlands), a research institute specialising in organic agriculture, human health and nutrition, has conducted several projects with organic farmers, breeders and researchers. The aim of these projects was to arrive at varieties that are better adapted to Dutch organic farming systems and comply with the ecological and ethical principles of organic agriculture. In this exercise the following steps were included: investigating the obstacles for seed companies to begin organic propagation of varieties for organic farming systems, and developing criteria for and leading the national and international discussion on assessment of plant breeding and propagation techniques compatible with the principles of organic agriculture (Lammerts van Bueren, 1993, 1994, 1996; Velema & Lammerts van Bueren, 1996; Wirz & Lammerts van Bueren, 1997; Lammerts van Bueren et al., 1998, 1999, 2001d; Heyden & Lammerts van Bueren, 2000; Lammerts van Bueren & Luttikholt, 2001). Not only did these projects involve desk study but field work with organic farmers was also included; conducting and adapting variety trials on organic farms with farmers defining crop ideotypes in several regions, and finally starting participatory plant breeding projects with several farmers (Lammerts van Bueren & Hulscher, 1999; Lammerts van Bueren et al., 2000, 2001a, 2001b, 2002a, b; Hulscher & Lammerts van Bueren, 2001; Lammerts van Bueren & Van den Broek, 2002a, b, c; Lammerts van Bueren, 2002).

Involving mainstream science

To date the results of the above-mentioned projects of the Louis Bolk Institute have been published in reports and articles aimed mainly at a readership consisting of organic farmers, because organic farming systems have been developed by organic farmers themselves with some additional research from private institutes, such as the Louis Bolk Institute. Only recently has there been more support from governments for research on organic farming systems by mainstream institutes and universities (Niggli & Willer, 2002). This implies that it is no longer farmers only who are converting from a conventional approach to an organic approach, but also scientists (Colijn-Hooijmans, 2001). For rapid progress, it is important to involve mainstream science in research projects focussed on questions related to organic plant breeding and propagation. Pressure has been brought to bear as most European governments are now striving for 10% organic agriculture of the total agricultural area by 2010 (a.o. LNV, 2000). For the organic sector it is important that this research is based on the understanding of the possibilities and limitations of the organic farming system (Lockeretz, 2000; Baars, 2002). Illustrative is the question often asked, whether or to what extent organic plant breeding differs from conventional breeding for simply another market sector, and the question of whether the organic sector is better off with a 'clean' start by using chemically treated seeds instead of untreated, organically produced seeds.
A better understanding of the ecological and ethical implications of the principles of organic agriculture will stimulate scientific involvement in future discussions and research projects aimed at designing and improving organic plant breeding and propagation. It can open new perspectives for the improvement of organic varieties in directions that have hardly received attention up to the present time. The general aim of this thesis is therefore to raise the subject of organic plant breeding and propagation to a scientific level.

Focus and objectives of this thesis

For the development of plant breeding and propagation for organic agriculture the question is how one can come to an ideal type of variety (crop ideotype) with ideal seed (Fig. 1). The starting points are the ecological and ethical principles of organic agriculture. However, plant breeding is not only determined by the principles of organic agriculture, but the technical, socio-economic and legal aspects aspects of breeding have also to be considered and have their influence on how the crop ideotype can be conceived. All these aspects play a role in the further process of propagation and seed certification in the realisation of ideal seed for organic agriculture. In this thesis the emphasis lies mainly on the ecological and ethical aspects of organic plant breeding and propagation. In many projects the participatory approach was central, not only involving farmers but also involving all the necessary players, including traders, breeders, scientists and policy makers. Elaborating the implications for socio-economic and legal conditions in a more extensive way is also necessary but beyond the scope of this thesis.

The main objectives of this thesis are:

- to clarify the ecological and ethical principles of organic agriculture,
- to define the consequences of the ecological principles of organic agriculture for a crop ideotype,
- to discuss the consequences of the ecological principles for an organic variety concept,
- to discuss the consequences of the ecological principles for organic propagation strategies,
- to elaborate the consequences of the ethical principles for organic plant breeding and propagation,
- to elaborate the consequences of the organic principles for organic plant breeding and propagation of spring wheat in the Netherlands as a case.

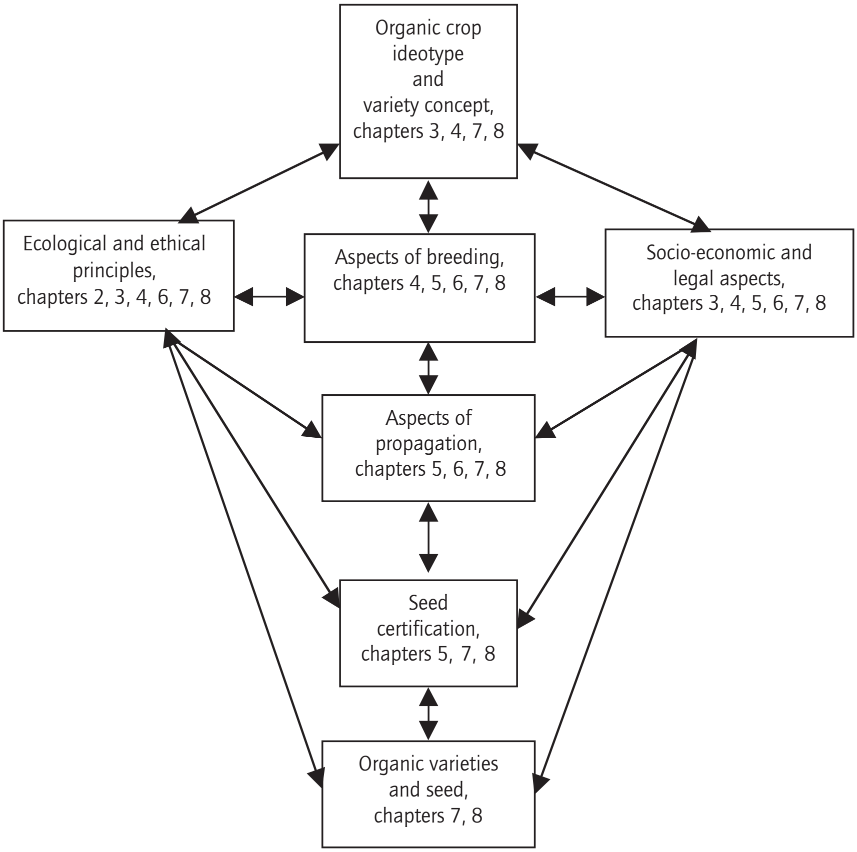

Figure 1. How to come to an ideal type of variety (crop ideotype) with ideal seed for organic agriculture.

Approach of the thesis
To meet these objectives concepts and strategies for organic plant breeding and propagation will be elaborated on the basis of the experience and results of research projects in the period from 1993-2002 completed with literature research. Most of the experience is based on the current organic agricultural situation in the Netherlands, but through international contacts and workshops many aspects of organic agriculture in the north-western and the middle part of Europe have been taken into account.
The ecological and ethical principles do not have an equal position in this thesis. The ecological principles of organic agriculture are already well established and regulated by the IFOAM standards and EU regulations, but the ethical principles are only recently being discussed and defined in the organic sector, and are not yet settled. Because the ecological and ethical principles of organic agriculture are not in the same stage of development, and have therefore different impact on the current practice, they have been described separately. This enables the distinction of short-, middle- and long-term directions of developments.
Once the ecological and ethical framework of organic agriculture has been defined (Chapter 2), the consequences of the ecological principles for organic plant breeding and propagation will be elaborated and discussed (Chapters 3, 4, and 5). This will be followed by a definition and discussion of the ethical principles (Chapter 6). Both principles will be integrated in the case of organic spring wheat production in the Netherlands (Chapter 7).

Outline of the thesis
In Chapter 2, the ecological and ethical principles of organic agriculture will be defined on the basis of the concept of naturalness, which was elaborated through a number of in depth interviews with key-players in the organic sector. This provided the basis for the development of a description of the ethos in organic agriculture.
In the following chapters (Chapters 3, 4, and 5) firstly the implications of the ecological principles of naturalness will be discussed. In Chapter 3, this will be done by clarifying to what extent the organic farming system differs from the conventional farming system. The meaning of the central principle in organic agriculture of stimulating the self-regulatory ability of the farm ecosystems through functional biodiversity will be described. This provides the basis for analysing the consequences of such an ecological principle resulting in a general ideotype for organic varieties. After having discussed the role of biodiversity at farm and field level, Chapter 4 will focus on the role of genetic variation at variety level. The implications of the ecological principles for the requirements and prospects of an organic variety concept and breeding strategies will be discussed, taking the economic and legal aspects into account.
Compared to the field of breeding, more experience is gained with organic propagation.

The obstacles and challenges of applying the ecological principles to the field of propagation, including the seed certification requirements, will be defined and perspectives will be described in Chapter 5. In this complex field of actors all involved in different ways, a description of the role of each partner in the process will be included.
In Chapter 6, the meaning of the ethical principles with respect to plant breeding and propagation will first be conceptualised and will then be instrumentalised. This includes the possible consequences for the evaluation of the breeding and propagation techniques and the way plants can be perceived in the selection process.
To give an example of how the concepts and strategies for organic plant breeding and propagation can be applied the case of spring wheat in the Netherlands is analysed (Chapter 7). Here the results of first concrete steps in the development towards ideal organic spring wheat varieties will be analysed and discussed, and further perspectives will be outlined. In order to eventually evaluate new varieties for their suitability for organic farming systems the protocol for variety testing needs adaptation. This has been realised for spring wheat in the Netherlands and the results are discussed in this chapter.
In the last chapter (Chapter 8) an overview of the given concepts and strategies for organic plant breeding and propagation, including their main obstacles and challenges, will be discussed.

2

The role of the concept of the natural (naturalness) in organic farming

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Abstract

Producers, traders, and consumers of organic food regularly use the concept of the natural (naturalness) to characterise organic agriculture and organic food, in contrast to the unnaturalness of conventional agriculture. Critics sometimes argue that such use lacks any rational (scientific) basis and only refers to sentiment. In our project, we made an attempt to clarify the content and the use of the concepts of nature and naturalness in organic agriculture, to relate this conception to discussions within bio-ethical literature, and to draw the implications for agricultural practice and policy.
Qualitative interviews were executed with a range of people in the field of organic agriculture and with consumers of organic products, on the basis of a list of statements about the meaning of the concept of naturalness formulated by the authors. Based on the results of the interviews, we distinguished three aspects of the concept of naturalness: natural as the organic (life processes), natural as the ecological, and natural as referring to the characteristic nature of an entity. We related these conceptual aspects to three main approaches within the field of organic agriculture: the no chemicals approach, the agro-ecological approach, and the integrity approach. It became clear that these approaches can also be recognised in the change of attitude of farmers as they convert from conventional to organic agriculture, and in the attitudes of consumers of organic food products.
We conclude that the idea of 'naturalness' can be used to characterise organic agriculture and to distinguish it from conventional agriculture, but only if naturalness not only refers to not using chemicals but also to ecological principles and respect for the integrity of life. Thus perceived, the principle of naturalness can also serve as a guide to future developments in the field of organic agriculture. As part of the holocentric ethics of organic farming the value of naturalness has three dimensions: a cognitive one, an emotive one, and a normative one.

