Lammerts van Bueren, E.T. , 2002. Organic plant breeding and propagation: concepts and strategies. PhD thesis Wageningen University. Louis Bolk Institute, Driebergen, 210 pp.

Summary

Organic agriculture is gaining societal, political and scientific recognition for its contribution to sustainable agriculture. As most European governments strive for a growth of organic agriculture up to 10% (or more) in 2010 there is a need for development of organic plant breeding in order to come to organic varieties with proper propagation.
Organic farmers have long accepted their dependence on conventional varieties. However, although organic farmers profit from the improvements of conventional breeding, the fact that most organic farmers in north-western Europe use modern varieties does not imply that those are the best varieties for use in organic farming systems. 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. Therefore, organic farmers require new varieties with characteristics that are better adapted to this kind of farming system. And when genetic engineering became important in breeding, organic farmers realised that they are not only concerned about new variety traits but also about how varieties are bred and propagated, and, thus, whether they comply with ethical principles valid in 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 definitions and standards for organic plant breeding and techniques to be used. The first step to close the organic production chain is set by the EU regulation 2092/91 allowing no more general derogation for the use of conventional propagated seed from 2004 onwards. Only the use of organically propagated seed will be permitted.
It is a great challenge for the seed sector to supply the organic market with sufficient quantities and adequate quality of organically propagated seed of current varieties. At the moment, only a few of these seed companies consider also breeding for organic agriculture. With the step of producing organic seed at a larger scale the commercial seed sector has now become economically involved and needs support not only from the organic sector to define their desired variety characteristics, but also from research to remove several obstacles to enable further improvement of organic propagation and breeding strategies.

The aim of this thesis is to further elaborate concepts and strategies for organic plant breeding and propagation to come from an organic crop ideotype and variety concept to organic varieties and seeds, and raise this subject to a scientific level. The main objectives of this thesis are, therefore, clarifying the ecological and ethical principles of organic agriculture, and to discuss the consequences of these principles for an organic crop ideotype and the needed plant breeding and propagation strategies. This is further demonstrated for organic spring wheat in the Netherlands as a case.

In Chapter 2, a framework is sought for the ecological and ethical principles in organic agriculture, questioning the concept of 'naturalness' to characterise organic agriculture in contrast to the 'unnaturalness' of conventional agriculture. Attempts have been made to

clarify the content and the use of the concepts of nature and naturalness in organic agriculture, to relate this conception to the bio-ethical literature, and to draw the implications for agricultural practice and policy. Qualitative interviews were conducted with a range of key-players in the field of organic agriculture and with consumers of organic products. Based on the results of the interviews, three aspects of the concept of naturalness were distinguished: natural as ‘the organic’ (life processes), natural as ‘the ecological’, and natural as referring to the characteristic nature of a living entity. These conceptual aspects have been brought in relation to three main approaches within the field of organic agriculture: the non-chemical approach, the agro-ecological approach, and the integrity of life approach. It became clear that these approaches could also be recognised in the change of attitude of farmers as they convert from conventional to organic agriculture, and in the attitudes of consumers to organic food products. The conclusion of Chapter 2 is 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 attention to 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, like in this thesis concerning the development of concepts and strategies for organic plant breeding and propagation.
In the following chapters first the consequences of the non-chemical and agro-ecological approach were analysed, as those approaches are well established in organic farming systems.

Chapter 3 describes 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 is discussed by describing the organic soil, weed, disease and pest management at farm, field and crop level. This gives the base for analysing the consequences of such ecological principles for demands on variety characteristics, resulting in a general crop ideotype for organic varieties. The desired traits include adaptation to organic soil fertility management, implying lower and organic inputs, better root system and ability to interact with beneficial soil microorganisms, weed suppressiveness, soil, crop and seed health, good product quality, high-yield level and finally high-yield stability.

In addition to the contribution of functional diversity at farm, field and crop level to higher yield stability, the potential benefits of more genetic variation at variety level are explored in Chapter 4. Modern breeding, supporting specialisation and genetic monocultures in modern agricultural systems, has over-extended the application of the pure-line theory. This outruling of genetic variation in modern commercial varieties grown in temperate regions has resulted in highly homogeneous, high- yielding varieties, also broadly adapted and thus grown over large areas, with increased vulnerability to fungal diseases. In Chapter 4, a variety concept including sufficient genetic variation and adaptation to organic farming systems is described for self-fertilisers. Concepts, results, obstacles and perspectives of a strategy to ‘restore’ genetic variation to a functional level for organic farming systems are discussed. This includes the role of different types of genotype mixtures: variety mixtures, (isogenic) multiline varieties and (isophenic) line mixture varieties. Most promising seems the concept of line mixture varieties. Such line mixture varieties are composed of lines which are carefully selected on the basis of phenotypical uniformity for a number of important traits but which are genetically different. The line mixture variety is composed to create increased disease control by resistance for several diseases, and the composition is also based on positive interaction between genotypes to achieve more stable and higher yielding potential. Because of the small markets adaptation to organic agriculture has not received enough priority in conventional breeding programmes until now. Therefore a new and broadened gene pool must be established by composite or population crossings among a large number of selected parents/varieties to come to better adapted genotypes. Because of the expected large plant ×environment × management interaction under the lower (organic) input conditions the most efficient way is to select under organic farming conditions as early in the selection process as possible. The possibility of the participation of farmers in the selection process of new organic varieties is discussed.