Keywords: organic agriculture and food, concept of nature and naturalness, ethics, environment, farm ecology, integrity of life

Introduction

In advertisements for organic food products, the 'naturalness' of the product (produced in a natural way) is often emphasised. Naturalness is regularly mentioned to characterise organic farming, and is contrasted with the unnaturalness of conventional agriculture. Supposed examples of unnaturalness are the following: dehorned cows in strawless yards, debeaked hens kept in large flocks, growing plants in a water culture, use of synthetic pesticides, modern reproductive techniques such as ovum pick up (embryo rescue) or genetic modification, etc. In discussions about genetically modified organisms (GMOs), the critique that the technique of genetic modification is unnatural is seen as one of the so-called intrinsic consumer concerns, not primarily based on the (extrinsic) consequences, the risks for human health or for the environment, but related to the human attitude towards nature (Reiss & Straughan, 1996; Nuffield Council, 1999; Task Group, 1999). In such discussions, organic farming is often mentioned as an alternative to the use of GMOs, again suggesting that organic farming could be seen as a (more) natural form of agriculture.

Critics[3] of the argument from (un)naturalness have argued that the focus on the concept of nature and integrity appeals to little more than sentiment and confusion. The terms 'nature' and 'natural' are said to refer to two things only. It can refer to everything in the universe, that is, everything to which the laws of physics, chemistry, and biology apply. This would imply that every sort of agriculture is natural, and no distinction can be made between different forms of agriculture. In this way one could argue that also genetic modification is natural, because natural processes at the molecular level are exploited, in contrast to fields such as chemistry where really synthetic products are made. The second sense of natural refers to pristine nature, unaffected by human interference. Then nothing humans do (including all agricultural activities) can be natural in this sense. So, either everything or nothing humans produce is natural. A more philosophical kind of critique of appeals to nature refers to the distinction between statements describing facts and normative statements. According to this distinction human values cannot be derived from nature. Doing so is called a naturalistic fallacy. In this kind of critique, the value-ladenness of the concept of nature or the natural is often overlooked. What is it that gives the word natural such a positive feeling for many people, as compared with the artefactual or the forced for instance? Or the other way round, when nature is opposed to culture, nature tends to get a more negative colouring. The human mind is then related to culture and the body to nature. According to some authors (see Sieferle, 1989) this opposition between people with a positive attitude towards nature and people with a more negative attitude has been deeply embedded in Western culture since the time of the Greek philosophers. Sieferle

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[3] This kind of criticism we recognised quite explicitly in the report of one of the referees of the first version of this article. Another example is a recent short article by Vijverberg (2001) about the difference between 'chemical' and 'natural'. An unambiguous meaning of natural is called 'the physical', as the opposite of supernatural or metaphysical. All man-made physical things become natural as well. Natural as opposed to artificial is regarded as a concept that is too ambiguous to be useful, because in our modern world what is usually called natural cannot be distinguished from what is cultural. The same arguments were put forward by the philosopher John Stuart Mill in the nineteenth century (see for this Sagoff, 2001). Mill argued that the term 'nature' can either refer to the totality of things or to those phenomena that take place without the agency of man (often called pristine nature) and that we have already passed that stage a long time ago.

distinguishes between the (Christian) view of a ‘harmonious nature’, which is good, which can be trusted, and the concept of a ‘fallen nature’, as a mirror of sinful humanity, which is threatening and seen as an enemy that has to be conquered. This distinction can be recognised in the opposition between natural healing methods (trusting the self-healing capacity of the human body) versus modern medicine (in which diseases have to be conquered as an enemy). As we will see in this article, a similar distinction can be made between organic agriculture and modern agriculture based upon experimental science.
It is clear from these discussions that an explication of the concept of nature and the (un)natural within organic agriculture is urgently needed, if only to prove that there is more at stake than just sentiment and confused ways of argumentation. It is important for the producers and consumers of organic food and for all those involved in education and propagation of organic agriculture. The goal of our research project is, therefore, to clarify and make explicit the concept of naturalness in organic agriculture and the attitude of organic farmers and consumers of organic products towards nature. Is the scope of the concept of naturalness in organic agriculture indeed limited to the two meanings distinguished by the critics, or is more involved?

Materials and methods

This project has been conducted at the Louis Bolk Institute in 1999-2001 within the framework of the stimulation programme Ethics and Policy of the Netherlands Organisation for Scientific Research (NWO) (Verhoog et al., 2002a). Four phases can be distinguished in the project:

Interviews with key-figures in the field of organic farming in the Netherlands
An obvious way to do empirical research about the view of nature of producers of organic food would be to use a bottom-up approach of concept-mapping: the people who are interviewed are free to choose their own formulations, which are then grouped together in some previously selected way. Instead of this method, we have chosen a top-down method. The authors have already had long experience with discussions in both bio-ethics and organic agriculture (plants, animals, nutrition). Before this project began the bio-ethicist in the group had done research on the use of the concept of nature and integrity in discussions about the genetic modification of animals (Visser & Verhoog, 1999). One of the goals of the present project was to extend the theoretical framework developed in that context to the field of organic agriculture (including plants as well as animals). Because of this background, the authors decided to write a discussion-document in which they formulated what they believed to be the meaning of naturalness within organic agriculture.

The discussion document contained explicit statements about the meaning of naturalness in the following areas: the relation between (agri)culture and nature, biotechnology, sustainability, agro-ecosystem, animal husbandry, arable cropping, food and nutrition, and bio-ethics. We here give a shortened version of the 16 statements in the discussion document related to the production process, without the explanation that accompanied them:

1. A widely accepted characteristic of organic agriculture compared with conventional agriculture is its naturalness.
2. Control of the production process is not directed at becoming independent of nature. It is control with respect for nature and natural processes. Because of this organic agriculture is closer to nature than conventional agriculture.
3. Organic agriculture wants to integrate culture and nature.
4. Genetic manipulation is seen as unnatural and in conflict with important values of organic agriculture related to respect for life and species barriers.
5. Biotechnology can have effects that are positive for the environment, but it is not a technology that is 'green' in the ecological sense.
6. Genetically modified food is considered to be unnatural because of the way it is produced.
7. Sustainability is defined within the context of the agro-ecosystem as a whole, in which no use is made of techniques and substances that are foreign to the system.
8. The naturalness of organic agriculture is not always a guarantee that it is good for the environment.
9. Means of production in organic agriculture must show respect for plant, animal, nature and environment.
10. (and 11 combined) The organic farm is an agro-ecosystem with a characteristic 'individuality', in which the farmer is aware of the interrelatedness of all the elements of the system.
12. Naturalness in organic animal production primarily means that the characteristic 'nature'of the animals is taken into account (using natural medicine, supporting natural behaviour, and respect for animal integrity).
13. It is out of respect for animal integrity that some modern reproduction techniques are rejected.
14. In organic agriculture the characteristic nature and integrity of plant species are respected.
15. In organic agriculture we see a gradual transition from growth in open soil to growth in greenhouses. On the basis of the concept of naturalness it is hard to draw a sharp borderline, except for hydroponics.
16. Food that is grown in a natural way is considered to be important by consumers.

The qualitative interviews were meant to check whether key-figures in the field of organic agriculture agreed with these statements, and to find out whether important aspects of the concept of naturalness were missing in the document. Key-figures are defined as people who, according to the authors, possess expert knowledge about one or more of the following areas of organic agriculture: dairy cattle, pig keeping, hen keeping, animal feeding, horticulture, plant breeding, food processing and trade, control organisations, education and information, and representatives of organisations defending the interests of organic farmers and consumers. We interviewed 25 key-figures. The results were summarised and discussed in a workshop.

Interviews with representatives of consumer organisations and consumers
We first had interviews with some representatives of consumer organisations. These interviews were meant to check the views of the authors, as expressed in the following statements (formulated before the results of the interviews with the consumers were known):

17. A consumer of organic products will be more aware of a relation between nature and agriculture than a consumer of conventional products.
18. Consumers of organic products will spontaneously reject biotechnology, because it is associated by them as being artificial, unnatural, unknown, and therefore worrying and probably dangerous.
19. Consumers will associate naturalness with sustainability and care for the environment.
20. The consumer will be unaware of the concept of an agro-ecosystem.
21. The consumer will associate naturalness with animal welfare rather than the use of natural medicine.
22. The consumer will regard as unnatural many ways of organic production that are considered natural or indispensable by the producers.
23. Consumers who buy organic food at the market or directly from the farmer will know most about food production in general and naturalness in particular.

We then compared these statements with the view of consumers of organic products. Being interested in the values and motives of consumers for buying organic food, and the role of naturalness therein we decided to use a qualitative approach. A quantitative approach is not helpful in a situation where there exists confusion about the boundaries and meaning of the concept of naturalness. To find out what consumers have in mind when they say that organic agriculture is more natural than conventional agriculture a qualitative method is more useful. The in depth interviews with consumers were done by a marketing research centre (Motivaction; see Van Amersfoort & de Wit, 2000) by means of 18 paired-interviews and 2 single interviews, 10 in a more urban and 10 in a more rural city. The consumers had used organic basic food products for at least one year. The interviews with the consumers were done after those with key-figures in the field. The questions were formulated by Motivaction on the basis of the discussion-document of the authors and the results of the interviews with key-persons. Questions were grouped in the following way:

- the personal experience of consumers with nature, organic agriculture, conventional agriculture;
- the mutual relations between naturalness, care for the environment, sustainability, and vitality;
- methods of production and processing organic food (plants and animals);
- criteria used by consumers in purchasing organic food products.

Normative (ethical) research aiming at a reconstruction of the system of values and norms of organic agriculture, and the role of different aspects of the value of naturalness within this system
The bio-ethicist in the research group wrote a discussion-document in which he tried to situate the organic conception of naturalness in relation to different bio-ethical theories and meta-ethical discussions. This discussion-document has been critically reviewed by representatives of three different bio-ethics centres in the Netherlands. This led to a substantial revision of the original document.

Policy phase
In the last part of the research project, the authors drew conclusions as to the policy implications. On the basis of the results of the empirical and normative phases in the research project, policy implications were formulated, relating the concept of naturalness to several styles of organic agriculture that can be distinguished in the present situation. These implications were discussed at a workshop.

The role of the concept of naturalness in the field of organic farming, including consumer perception of naturalness

Interviews with people holding key-positions in the field of organic farming
As expected, the respondents did not agree with all the statements formulated by the authors. On the whole, all respondents agreed on the statement that organic farming is more natural than conventional farming, which is considered to be more artificial. All realised that farming as such is a cultural activity in which human beings interfere in nature. It is the way of interference that makes the difference. When the concept of nature is understood as pristine, wild nature, without any interference of human beings, it becomes impossible to talk about naturalness in

connection with agriculture. This is realised very well within the field of organic agriculture. And yet, most respondents considered it a useful concept in comparison with conventional farming. The question then becomes why they think so and what they mean by 'more natural'. Summarising the results of the interviews, most respondents found organic farming to be more natural because:

- Although organic farming is part of human (agri)culture, its aim is to be harmoniously integrated into nature (finding a balance between human interests and nature's interests). Conventional farming, on the other hand, shows a tendency to become independent of nature (fully controlled by technology, mainly aiming at high production).
- Nature (a natural entity) is not seen as a mechanistic material system but as a complex organic, living whole.
- The concept of nature as an organic whole corresponds with the daily human experience of nature, in contrast to the more analytic, abstract, and reductionistic concept of nature underlying modern science (which has a great influence on modern agriculture).[4]
- In organic farming, man interferes less radically in natural processes and living entities and the means used are less artificial or synthetic ('natural means'). It is considered to be a gentler technology, making use of the laws of nature at an ecological level, versus the harder technology (including genetic manipulation) of conventional farming.[5]
- There is a positive attitude towards nature: nature should be considered as a friend and not as an enemy. Therefore, one can speak of a dialogue, as if nature is a partner, with a self-organising capacity. This idea returns in the rejection of certain modern (genetic) breeding technologies as being coercive, rather than eliciting.
- There is a wisdom in nature that enables the farmer to learn from nature: nature as a teacher (when the farmer makes mistakes it has consequences in the ecosystem or the health and behaviour of plants and animals; from that the farmer can learn). Carrying capacity of the ecosystem, recycling, harmony, precautionary principle (derived from the complexity of nature).
- It is because of the wisdom of nature that nature is considered 'good', deserving our respect. It does not mean, as many critics suggest, that what takes place in (pristine) nature is automatically good or healthy for human beings
- Many organic farmers try to stimulate natural biodiversity within their agro-ecosystem.
- Genetic engineering and several other modern reproductive techniques in plants and animals are rejected out of respect for natural species barriers (the species-specific 'nature', the

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[4] It is the latter conception that is used by the critics mentioned in the introduction: nature as everything to which the laws of physics, chemistry and biology apply.

[5] The words 'gentle' and 'hard' are used here in the way it has been formulated by A. von Gleich (1989).

integrity of the plants or animals). There is also the uncertainty involved in applying the results of reductionistic thinking in the environment (human arrogance in believing that one can control a complex organic system with gene technology).

On the whole respondents agreed with the 16 statements formulated by the authors. One or two respondents said that sustainability or vitality should be the most important goal (value) of organic farming, instead of naturalness.
As to the statements about gene technology, one person had no problems with the technology as such, only with the intention behind it, and the present socio-economic context in which the technology is developed. Gene technology, although unnatural, could still contribute to a better environment. An interesting critique of gene technology was that it makes the farmer dependent on specialists from outside; the farmer loses control over the agro-ecosystem.
With respect to sustainability, some agreed that with a very restricted definition of naturalness (using products of natural origin, thus not produced synthetically in the laboratory), it is true that this does not automatically lead to a healthy environment (think of excess use of organic manure, or copper). Also the effect on the ecosystem should always be considered. Others think that organic farming is automatically sustainable if the farmer takes the harmony, stability, or ‘nature’ of the agro-ecosystem as its guiding principle (carrying capacity, recycling, low use of energy, etc.). Problem areas are the cultivation of fruit and rearing of pigs and poultry for meat production only.

Interviews with consumers about their perception of nature
Representatives of consumer organisations expect that naturalness is an important criterion for consumers of organic products, and that there is not a fundamental difference between consumers of mostly organic products and consumers of biodynamically produced food. More important is the difference between consumers who buy in supermarkets and those who buy in health-food stores. For consumers, more natural food is related to less interference, less processing, less artificial, no use of additives. Consumers will not connect the naturalness of the production of food with sustainability or with the idea of an agro-ecosystem. Naturalness in connection with the production of animal food is brought into relation with a high standard of animal welfare (natural behaviour, not forcing animals to grow fast, not mutilating the animals, etc.). It is expected that consumers will consider unnatural: heating of greenhouses, artificial light, plastic groundcover in spring, a lot of synthetic manure to let plants grow fast, tomatoes in winter.
These expectations proved to be quite reasonable when we compare them with the results of the consumer interviews:

- In spontaneous descriptions of organic agriculture consumers often use the word nature or natural (natural balance, naturalness as norm, closer to nature, producing as natural as possible, leaving nature in its value, using the forces of nature).
- Most consumers do not define nature as wildness, but as everything that lives (growing by itself). The concept of nature has an emotional meaning as well: peacefulness, silence, freedom, becoming yourself, holidays.
- The amount and way of processing a primary food product influences the naturalness. Less processed food, or food processed in a traditional way without additives is associated with more natural food.
- The more artificial the food production and process the less natural it is. Genetic engineering is from that point of view very unnatural.
- Production related to season and region, amount of energy input, but also the kind of package material, affects the (perceived) naturalness of food.
- Consumers can perceive a special food process as natural, but this is not always a reason to buy the product. For pragmatic reasons, they can choose a more desirably processed food product (which might not be natural at all).
- Natural(ness) in general is associated with: simple, pure, non-artificial, unspoilt, and fair.
- Agriculture in general is in some ways a natural activity: outside, fresh air, contact with plants and animals on a caring and basic level. It is clear to consumers that organic agriculture is more natural than conventional agriculture.
- The concepts of naturalness and care for the environment correspond more with the idea of organic farming than vitality or sustainability. Naturalness is one of the basic conditions of organic agriculture (besides: care for the environment, no pesticides, and food safety).
- Sustainability is in the first place associated with paint and materials used in buildings. In the second place food from organic agriculture is seen as *less* sustainable by part of the consumers because they presume that it is less storable, or *more* sustainable if people look at the impact on the soil.
- Vitality is a very difficult concept for consumers when associated with food or agriculture. They can only imagine a very healthy and vital looking organic farmer.

The consumer interviews also brought out, as was expected by the people holding key-positions in organic agriculture, that most consumers have little knowledge of food production in general and organic production in particular.

Interpretation of results

To be useful for any policy with respect to the future of organic agriculture, the meaning of nature or the natural that is implicit in the results as presented has to be re-interpreted and be made more precise. We have done this in a step-by-step approach, by comparing that meaning with the definition of the natural as used by critics (see introduction). Critics say that 'nature' can mean only two things:

A. everything in the universe (everything to which natural laws apply);
B. pristine nature.

A. The first meaning (everything in the universe) is far too general to do justice to the complexity of the concept of nature. In the organic view of nature, a distinction is made within the universe between inorganic and organic nature. Agriculture is primarily related to organic or living nature. That is why it is called *organic* agriculture (in the Netherlands: *biological* agriculture), clearly indicating that it deals with the realm of living nature.
   This leads us to the first interpretation of the distinction between what is natural and what is unnatural: the natural is related to the realm of living nature, that is nature as it is experienced spontaneously by most people (see also the interviews with consumers). This common sense view of nature is not the same as pristine nature. What is important is that it lives and grows by itself. On reflection, one can distinguish several aspects of this interpretation:
   - Living as opposed to dead (inorganic nature is dead in this sense).
     Chemical pesticides and herbicides are related to death, not to life.
   - The idea of the autonomy of life.
     Life processes have emergent properties compared with non-living nature. In genetic modification techniques, the level of life is reduced to the molecular (physico-chemical) level.
   - Natural substances versus synthetic substances, produced in the laboratory.
     The laboratory or the factory is associated with the mechanical (the machine-like), a metaphor that is traditionally opposed to the metaphor of the organic.

In organic agriculture this emphasis on the autonomy of life-processes can be approached negatively and positively. The negative approach we have called the no chemicals approach (where 'chemical' stands for all synthetic inorganic substances), and the positive approach the agro-ecological approach.

Approach 1: The non-chemical approach
This approach to organic farming is very similar to the one that is defined by official legal standards. It is a negative approach in the sense that organic agriculture is said to distinguish itself from conventional farming because no chemical pesticides, no synthetic fertiliser, no GMOs, etc. are permitted. Farmers have to replace (bio)chemical-synthetic substances by more natural substances. Instead of chemical sprays against diseases farmers use 'natural' sprays or biological control, synthetic fertiliser has to be replaced by organic manure, and instead of herbicides, mechanical weed control is used. Even the use of homeopathic remedies in animal husbandry can be seen from this point of view. Homeopathic medicine is believed to be more natural because it is derived from natural substances, and not from chemical substances synthesised in the laboratory.
This approach often is the first step in the conversion process from conventional to organic farming. Farmers are motivated to stop using unnatural chemical sprays and artificial manure. This approach is linked to a rather limited view of human and environmental health. The distinction between living (organic) nature and dead (inorganic) nature is then associated with the distinction between healthy and unhealthy (related to death). Using no chemical pesticides and herbicides (etc.) is believed to be healthier not only for the environment, but also for humans. Although this association definitely is not true in all cases[6], it is related to a strong belief of producers and consumers that organic food is healthier. This also is the motivation behind the fast process of the industrialisation of organic food production (the 'Organic-Industrial Complex'), especially in the USA (Pollan, 2001; Sagoff, 2001). Pollan discovered that the way of thinking behind this industrialisation process is very much conventional. The aim is to produce uniform organic products that have to be substantially processed in order to transport them over long distances.
Experienced organic farmers believe that this negative approach to organic agriculture, based on a too limited conception of the natural, is not enough. They think that organic farming needs a more fundamental change in the way of thinking about how to handle problems and find solutions. Put rigorously, they think that the no chemicals approach is still based on the suppression of symptoms, and the desire to create a highly controllable environment in which pests and diseases have to be fought and to be eliminated. Organic farming should be more than substituting natural substances for those permitted by the organic regulations. The thinking of the no chemicals approach remains analytical. Acting is based on symptom reduction and

[6] **Many critics of organic farming keep on emphasising that 'natural' food can be very dangerous for humans (health risks of organic manure, poisonous substances within natural plants) or for the environment (the use of pyrethrum or copper for instance).**

solutions have a piecemeal character. This brings us to the second (ecological) approach to organic agriculture and the concept of nature underlying it.

B. When nature is defined as pristine nature, as the opposite of culture, then any form of agriculture is unnatural by definition, because pristine nature is defined as nature uninfluenced by human action. The results of our interviews show that most respondents do not share this dualistic ('either-or') view of the relation between nature and culture. The second interpretation of what is meant with 'natural' has to do with this relation between nature and culture. We think that in the organic view of the relation between (agri)culture and nature, it can best be described as a polar, dialectical relation. This means that:
   - The two poles (nature and culture) cannot be defined independently of each other.
   - One pole cannot be reduced to the other.

To look at the relation between nature and culture as a polar relation has important consequences. The first consequence is that it becomes legitimate to speak about human agricultural activities as more or less natural. This will be made explicit in the second, agro-ecological approach to organic agriculture. It is recognised that agriculture is a cultural activity, but the word 'ecological' is added to emphasise that it aims to be as natural as possible. This means that the relative autonomy of the nature pole is respected. The more this independence is respected, the more natural an agricultural practice is. This independence manifests itself not only in the application of natural substances, but also in integrating the self-regulating ability of living systems and in respecting the intrinsic worth of natural entities.
The second consequence of the polarity relation is that in a polarity relation all conceptions of nature get a value component. This led us to distinguish a third approach in which the man-nature relation within organic agriculture is looked at from a more ethical level. This approach we have called the integrity approach to organic agriculture.

Approach 2: The agro-ecological approach (focus on context)
That the nature pole has a value of its own was apparent from the interviews. In the agro-ecological approach this shows itself in the fact that in the agro-ecosystem, self-regulation is a very important principle. Conventional farming shows a tendency to become totally independent of nature, fully controlled by technology in an artificial environment. Although the plant itself still is a living organism, it is isolated from its natural surroundings. In organic farming, we find the opposite tendency, namely to integrate agricultural activities into nature. The farmer learns from nature. In practice this means that nature is defined as an ecological system, and the ecological farmer wants to model the agricultural practice as an agro-ecosystem.

During their conversion period, farmers might experience that they cannot ignore the ecological context when they are confronted with problems such as diseases. They notice that under organic circumstances, it is not sufficient just to avoid chemical pesticides and artificial fertilisers. A new attitude and another way of acting is needed based on the prevention of problems through knowledge of ecological processes. To sustain plant health, farmers begin to understand that the 'living soil' and soil life in particular needs to be taken care of. They experience that a soil with a good structure, sufficient organic matter, and active soil life is a necessary condition for healthy plant growth. Organic manure feeds the soil life. Organic farmers start realising that "we need to feed the worms and not merely the plants".

Diseases are now seen as symptoms of imbalanced systems: lack of balance between plant or animal and farm environment. Rather than fighting pests and diseases with chemicals, the emphasis shifts to control of the environment. To control aphids, for instance, the farmer has to create an internal system-controlled environment, rather than using repeated input from outside by spraying with natural sprays, or buying natural enemies. A more diverse environment is necessary in which plants growing in hedges, borders or ditches maintain natural predators within the farm system. Plant strength can also be increased through the right choice of manure, or by sound crop rotation.

All this means that farmers start to think in a more ecological way, looking for the broader context of a problem and realising that the farm should be transformed into a complex, sustainable, and balanced agro-ecosystem. Terms like closed system, mineral cycle, self-regulation, and biodiversity are important keywords to characterise naturalness in this approach of organic agriculture. One needs to work together *with* nature instead of fighting *against* nature. Solutions are based on rational, experiential, and experimental ecological knowledge.

Approach 3: The integrity approach

This approach is implied in the second consequence of the shift to a polarity view of the relation between nature and culture. In a dualistic view of this relation, culture, as the product of the human creative mind, is often opposed to nature as being a material object only. Nature in this view has no meaning or value in itself. The critics mentioned in the introduction totally neglect this valuational aspect of the concept of nature or the natural.

In a polar relation between nature and culture, the concept of nature always has such a valuational aspect. Results of the interviews indicate that for many organic farmers this valuational dimension is intentionally implied when they speak about the 'natural'. It manifests itself among others as respect for the integrity of life, for the agro-ecosystem, and for human needs (including social and economical integrity). The term 'natural' here refers to taking into account the characteristic nature of plants, animals, humans, and ecosystems because nature has

an intrinsic value.
Respect for the integrity of the farm ecological system, the living soil, the plant and animal species used is the result of an inner process of involvement with the way of being of natural entities. Farmers begin to experience that their focus on problems and solutions is connected wth their personal attitude and their personal relationship with either the soil or the cultivated plants or animals. They experience that the organic farming system is more than merely a complex ecological mechanism and more than the sum of the parts. This feeling is also present in relation to the plants or animals they take care of. They develop a respect for the wholeness, harmony, or identity of a living entity based on a personal involvement with the life of plants or animals. This attitude of respect inspires the farmer to find the right course of action at the right moment in the specific farm context. This respect for integrity has first been recognised in the field of animal husbandry. The animal's needs have to be understood by farmers in the context of the farming system. Cows should be fed as ruminants instead of monogastric animals like pigs and poultry. They should be kept as horned animals in a well-balanced herd. Dehorning can only be avoided if the farmers are prepared to develop a new way of acting based on the cow's needs in terms of herd management, housing, and feeding (Baars & Brands, 2000; Waiblinger et al., 2000). Also the cows' need for outdoor summer grasing is derived from respect for the cow's 'nature'. Outdoor grazing cannot be replaced by an outdoor run only.
As to the socio-economic aspects, we want to mention Community Supported Farms (Groh & McFadden, 1990) as an attempt to enlarge the concept of sustainability within ecological farming to the socio-economic sphere as well. In this system, prices of products are no longer determined by the free market system of supply and demand, but are based on the needs of the family living at a farm. Also soil prices should not be related to the free market but should be based on the agricultural use of the soil for the production of high quality food. The idea of consumer-supported farms is also of interest to consumers who are looking for less anonymous food products.

Bio-ethics and the ethos of organic farming

The authors have become convinced that naturalness is or could become an important element of the ethos of organic agriculture. The ethos is the system of ethical norms and values, the 'philosophy' behind organic agriculture. What is lacking in the no chemicals and in the agro-ecological approach is respect for the 'otherness', the identity, the characteristic nature of natural entities as partners of humans; and the realisation that humans are participants in nature. In the organic sector the ideal is to reach integration of culture and nature, without giving up the relative autonomy of both man and nature.

The authors conclude that naturalness is of moral value in organic agriculture. In the literature on value-clarification three components of the process of moral valuation are distinguished[7]:

- A rational (cognitive) dimension. To this belong the concept of nature, and of the relation between man and nature, in so far as these are connected with the valuation of nature. Different worldviews, including the scientific one, can play a role here.
- An emotive dimension. One must have the feeling that it is good, and that one feels good by it. Several basic attitudes towards nature can be distinguished: man as ruler, man as steward, man as partner of nature, and man as participant in nature. The basic attitude can be positive (nature is good, the wisdom of nature, etc.) or negative (nature is threatening, it has to be controlled, etc.).
- A normative dimension. The consequences of the foregoing dimensions for human action, for what we ought to do or not to do with nature. Here several bio-ethical frameworks can be distinguished: anthropocentric, zoocentric, biocentric and ecocentric.

There should be a certain consistent relation between these three dimensions. The emphasis on integration of culture and nature in organic agriculture, and a positive attitude towards nature as having a good of its own, asks for more holistic methods of research in which the autonomy of natural entities as partners is respected.

Of the different bio-ethical frameworks, there is not one that by it self is sufficient to characterise the ethos of naturalness in organic agriculture. Some form of man-centered stewardship is needed to emphasise the special role of man in nature, as a bearer of culture. The zoocentric element, which refers to the needs and subjective feelings of animals, is of great importance in organic agriculture. Combined with the attitude of partnership, this leads to some form of egalitarianism. In the biocentric framework, this is extended from animals to plants. Respect for the integrity of all living beings is present in organic agriculture. It plays a great role in the evaluation of modern reproductive techniques such as genetic modification. The ecocentric element is very important with respect to organic agriculture (especially in the agro-ecological approach). It can be recognised in the positive attitude towards wild nature, and respect for the wisdom of nature, especially in connection with the principle of self-regulation, the 'self' referring to the relative autonomy of nature. The principle of ecological sustainability is of great importance in organic agriculture: taking care of the fertility of the soil, rotation of crops, no use of chemical pesticides, etc. To be able to prevent diseases, it is necessary to understand the

[7] We refer here to the literature on value clarification (Simon et al., 1978) where these three dimensions can be recognised in the processes involved in all valuing: feeling, thinking, communicating, choosing, and acting. The three dimensions are also mentioned by Keulartz et al. (2000) in their study of conceptions of nature in relation to natural habitat restoration projects in the Netherlands.

coherence of the whole agro-ecosystem. The idea of preservation of diversity is extended to agricultural breeds and varieties. Finally, the ecocentric attitude is present in the idea of participation in nature, which brings with it an element of care and responsibility (precautionary principle and sustainability).

Somehow, the elements of the different bio-ethical frameworks have to be integrated in a new way, to do justice to the ethos of naturalness in organic agriculture. We have called this integrative framework: holocentric. The details of such a holocentric ethic have to be elaborated with the participation of the organic sector itself. Used as a guide in the process of further improvement of the organic production system, it does not exclude the making of compromises, but these should always have a temporary nature. It should be a source of inspiration, to come to moral decisions for those involved. It is not meant to be a strict juridical framework.

Discussion and conclusions

In reconstructing the results of the interviews, the authors have distinguished three meanings of the concept of nature, the natural, and naturalness in organic farming: firstly, natural as related to the realm of life and life processes (the organic); secondly natural as the ecological and thirdly natural as referring to the characteristic nature of an entity. These meanings have been connected to three different approaches in the field of organic agriculture: the non-chemical approach, the agro-ecological approach, and the integrity approach.

The three approaches could be seen as separate styles of organic farming. It also became clear, however, that these approaches can be recognised in the inner conversion process of farmers from conventional to organic agriculture (Bloksma, 1991; Dutilh & Mustard, 2001). Østergaard (1997), who was looking for the learning process of Norwegian orgaoic farmers during conversion, mentioned that through a continuous interaction between intentions, experience, experimenting, and information acquisition, the farmer successively gains knowledge about a new situation. At a certain stage, converting to organic agriculture means a personal ‘shift of paradigm’: old goals are left and new visions and goals are developed. So conversion consists of an internal or human part and an external, agronomic-technical or practical part. Although this does not mean that all farmers integrate the last level, there surely is a tendency in that direction.

Contrary to what critics say about the concept of the natural, we believe that good reasons can be given and are given why organic agriculture is more natural than conventional agriculture. It is not just a matter of defining the natural in a different way than do the critics; it is also believed that organic agriculture really is ‘closer to nature’. We conclude therefore that the concept of naturalness may be used to characterise organic agriculture and to distinguish it from

conventional agriculture, but only if all three aspects of the natural mentioned in this chapter are included. We think that the concept of naturalness is misused when only the first meaning is adopted, as is done in the non-chemical approach to organic agriculture. It should also include respect for ecological principles and for the integrity of living nature as a whole.
With naturalness as a criterion, the no chemicals approach is not sufficient enough to distinguish organic farming from an environmentally friendly, integrated form of conventional agriculture. When this first approach is broadened with knowledge and awareness of system ecology and respect for the integrity of life we have an important condition for further development and optimisation of organic farm management and organic product quality. Then it will be feasible to use the holocentric ethos of organic farming as a future guide for the organic sector as a whole, rather than the alternative of breaking up organic agriculture into different permanent styles, with separate trademarks. But then, a conversion in thinking is not only necessary for farmers but also for new policy makers, traders, processors, consumers, and researchers (Van Ruitenbeek, 2001; De Wit & Van Amersfoort, 2001; Baars, 2002). With the rapid growth of the organic sector, as implemented in several European policies, there is a risk that the implementation and interpretation of organic farming in the standards, in advising farmers, and in research, will mainly be focused on the first approach, thereby losing its connection with the intentions of organic agriculture.[8]

The authors presented their conclusions at an interactive workshop with participants who were involved in several policy issues related to organic agriculture. The participants were asked to give their answer to three questions:

- Do you recognise the three approaches in organic agriculture distinguished by the authors, and the conception of naturalness, which is related to it?
- Do you agree with the conclusion of the authors that the claim for naturalness is a useful criterion to distinguish organic agriculture, under the condition that all three aspects of naturalness are included?
- What are the implications of these conclusions for policy?

A large majority of the participants found the grouping recognisable and convincing, and a good basis for a discussion about the future direction of organic agriculture. It is useful as an inspirational guide, not as a normative (juridical) standard. It should become the subject for debate in the organic movement, including farmers (especially those planning to convert to

[8] The International Federation of Organic Agricultural Movements (IFOAM, 2002) makes a distinction between general principles, recommendations, and standards. We use the word ‘intentions’ as similar to principles because the general principles are described as the ‘intended goals’ of organic farming.

organic agriculture) as well as retailers and consumers. The grouping can create greater transparency, both inside and outside of the organic movement.


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Ecological concepts in organic farming and their consequences for an organic crop ideotype

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Abstract

Currently, 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. The organic farming system differs fundamentally in soil fertility management, weed, disease and pest management, and has higher demands on product quality and yield stability compared with conventional farming. Organic farming systems aim at resilience and buffering capacity in the farm-ecosystem, by stimulating internal self-regulation through functional agrobiodiversity in and above the soil, instead of external regulation through chemical protectants. For further optimisation of organic product quality and yield stability new varieties are required that are adapted to organic farming systems. The desired variety traits include adaptation to organic soil fertility management, implying low(er) and organic inputs, better root system and ability to interact with beneficial soil microorganisms, ability to suppress weeds, contributing to soil, crop and seed health, good product quality, high yield level and high yield stability. In the short run, organic crop ideotypes per crop and per market sector can help to select the best varieties available among existing (conventional) ones. However, until now many of the desired traits have not received sufficient priority in conventional breeding programmes. Traits such as adaptation to organic soil fertility management require selection under organic soil conditions for optimal result. The limited area of organic agriculture will be the bottleneck for economic interest in establishing specific breeding programmes for organic farming systems. The proposed organic crop ideotypes may benefit not only organic farming systems, but in the future also conventional systems moving away from high inputs of nutrients and chemical pesticides.

Keywords: organic farming, biodiversity, self-regulation, crop ideotype

Introduction

Organic agriculture is often described as a natural farming system. It is characterised by refraining from chemical-synthetic inputs, like chemical fertilisers and pesticides. It controls undesirable quantities of crop associates by stimulating the self-regulatory capacity of the agro-ecosystem as much as possible, for example by using agrobiodiversity at different levels of management (farm level, crop species level, variety level) within the organic farming system (Anonymous, 1991; IFOAM, 2002).

Verhoog et al. (2002) concluded that the concept of 'naturalness' as used in the context of organic agriculture not only refers to the avoidance of chemical inputs and the application of

agro-ecological principles, but also implies the acknowledgement and appreciation of 'integrity of life'. To be able to further optimise the organic farming system there is a need for varieties that are better adapted to the organic system and that are in compliance with the concept of naturalness.
Currently, organic farmers largely depend on varieties supplied by conventional plant breeders, who use conventional breeding and seed production techniques and develop varieties for farming systems in which artificial fertilisers and agro-chemicals are widely used. Organic agriculture is not merely a product-oriented farming system and thus requiring certain variety traits related to productivity, but it is also a production-controlled system that takes the breeding and propagation techniques and strategies into account; these are partly related to the concept of integrity of life. However, the latter issues are beyond the scope of this chapter and are discussed in Lammerus van Bueren et al. (2002f) and Lammerts van Bueren & Osman (2002).
This chapter will describe the kind of variety characteristics required to fit and support a self-regulatory, organic farming system from a non-chemical and agro-ecological point of view. We will first describe in what respect the organic farming system differs from the conventional one to stress the need for different variety traits, to analyse the complex and subtle management by the organic farmer using the ecological tools available and to describe the role of varieties in this context. Then the characteristics of the organic farming system and its main components will be discussed in more detail, resulting in consequences for specific characteristics of varieties desired for organic farming. In the light of the perspectives for achieving such traits, ultimately a crop ideotype for organic agriculture will be described.

Materials and methods

Data for this contribution are from research conducted at the Louis Bolk Institute, including variety trials with several crops under organic farming conditions in the period 1993-2002 (see Lammerts van Bueren, 1994; Lammerts van Bueren et al., 1998, 1999, 2001c, 2002b; Heyden & Lammerts van Bueren, 2000). Other results are based on information obtained from organic farmers and Dutch seed companies. The information is completed by literature research.

The self-regulatory ability of the organic farm-ecosystem: system stability and yield stability

Although organic agriculture is nowadays known for its avoidance of the use of agro-chemicals and its consequent striving for environmental benefits, organic agriculture is more than merely replacing chemical by natural compounds (IFOAM, 2002). In organic agriculture one does not want to rely on (phytosanitary) agro-chemical intervention because of the application of the concept of the integrity of life at the level of the ecosystem (Verhoog et al., 2002b), see Chapter 2. Production, however, remains very important for an organic farmer, but equally or even more important than productivity *per se* is the sustainability of the system. This implies that one appeals more to the ecological, self-regulatory and self-supporting ability of the agro-ecosystem (e.g., natural pest control and biotic regulation of soil gertility) through low input, and preventive, ecological practices than through high external inputs (Lampkin, 1990).

System stability

The self-regulatory ability of organic agro-ecosystems can be defined as the capacity to either resist the effects of small and large perturbations or show enough resilience to counter them without high input (chemical protectants) from outside the farm-ecosystem. Such system stability or resilience can often be found in multi-species agro-ecosystems and is important for risk reduction and yield increase (Vandermeer et al., 1998), but also for reducing population densities of harmfull organisms and increasing densities of beneficial organisms, both in the short and the long run.

Organic agriculture bases its sustainable, self-regulatory production system on the concept of a farm as an agro-ecosystem. An agro-ecosystem, defined as an ecological system within the agricultural context (i.e. with inputs, withdrawal of products, and interference by the farmer) is shaped by the strong interaction between the (variations in) abiotic and biotic environment, the genetic composition of species involved and the management resources available to the farmer (Swift & Anderson, 1993; Almekinders et al., 1995; Vandermeer, 1995). Among the biotic diversity there are associated organisms that are harmfull for crops, others that are beneficial for crop development, and also predators of e.g. damaging insects that together contribute to the self-regulating capacity of the agro-ecosystem through balancing and feedback mechanisms (Almekinders & Struik, 2000). The challenge for an organic farmer is to manage and support all these interactions on different levels in such a way that his farm can utilise ecosystem functions such as biological pest control, nutrient cycling, water and soil conservation provided by agrobiodiversity, in order to increase output, output stability and resource-use efficiency (Southwood & Way, 1970; Altieri & Nicholls, 1999). Organic agriculture regards biodiversity as an irreplaceable production factor or even a driving force at different levels of the farming system, and as an instrument for preventing (too high pressure of) diseases, pests and weeds (Geier, 2000). Such a self-regulatory, stabilising force in agro-ecosystems is not merely provided by a large biodiversity and high numbers of species *per se*, but mostly by a selective number of specific, functional species in a proper ratio: functional biodiversity (Southwood & Way, 1970; Altieri, 1999; Tilman, 1999; Finckh et al., 2000). Almekinders et al. (1995) stated that as a consequence of the variation in the factors that determine the agro-ecosystem, there is variation in their interaction and in the resulting agrodiversity. And because of the hierarchical structure of the agro-ecosysteem, variation in management by the farmer is both part of agrodiversity and the factor that manages it. It means that each organic farmer has to find his own way in managing site-specific diversity and identifying the correct assemblages of species (in time and space) that will best realise – through their biological synergism – the self-regulatory capacity of his individual farm-ecosystem. Next to the given differences in environmental conditions and the socio-economic context of each farm, differences in cultural practices, and the knowledge, skills and motivation of each farmer result in specific farming styles (Van der Ploeg, 1990), emphasising that the farmer himself is also part of the agrodiversity-complex. More than his conventional colleague who has greater means to control or overrule diversity, an organic farmer has to translate and apply general ecological knowledge to his specific farm situation (Baars & De Vries, 1999). In the biodynamic part of the organic movement the notion of uhe above-mentioned unique constellation of every single farm is not only expressed in the basic concept of a farm as an agro-ecosystem, but more specifically in the concept of a farm as a living (developing) organism with its own farm identity or individuality. The specific farm identity can be recognised and characterised, and can then be used by the farmer as a guiding principle to design and fine-tune the appropriate set of measures to enhance the resilience and stability within his farm-ecosystem for optimal farm and product quality (Lammerts van Bueren et al., 1990; 1992; Klett, 2000).

Yield stability

The reliability of an organic farming system depends not only on (high) yield levels with low inputs, but also largely on yield stability. Although organic farmers may gain relatively more system stability after their conversion period and several years of good farming practices, they still have few external inputs to quickly control or correct farm conditions during the growing season against undesired heterogeneous environmental conditions in time (weather, climate) and space (soil, topography). Reduced system stability can result in yield reductions and lower yield stability. In humid and temperate sea climate areas, like in the Netherlands, yield reductions are mostly due to the infection of crops (varieties) by fungal diseases (Theunissen & Köhl, 1999). In years with dry weather conditions organic farming systems can profit from the higher soil aggregate stability and can in some cases yield higher than the conventional system where organic matter content of the soil is often lower due to the use of mineral fertilisers (Raupp, 1996). The fact that yields fluctuate much more in organic agriculture than in conventional systems (Box 1 and Table 1), has become one of the most important factors that limit the growth of the organic market share (Spiertz, 1989; Raupp, 1996; Tamm, 2000; Mäder et al., 2002).

Box 1. Yield stability in organic farming systems.

In the Dutch project Development of Farming Systems (DFS) the organic farm showed lower yields than the conventional system and higher yield variability in the first five years (conversion period: 1980-1984). In the next period of five years (1985-1989) the yields remained lower than in the conventional or the integrated (reduced inputs from non-renewable resources) system due to lower nutrient supply and availability, variety choice and more infection by foliar diseases. The yields of the organic potato crop were in both periods of five years highly variable. Yields were mostly related to the (variable) severity of the *Phytophthora* infection. Although the yields of winter wheat in the organic system in both periods were lower than in the conventional system, the variability (expressed as the CV) did not differ much from the integrated system (in the first period) or from the conventional system (in the second period). For sugar beet the variability of the organic system was comparable with that in the integrated system but both were higher than that of the conventional system. For the onion crop the differences in yield stability between the organic and the integrated and conventional systems were the highest shown in this table. Like potato, onion is highly sensitive to weather conditions and weed and disease pressure. In one year the onion yield of the organic system was as high as that of the conventional system (Spiertz, 1989 and unpublished data). Note that the yields of ware potato and winter wheat in the organic system considerably increased after the transition period, whereas the coefficient of variation remained more or less the same, see Table 1.

This means that more research is needed to further optimise the organic farming system and to understand the different interactions within the farming system, including research on the role of variety improvements. In our experiences with variety trials with organic farmers the farmers in general do not so much look for higher yield potential, as for 'reliable' varieties that are able to cope with unfavourable weather and soil conditions (Lammerts van Bueren et al., 2002b). Selecting the proper variety can contribute to yield stability through different specific traits, as will be discussed in this chapter, but also by more general traits such as flexibility, robustness and buffering capacity.

Table 1. Comparison of average yields, standard deviations and coefficients of variation over five successive years for the crops ware potato, winter wheat, sugar beet and onion grown in the conventional, integrated and organic farming systems of the DFS (Nagele, The Netherlands) from 1980-1984 and 1985-1989 (adapted after Spiertz, 1989 and unpublished data from Praktijkonderzoek Plant & Omgeving – Akkerbouw, Groene Ruimte en Vollegrondsgroente, Lelystad (PPO-AGV).

	Average yield (tonnes/ha)		Standard deviation (tonnes/ha)		Coefficient of variation (%)	
	'80 -'84	'85 -'89	'80 -'84	'85 -'89	'80 -'84	'85 -'89
Potato						
Conventional	49.3	52.4	7.3	2.7	14.7	5.2
Integrated	33.3	52.5	4.7	5.9	14.2	11.3
Organic	27.2	36.2	7.4	11.6	27.2	31.9
Winter wheat						
Conventional	8.0	7.3	0.7	0.8	8.2	11.3
Integrated	7.0	6.8	1.0	0.7	14.7	10.8
Organic	4.4	5.3	0.6	0.7	13.2	12.8
Sugar beet						
Conventional	63.7	-	4.5	-	7.1	-
Integrated	62.3	-	8.7	-	13.9	-
Organic	45.8	-	6.2	-	13.6	-
Onion						
Conventional	-	43.1	-	6.4	-	14.8
Integrated	-	32.4	-	3.8	-	11.8
Organic	-	26.9	-	13.5	-	50.1

It is in this context of a self-regulatory farming system that the organic sector is developing a concept for improved varieties adapted to organic farming systems. In the following sections we will describe the self-regulatory, organic farming system in more detail by describing soil, weed, pest and disease management, product quality and yield stability, in order to understand the consequences for the requirements on variety characteristics.

Soil management

Description of soil management in organic farming

For organic agriculture the basis of sound organic crop production is the care taken to build up

soil fertility, based on three, inextricably interrelated components of soil management: the physical (water holding capacity, structure, etc.), chemical (nutrient dynamics, pH), and biological (soil biota) component (a.o. Vandermeer, 1995). Soil fertility in organic farming means: well managed soil organic matter in the soil, good soil structure, diverse soil biota, and a high nutrient and water holding capacity by using compost and stable manure (Koopmans & Bokhorst, 2000). The idea of an organically well managed soil is that one can build up over time buffering capacity and resistance to an imbalance in growing conditions as part of the strategy to enhance the self-regulatory capacity of the farm-ecosystem (e.g. Oades, 1984; Bokhorst, 1989; Jordahl & Karlen, 1993).
The use of organic manure makes the availability of nutrients less controllable. This might result in a lower yield stability. On the other hand, in organic systems often a higher soil organic matter content is observed than in conventional systems. This might partly compensate for the yield limiting effect of the low nutrient availability by increasing the water holding capacity and nutrient retention capacity of soils under organic production. Another matter worthy of attention is that in low(er) input systems, such as organic farming, within-field variation might affect yield stability (Van Noordwijk & Wadman, 1992; Almekinders et al., 1995). Most essential in the use of organic fertilisers is the necessity for active soil organisms, like earthworms, nematodes, collemboles and mycorrhizas, to regulate nutrient cycling processes, to make nutrients available to the crops, to maintain the soil structure and to suppress pests and diseases (Hendrix et al., 1990). Studies have shown that low(er)-input systems like organic systems harbour diverse soil biota, especially earthworms, more so than in the conventional agricultural system (Zwart et al., 1994; Fliessbach & Mäder, 2000). A clear example is given by a long-term comparison of an organic and a conventional system where the root length colonised by mycorrhizae in the organic system was 40% marger than in the conventional system (Mäder et al., 2002). Mycorrhizae are especially important as intermediaries for the uptake of phosphates by the plant in organic farming systems. Compared with most other nutrients the phosphate supply to a plant depends much more on the size of the root system, the density of its root hairs and the intensity of its ramifications through the soil, due to the slow rate of diffusion of phosphates (Lampkin, 1990; Ritz & Griffiths, 2001). In conventional farming mycorrhizal associations are generally not considered to be important because usually large quantities of soluble phosphates are applied.

Besides organic and composted manure, crop rotation and crop residue management are also fundamental tools for enhancing soil fertility. Nutrient catch crops, green manure crops, trap crops and crops with a relatively low harvest index, like cereals, contribute to the organic matter in the soil after harvest (Wijnands & Vereijken, 1992; Struik & Bonciarelli, 1997; Wijnands et al., 2002a) and at the same time may provide other services to improve soil health. Integrating these tools and attuning them to each specific farm, site and soil will be even more important in the future with reduced availability of manure input. This is because in the ongoing development of organic farming the aim is to close nutrient cycles within the organic sector and to become independent of stable manure from conventional farming systems (Hendriks & Oomen, 2000; Koopmans & Bokhorst, 2002). With tightly closed nutrient cycles, nitrogen will be less of a problem than for instance potassium and phosphorus, because nitrogen can be supplied by growing legumes that live in symbiosis with nitrogen-fixing organisms, but the losses of potassium and phosphorus will have to be compensated for by external inputs.

Consequences of organic soil management for variety requirements
The consequence of the above-described organic soil fertility management is that in such farming systems plants have to form and maintain a!larger and more active root system for nutrient uptake (i.e. have to be efficient in acquiring nutrients) and are more dependent on interaction with beneficial soil microorganisms that promote nutrient uptake. Therefore organic farmers require varieties that are adapted to such specific low(er) input soil management and that are efficient in nutrient and water uptake under organic farming conditions (1), that have an adequate root system architecture (2) and can interact with beneficial soil microorganisms (3). Moreover, such varieties need to be efficient in the use of nutrients, i.e. produce relatively large amounts of desired products per unit of nutrient and water taken up by the plant. These varieties are directly related to higher yield levels, but indirectly also – through optimal growing dynamics – to lower disease, pests and weed population levels (e.g., Van Delden, 2001).

1. Organic varieties need adaptation to low(er) and organic input conditions
For a certain yield stability organic farmers require varieties adapted to low(er) and organic input conditions. However, some modern varieties require high nitrogen to show their potential for higher yields (Schroën, 1986). Foulkes et al. (1998) concluded that the varieties before and during the 1960s were more nitrogen-efficient in uptake than more recent ones selected under higher nitrogen-levels. But also among modern wheat varieties, nitrogen-efficient genotypes have been found in trials under a conventional fertiliser regime (Ortiz-Monasterio et al., 1997; El Bassam, 1998; Le Gouis et al., 2000). In several variety trials and practical experiences under organic conditions varietal differences in lower-input adaptation have been observed among modern, conventionally bred varieties of different crops, including winter wheat (Kunz & Karutz, 1991; Welsh et al., 2001), spring wheat (Lammerts van Bueren et al., 2001c; Osman & Van der Brink, 2002) and cabbage (Lammerts van Bueren et al., 2002b).
Adaptation of varieties to organic inputs also means that the varieties should show a steady growth and therefore can cope with less controllable and more fluctuating nitrogen-dynamics

without resulting in irregular crop development causing inferior quality due to diseases or disorders. In several carrot variety trials under organic conditions varietal differences in tendency to develop growth cracks were observed (Lammerts van Bueren et al., 2001c). Above-mentioned results suggest that improvement of lower-input genotypes can in principle be expected via screening, selection and breeding.

2. Organic varieties need an adequate root system architecture
In organic and lower input systems root systems should be able to explore deeper soil layers and be more active than in conventional systems. Therefore organic farmers need varieties with a root system that is able to grow deeply and that can exploit unpredictable and stressful soil environments (water and nutrient availability). There are observations that under poor nitrogen conditions root growth is relatively favoured compared with shoot growth (Brouwer, 1983; PAV, 1985). However, root topology is not only influenced by soil structure and nutrient and water distribution in the soil, but is also genetically controlled (Jenison et al., 1981; Fitter et al., 1991; Fitter & Stickland, 1991), and might be negatively influenced if selection for high yields occurs under high-input agricultural systems with nutrients readily soluble in water (Siddique et al., 1990). This indicates that selection for adaptation to organic farming systems should preferably occur under organic conditions.
Research is being carried out to find markers linked to genes controlling root architectural traits to be able to incorporate some of the deep rooting attributes of stress-adapted wild relatives through indirect selection on the marker genotypes (Johnson et al., 2000; Burger & Kik, 2001).

3. Organic varieties need large capacity to interact with beneficial soil microorganisms
Because in organic farming systems the input level is lower, a high nutrient uptake efficiency is essential as much as the ability to interact with other soil organisms, such as bacteria and fungi, enhancing plant mineral nutrition (Lee & Pankhurst, 1992; Mäder et al., 2000). Differential interactions between plant genotypes and beneficial microorganisms have been demonstrated for species of mycorrhizal fungi, and plant growth promoting rhizobacteria (Manske, 1990; Smith et al., 1999; Balkema-Boomstra, 2001). Hetrick et al. (1993) found that modern wheat cultivars are less responsive to mycorrhizal symbiosis, which can be a result of selection under high input conditions. Although it is known that molecular interactions between microorganisms and plant roots are genetically determined, varieties have not yet been bred for beneficial interaction with mycorrhizae or other beneficial microorganisms. In the interaction between legumes and rhizobia the presence of nodulating mutants is one of the strongest indications that breeding for more intense interaction with beneficial plant-associated microbes is possible (Jacobsen, 1984). Learning more about the genes involved in these beneficial plant-microbe interactions will yield a

more complete picture of plant health and provide new targets for crop improvement (Smith et al., 1999). Since organically managed soils harbour more beneficial microorganisms than conventionally managed soils, it is obvious that breeding appropriate varieties for such farming systems will require selection under organic soil conditions.

Weed management

Description of weed management in organic farming

Weeds are often cited as the most significant problem in organic farming systems and they are certainly the problem that most concerns the farmers, who are considering converting their farm from a conventional one into an organic one. Because in organic farming systems no herbicides are allowed, the emphasis is on prevention, decision-making (timing) and control technology. Control on organic farms of yield- and quality-limiting weed populations requires strategies that account for long-term effects. This in turn requires knowledge about the population dynamics of weeds over a rotation, and about the seed setting of weeds (Lampkin, 1990; Kropff et al., 2000). If weeds are not suppressed in time they may become very aggressive (competitive) and complete their life cycle thus producing a seed bank for the coming years and the subsequent crops in the rotation. The weeds that cause the biggest problems are annual species in the plant row that can produce seeds in a short time and throughout the year, such as *Stellaria media* and *Poa annua* (Van der Weide et al., 2002).

The preventive measures aim at reducing the supply of weed seeds and the multiplication of weed plants, and at destroying weeds before the crop is sown. Measures can be taken at different levels (Van der Weide et al., 2002): farm level (rotation, intercropping, adjusting (uniform and broad) row distances for adequate mechanical management), crop level (building up tolerance of a crop by optimising the growing conditions) and variety level (genetic characteristics for competitiveness through plant architecture, rapid juvenile growth, deep rooting or allelopathic exudates). Not only do crops differ in their competitiveness towards weeds, but also within a crop species varieties have been found to differ in competitiveness (Regnier & Ranke, 1990; Lotz et al., 1991; Müller, 1998). Because of the poor competitiveness of winter wheat varieties in an early growth stage under organic farming conditions and due to the limited possibilities of mechanically controlling weeds under the often relatively wet Dutch weather conditions in late autumn, many organic farmers in the Netherlands have switched from winter wheat to spring wheat (Lotz et al., 1990; Lammerts van Bueren et al., 2001c; Lammerts van Bueren & Osman, 2002). This example shows how the lack of appropriate varieties can have great impact on the organic farming system, and shows the need for more attention to be paid to the characteristic of weed suppressiveness, as part of the necessary preventive strategies. Apart from practical experiences in most cases information is lacking on growth characteristics of cultivars that contribute to competitiveness. It indicates that until now weed competitiveness has received little attention from breeders.

Consequences of organic weed management for variety requirements
The weed suppressive ability of varieties can contribute to the self-regulation principle of the organic farming system especially when under wet weather conditions the mechanical weed control cannot be done in time or is not effective enough, causing an increase in the labour needed for hand weeding. Thus organic farmers require varieties that have a rapid juvenile growth and the ability to cover or shade the soil in an early stage of crop development to outcompete weeds for light. This is especially important for those crops that grow during winter and early spring when mineralisation is low and weeds grow (more) easily under conditions where the soil is poorly covered by crops, as with winter cereals. In general, a denser crop canopy, as influenced by canopy architecture, improves the crop's ability to compete with weeds. Canopy architecture includes factors such as crop height (cereals), leaf area, leaf angle, leaf stiffness, and leaf shape (Regnier & Ranke, 1990). Most effects of competition for light, water or nutrients can be expected for seed-producing weeds and not so much for vegetatively propagating weed species. Differences in variety performance in competitive ability were shown in several variety trials. Among varieties of wheat and barley taller varieties were more competitive, including those with either longer or broader leaves, but also those varieties that could establish themselves better with the low mineralisation rate in the early spring (Kunz & Karutz, 1991; Eisele & Köpke, 1997; Müller, 1998). Among varieties of sugar beet and cabbage those with more horizontally arranged leaves, and among carrot varieties those with more and longer leaves were best at weed suppressiveness because of an earlier closing canopy (Lotz et al., 1991; Lammerts van Bueren et al., 2001c; 2002b). Grevsen (2000) concluded from field trials that cultivar choice avoiding too small sized and semi-leafless pea cultivars, together with a higher seeding rate could control weeds in organic pea production for the industry. Also, in rice systems increased concern about herbicide use induced studies about the competitiveness of rice varieties. Detailed studies on trade-offs between different traits (like competitiveness versus yielding ability or sensitivity to diseases) have to be conducted to make this option feasible (Bastiaans et al., 1997).
Interference of crops with weeds may also involve the production of inhibitory allelopathic substances by living roots or shoots of crops. There are some examples of genetic differences between varieties in growth-restraining effects on very specific weed species, but also some results showing that allelopathic potential may result in reduction of yield or yield quality (Regnier & Ranke, 1990; Balkema-Boomstra, 2002). The latter concluded that the practical

importance of breeding for allelopathic substances might be relatively small and that breeding for more aggressive crops can have more perspectives.
It can be concluded from the above reviewed literature that in principle there are perspectives for undertaking more purposeful breeding attention for weed competitiveness among cultivars.

Disease and pest management

Description of plant health, disease and pest management in organic farming
The consequences of losses due to pests and diseases in organic farming systems differ considerably, depending on region, crop, farm structure or market demands. In general, yields in organic agriculture are 20% lower due to a lower nitrogen-input and in some cases due to pests and diseases (Tamm, 2000; Mäder et al., 2002). Further growth of the organic sector can be supported if the yield stability can be raised by a better control of diseases and pests. As in weed management, disease and pest management in organic farming systems is interwoven with the total ecological lay-out of the farming system and the sophisticated use of agro-ecological knowledge, and aims at enhancing the self-regulatory capacity and building up high tolerance to pests and diseases instead of regulation with chemical protectants (Wijnands et al., 2002b). The central concept of plant health in organic farming is: good growing conditions and avoidance of stress will enhance the natural tolerance of plants against plant competitors (Bloksma, 1987; Bloksma & Van Damme, 1999). The occurrence of many plant diseases can therefore be seen not as the cause of inferior growth but as a result of an imbalance between plant and growing conditions, causing an imbalance in metabolism which attracts insects, fungi and bacteria (Daamen, 1990; Bloksma, 1991; Tamis & Van den Brink, 1999). Next to the already described soil fertility with good soil structure and water household, diversification strategies, such as wide crop rotations, mixed or intercropping, shelter and flowering crops for natural predators are essential in crop health management strategies at farm level. At crop level optimisation of growing conditions include avoidance of a critical period, broader row- and plant distances, and optimising nitrogen supply. The tools a farmer can handle differ in relation to soil-borne, air-borne and seed-borne diseases.

Soil-borne diseases
In organic agriculture most soil-borne diseases and pests can be controlled by stimulating biodiversity in and above the soil, by feeding soil life with organic soil amendments and good soil management, and by choosing site-specific crops in a balanced rotation. Although the power of disease suppressive ability of (organic) soils and soil life is known, more research is needed to be able to use soil life as a management tool to increase the power of soil defence in a more

controlled way (Hoitink et al., 1997; Van Bruggen & Semenov, 2000).
More research has been carried out on and more experience gained with rotations. Although the need for crop rotation is also being recognised in conventional farming, organic farming is simply not possible without adequate crop rotation. Success is intimately related to the choice of the right crops in the right sequence and in the right frequency suppressing not only populations of soil-borne pests and diseases, but also of weeds and creating a diverse soil life where beneficial organisms also flourish (Francis & Clegg, 1990; Altieri, 1999; Altieri & Nicholls, 1999; Mäder et al., 2002). Most soil-borne, immobile pests and diseases, such as wheat and cereal cyst nematodes and *Sclerotium cepivorum* in onion, can be prevented in such organic farming systems, and do not require specific resistance traits in varieties grown by organic farmers. Only in cases where rotation and soil management do not have the desired effect, as is known during conversion periods and with less or non-specific disease and pests, resistant varieties can offer an additional alternative. Examples of such, needed by organic farmers are sugar beet varieties resistant to cyst nematodes and Fusarium-resistant rootstocks for tomato.

Air-borne diseases
From comparative studies between conventional and organic/reduced-input systems Van Bruggen (1995) concluded that in organic or reduced-input farms root diseases and pests are generally less severe than, or just as severe as, some specific foliar diseases. Foliar diseases are more difficult to control by biological or cultural measures than root diseases, because foliar disease development is much more determined by climatic factors than by antagonistic or parasitic interactions on the leaf surface, while the reverse is true for root disease development. Many foliar diseases and pests are air-borne, so that rotation (diversification in time) plays a limited role, although spatial crop diversification in combination with varietal disease resistances has an effect at a regional scale. For most air-borne diseases good crop management will improve the tolerance of a crop. Shortage as well as an overdose of nutrients reduces the tolerance of the crop (Tamis & Van den Brink, 1999). Essential in organic farming systems is gaining and maintaining soil fertility (concerning biotic as well as abiotic components), as described before with an active soil life (micro- and macrobiota), good soil structure and crop specific manuring for buffering and resistance to unbalanced plant growth. Another diversification strategy to reduce spreading of air-borne diseases, such as rusts and powdery mildew in cereals and pests, is through mixed cropping and variety mixtures, creating more within-field genetic variation (e.g. Wolfe, 1985; Finckh & Mundt, 1992; Finckh et al., 2000b), or the strategy of undersowing legumes in non-nitrogen fixing crops (Theunissen, 1997; Altieri & Liebman, 1986). Although such strategies have in general proved to be worthwhile in controlling diseases and pests, more work has to be done to make the acquired knowledge more adaptable

to specific farm conditions. Other diversification practices for enlarging the self-regulatory ability of the farm-ecosystem related to crop health include biological control using natural predators. Therefore a farmer has to manage an ecological infrastructure (the total of more or less deliberately introduced non-productive elements) on the farm for shelter and food web, like flower rows, ditches, hedges and even certain weeds or herbs (Smeding & Joenje, 1999). Despite organic management there are still some air-borne diseases that are hard to control in organic farming systems, like potato late blight *(Phytophthora infestans*) or apple scab (*Venturia inaequalis).* Such diseases stress the need for non-chemical, natural fungicides or pesticides in the short run. The availability of 'natural' sprays on the basis of e.g. *Bacillus thuringiensis*, *Pyrethrum*, and sulfur, permitted in the organic sector, is very limited, and not the main focus of organic farming systems (Sukkel, 1999). There is a lot of discussion about sprays based on natural compounds, because they have a broad spectrum and do not just affect the target organism but also beneficial organisms. Such problems indicate that more tolerant or resistant varieties are urgently needed and can contribute to adapting the plant to organic farming systems.

Another aspect that has received a lot of attention recently is the mycotoxins produced by *Fusarium* spp. on cereal grain. The FAO (FAO, 2000) concluded in a review that this problem is not larger in organic agriculture than it is for conventional cereal production. All research that is focussed on other strategies than chemical protectants, to improve the tolerance of cereals against Fusarium, will also benefit the organic sector (Lammerts van Bueren & Osman, 2002), see Chapter 7.

Seed-borne diseases

The EU-regulations on organic farming require the use of organically produced seeds and will no longer allow further derogations for the use of conventionally produced seeds by the end of 2003 (Anonymous, 1991). This encourages even more conventional seed producers to begin seed production under organic conditions and confronts them with the problems of controlling seed-borne diseases without chemical seed and soil treatments. Organic seeds have to fulfil the regular phytosanitary requirements for seeds, so that the production of seeds with or without low levels of seed-borne diseases requires more knowledge and experience than is currently available. Although the organic farming system is designed to reduce the disease pressure, an organic farmer expects to start with seeds that are free from harmful diseases, especially when these have not yet occurred on his farm and he therefore has high demands on seed quality. Particularly when growing conditions during germination are not optimal, as in spring, plants can suffer from germination fungi, such as *Fusarium* spp. on cereals and grass (Hulscher & Lammerts van Bueren, 2001). Other seed-borne diseases that have proved to be difficult to control in organic crop and seed production are for instance *Alternaria radicini* and *A. dauci* on carrot seeds, *A. brassicicola* on cabbage species, and *Rhizoctonia solani* on seed potato (Lammerts van Bueren, 1994; Groot, 2002; Lammerts van Bueren et al., 2002e). For organic seed production more attention to developing varieties that not only prove to be sufficiently resistant or tolerant during ware production but also during seed production is required, see Chapter 5.

Consequences of organic disease and pest management for variety requirements
Apart from the question which crop(s) suit(s) best in the given farm context, and in which sequence and in what frequency, a farmer makes use of the possibility of choosing among available varieties. The availability of resistant and otherwise organically adapted varieties is an important factor in designing a possible composition of the rotation. Because an organic farmer has hardly any curative means he, in contrast to his conventional colleague, will have to give more priority to varietal disease resistance, even if this is associated with a lower productivity. Because in many cases, organic farmers can keep the disease pressure low with ample rotation and low nitrogen input, the focus is not merely on absolute resistance; in many cases tolerant or field resistant varieties can be sufficient. The priorities go more in the direction of resistance against fungal, air-borne diseases and not of soil-borne diseases and pests. For air-borne, non crop-specific pests, like aphids, and diseases like *Botrytis*, adequate soil and water management is required. Varietal characteristics can be instrumental for better adaptation to organic soil and water management in order to improve a steadier and more balanced plant growth and therefore improving the tolerance of the plant against such non-specific pests and diseases. For crop-specific air-borne and seed-borne pests and diseases special cultural practices in combination with resistant or tolerant varieties are required.
We have learned from the variety trials with organic farmers, that the most important aspect that they look for is more plant-health-supporting traits in varieties than merely resistance traits. Plant architecture is a very important focus for farmers wishing to reduce mostly the fungal diseases (Lammerts van Bueren et al., 2001c). For instance, a longer peduncle and less compact ear for cereal crops, or a less compact growth habit and more planophyl-orientated leaves instead of leaves hanging close to the stem for greenhouse tomato. Niks & Rubiales (2002) refer to several other different avoidance and defence mechanisms in plants to be explored to diversify the breeding strategies for durable resistance in plants. For some crops such a focus is even more important if there is too little knowledge or there are no adequate tools yet available in organic agriculture to control complex diseases, like late blight in potato or Alternaria in carrot. As there are no varieties available that are fully resistant against these diseases they specifically challenge researchers to look for multifactorial solutions and require interdisciplinary research, including

genetic, epidemiological and agronomic strategies (Hospers et al., 2001; Kessel et al., 2002). The strategies in this case focus on crop and farm sanitary measures, different cultural practices and avoidance strategies with early bulking varieties, higher disease tolerance, and exploiting differences in resistance components to delay the infection and sporulation rate. Due to the problem with Phytophthora the assortment of main varieties used in Dutch organic agriculture differs totally from the ones used in conventional agriculture (own unpublished data, 2001). Such a shift in variety assortment will also occur in the near future for crops where the organic propagation is in development and susceptibility for mostly fungal diseases during seed production phase forces seed companies to carefully select varieties that are suitable to be propagated organically without chemical protection.

Another area on which organic farming will focus more in future is the suitability of crops and cultivars for intercropping, mixed cropping and mixed varieties (Wolfe & Cormack, 2000; Lammerts van Bueren et al., 2002d). This requires more breeding efforts for an adapted type of plant architecture to allow for instance an undersown, companion crop, like clover.

Product quality

Variety characteristics should not only suit and optimise the non-chemical and agro-ecological cultural practices of organic farming systems and benefit the quality of the environment, but should also lead to optimal product quality for traders, processors and consumers. Part of the (negatively formulated) quality concept is the absence of chemical residues.
Organic products are not to be treated with chemical substances neither before nor after harvest during storage. This is for instance the case with potato and onion requiring higher demands for varieties with good long term storage potential without the use of chemical sprouting inhibitors (Lammerts van Bueren & Van den Broek, 2002b).

Next to the absence of chemical inputs and residues good product quality also includes positive quality aspects such as taste. Because organic products are promoted to be healthier for the environment, and are less forced into a luxurious growth due to a lower nitrogen-input, in general organic products yield averages are 20% lower, and are expected to taste better (Wende, 1996). The organic sector in search of improving the quality of taste in organic products, like carrot, tomato and strawberry, tries to distinguish itself in the market in this respect. Sensory qualities, like taste, are not only a result of environmental but also of genetic influences. Simon and co-workers (Simon et al., 1982; Simon, 1993) stated that substantial genetic variation frequently exists for many quality traits in crops such as carrot, cucumber, onion and garlic. As breeding

programmes have until now paid relatively little attention to these traits and because variation for such traits exists, potential future progress is to be expected (Simon, 1993). Taste is an important criterion in organic carrot variety trials and added to organic breeding programmes (Bauer, 2000; Hagel et al., 2000; Lammerts van Bueren et al., 2001c; 2002b).
Another quality aspect that requires attention in the organic sector is improvement of the baking quality of wheat and other cereals. Because organic bakers are not in favour of using synthetic additives and also prefer home-grown wheat, many variety trials are focussed on varieties with high bread-making quality and sufficient yield under the low(er) input conditions of organic farming systems (e.g., Welsh et al., 2001; ITAB, 2001; Lammerts van Bueren & Osman, 2002). Already several specialised organic wheat breeders are aiming at improving the bread-making quality of cereal varieties (Kunz et al., 1995).

Crop	Variety characteristics required by organic farmers	Chemical solutions available for conventional farmers
Apple, pear	Ability to take up calcium Little biennial bearing Fruit set also under cold weather conditions Self regulating June drop of fruitlets	$CaNO_3$ leaf sprays (apple) Flower pruning agents Gibberellic acid for parthenocarpy (pear) Hormones
Lane trees	Natural tendency to branch	Branching hormones for roots and stems
Subtropical fruit	Skin with natural wax layer	Coating of the skin
Cereals	Long straw and peduncle Less compact ear against ear diseases	Fungicides
Cereals, carrot, cabbage, etc.	Rapid juvenile growth to cover the soil	Herbicides
Potato	Hairy and tougher leaves against aphids	Insecticides
Potato, onion	Long-term storability without sprouting	Chemical sprouting inhibitors
Onion, cabbage	Leaves with a wax layer for tolerance against fungal diseases	Fungicides

Table 3. General criteria for desired variety characteristics for organic farming systems derived from the agro-ecological approach.

Variety characteristics	Criteria
Adaptation to organic soil fertility management	Adaptation to low(er) and organic inputs; ability to cope with fluctuating N-dynamics (growth stability); efficient in capturing water and nutrients; deep, intensive root architecture; ability to interact with beneficial soil microorganisms, like mycorrhizae, atmospheric nitrogen-fixing bacteria; efficient nutrient uptake, high nutrient use efficiency.
Weed suppressiveness	Plant architecture for early soil cover and more light-competition, allelochemical ability; allowing and resisting mechanical/physical control.
Crop health	Monofactorial and polyfactorial, durable resistance; field tolerance; plant morphology; combining ability for crop or variety mixtures; capable of interaction with beneficial microorganisms that enhance plant growth and suppress disease susceptibility.
Seed health	Resistance/tolerance against diseases during seed production, including seed-borne diseases; high germination percentage; high germination rate; high seedling vigour.
Crop quality	Early ripening; high processing/baking quality; good taste; high storage potential.
Yield and yield stability	Maximum yield level and yield stability under low-input conditions.

Desired variety characteristics and crop ideotypes for organic farming

Examples of different crops and the variety demands of organic farmers compared with the chemical solutions in conventional agriculture, are given in Table 2. The general variety characteristics as discussed before on the basis of the agro-ecological approach to enhance the self-regulatory ability for the main components of organic farming strategies, are summarised in Table 3.

For the above-mentioned, generally required variety traits priorities differ per crop. To arrive at varieties adapted to organic farming systems ideotypes have to be elaborated for different crops per market sector. At the Louis Bolk Institute we worked on ideotypes for organic varieties of several crops together with farmers and traders (Lammerts van Bueren et al., 2001c). The demands for carrot differ for different market sectors. For organic carrots supermarkets currently demand the same variety performance as for conventional carrots but those are not always the ones best for weed suppressiveness, disease resistance or taste (Lammerts van Bueren et al., 2001c). For onion the differences lie in the priority for a long storability without using chemical

Table 4. 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).**

sprouting inhibitors during storage. Disease tolerance is required mainly for *Peronospora destructor* and *Botrytis squamosa allii*, whereas *Fusarium oxysporum* and *Botrytis aclada allii* are less a problem in organic than in conventional agriculture, due to the wider rotation and lower nitrogen input. Onions have a poor root system and are therefore susceptible to drought and soil structure problems which requires varieties with a better root system for efficient water and nutrient uptake (Burger & Kik, 2001). Organic farmers have experienced that leafy onion varieties have more buffering capacity against drought in summer, which is possibly related to deeper growing roots. Because onion has a poor soil cover throughout the growing season anyway, organic farmers prefer varieties with more erect leaves to be able to control weeds mechanically as long as possible without damaging the leaves (Lammerts van Bueren & Van den Broek, 2002b). A greater difference is present in the ideotype for organic (spring) wheat, as shown in Table 4. Not only is disease resistance important but also a plant architecture that will more readily let the ear dry after rain or dew by having a longer stem, an ear higher above the flag leaf and a less compact ear. A better nitrogen efficiency is required and a leafy crop to cover and shade the soil starting in an early stage (Lammerts van Bueren et al., 2001c).
Plant architectural aspects arise particularly when farmers, with their experience and their farmer's eye, are involved in designing the crop ideotypes. Such plant architectural aspects are important in organic agriculture in relation to the cultural practices enhancing tolerance for diverse diseases, pests and weeds.

Organic farmers have experienced that there are trade-offs in their requirements. They have often reduced the nitrogen level to half the average in conventional systems and have to accept a certain reduction in yield (compared with the conventional yield potential) to obtain a more steady growth and tolerance for diseases and pests, and to increase quality traits like taste. New trade-offs may appear when more attention is paid to the aspects of organic farming systems. Van Delden (2001) pointed out that there could be trade-offs between improved uptake efficiency and weed suppressive ability. Increasing nitrogen uptake by increasing the root: shoot ratio may lead to less weed suppressiveness due to a smaller proportion of biomass in the shoot. Trade-offs require more research and close communication between farmers and plant breeders to discuss the possibilities and limitations of both organic farming systems and breeding.

Discussion and conclusions

That organic farmers use modern varieties does not mean that these are optimal for their farming system. The current modern varieties are adapted to conventional agriculture that has put in a lot of effort to minimise or simply overrule diversity in the cultivation environment, and

breeding has mainly been focussed on such relatively standardised farming systems (Jongerden & Ruivenkamp, 1996). In this contribution, it is explained how organic agriculture substantially differs from conventional agricultural farming systems. Although organic farming systems aim at enhancing the self-regulatory ability and resilience in the farm-ecosystem, they have nevertheless few possibilities to quickly react and interfere when corrections are needed. This explains why for further optimisation of the self-regulation principle of organic farming systems new varieties are needed, requiring traits that make varieties flexible and robust with adequate buffering capacity. Organic farmers do not require varieties with a higher yielding capacity in the first place because of the risk of losing such profit by (increased) disease susceptibility, but require varieties that show a higher yield stability through improved adaptation to organic farming systems and by that less yield reduction. This chapter shows that for organic farmers this implies more than merely a sum of potential resistant traits against pests and diseases; it also requires several additional plant architectural and other growth dynamical aspects of the plant that can contribute to yield stability and reduce the risks of quality and yield loss. So it is very important at this stage of conceptualisation of variety requirements and organic breeding programmes that breeders have close contact with organic farmers to better understand the organic farming system with its possibilities and limitations, and to benefit especially from the experiential knowledge of the farmers in their way of noting important plant architectural or growth dynamical aspects that can contribute to a higher yield stability. Here the farmers' eye can meet and support the breeders' eye in search for the best varieties for organic farming systems.
Referring to the current state of available inputs (practical and scientific knowledge, agronomic tools) our conclusion is that there is a great need and that there are enough arguments and perspectives to improve and adapt varieties to organic farming systems. Such new varieties will outperform the best conventional varieties for organic agriculture.
Most of these traits have received little or no attention from conventional breeding and research programmes until now or do not have the priority they have in organic farming systems. Additional research will be needed to be able to integrate new traits in breeding programmes. Solutions for dilemmas will have to be found in an interdisciplinary and transdisciplinary approach between agronomy, epidemiology and breeding.
Some traits like adaptation to organic soil fertility management require selection under organic soil conditions for optimal result (Lammerts van Bueren et al., 2002d), see Chapter 4. A bottleneck for the near future, however, will be the limited area of organic agriculture and therefore the limited economic interest of the conventional breeding companies to design specific breeding programmes for 'organic' varieties unless the conventional market can profit from such programmes as well. This will largely depend on societal pressure and governmental policy with regard to the reduction of chemical inputs in agriculture. There are examples that

show that as long as chemicals are relatively cheap (conventional) farmers will prefer highly productive varieties to more resistant and sometimes less productive ones (Bonnier & Kramer, 1991; Van den Berg, 2001). This development prevents in some cases the marketing of resistant varieties for organic agriculture, as is recognised for spring wheat (Lammerts van Bueren & Osman, 2002).

In the short run designing ideotypes with a participatory approach among farmers, breeders and traders can contribute to a more adequate selection of varieties suitable for organic farming systems from among the existing assortment of 'conventional' varieties. For the future our conclusion is that breeding programmes for new 'organic' varieties based on the proposed organic crop ideotype may benefit not only organic farming systems, but will also benefit conventional systems moving away from high inputs of nutrients and chemical pesticides.