Due to the EU regulations 2092/91 for organic farming the organic sector needs to close the organic chain by 2004, and thus to develop efficient schemes to produce adequate quantities of organically produced seeds and planting materials. Organic seed (planting material) is seed (planting material) produced by a crop that is planted and raised organically for at least one generation in the case of annual crops, and for two growing seasons in the case of biennial and perennial crops. In Chapter 5, problems associated with organic seed production are categorised into: a) market problems, b) technical problems, and c) problems with quality standards. The market problems are related to the limited area of organic agriculture and thus of the area of seed production per variety resulting in higher costs compared to conventional seed production. This will imply that the organic assortment of varieties per crop will be limited. The technical problems have to do with the lack of experience of the formal seed sector with organic seed production without chemical inputs (inorganic fertiliser and crop protectants). The main problems are: nutrient management, disease and pest management, and weed control. Among the diseases the seed-borne diseases require special attention. This also brings up questions and research needs related to seed quality. After this overview of the three problem areas, the role of the different actors to develop a strategy towards organic production of seeds and planting material is described. For successful production of organic seed and planting material, intensive communication between and mutual commitment of farmers, traders, breeders and governmental organisations are necessary. Farmers together with traders should be involved in variety testing and designing of crop ideotypes to identify the desired variety traits. Breeders can influence further improvement of organic seed production not only by organically propagating the best suitable, existing varieties, but also by integrating organic traits in future breeding programmes. Furthermore, a great effort is needed to carry out comprehensive and coherent activities related to the development of empirical knowledge and research-based information on adapting and improving cultural practice for organic seed production. This implies developing adapted varieties for healthy seed production, developing protocols for seed health testing, assessing threshold values, and designing organic seed treatments.
The expectation is that by 2004 for the most important crops there will be sufficient quantities of adequate quality of organic seed and planting material. However, ongoing optimisation of organic seed production management will be required to enlarge the cultivar assortment and to control the quality of organic seed and planting material.

After having discussed the consequences of the non-chemical and agro-ecological approaches for organic plant breeding and propagation, in Chapter 6, the ethical principles of organic agriculture are elaborated. 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. These principles have been described separately in this thesis.
The ethical principles are increasingly an issue in organic agriculture, not only in animal production but also in plant production, especially concerning plant-breeding methods. For more transparency in the ongoing discussions further conceptualisation and instrumentalisation are necessary.
Although the above-described non-chemical and agro-ecological approaches already express respect for nature and the nature of life, these approaches are mainly driven by or based on an instrumental (functional) point of view to benefit an ecologically and economically sound production system. Organic agriculture, however, also acknowledges an inherent, non-instrumental value of living organisms, thus independent on their utility for humans, out of respect for their ‘otherness’ and their being more or less ‘autonomous’. This indicates that in organic agriculture also plants and animals are ethically relevant in decisions on human exploitation of such organisms. The integrity of living organisms is part of the concept of intrinsic value and refers to the characteristic nature or way of being of living

organisms, their wholeness, completeness, their species-specific characteristics and their being in balance with the species-specific environment.
This concept of the inherent nature of plants can be made operational by deriving principles from the relevant characteristics at four different levels of the nature of plants: integrity of life, planttypic integrity, genotypic integrity and phenotypic integrity. Criteria derived from those principles are used to assess whether existing breeding and propagation techniques are compatible with the integrity of plants. Techniques at whole plant or crop level are in line with the principles of organic farming, respecting the self-reproductive ability and the reproductive barriers. *In-vitro* techniques and techniques at DNA level (genetic modification) are not compatible with the integrity of plants, except for the use of DNA markers. The concept of integrity of plants can also give direction to the perception of the plants in the selection process. In the selection process the so-called 'breeder's eye' can be seen as a more or less consciously applied instrument to perceive aspects of the wholeness or phenotypic integrity of a plant.

In Chapter 7 an example is given of what the meaning is of the concepts and strategies for organic plant breeding and propagation by describing the case of spring wheat in the Netherlands. Spring wheat has a central role in the crop rotation of the organic farming systems. It is not only grown for the grains as product for feed and human consumption, but equally important is the production of straw for composting stable manure to contribute to soil fertility.
Progress has been enhanced by developing a participatory approach in which farmers' eye can guide the focus of conventional breeders' eye in the organic sector. Designing a crop ideotype for organic spring wheat was an important tool for that purpose. Most modern, conventional varieties do not match the proposed ideotype as they lack the plant architectural characteristics that contribute to weed suppressiveness and disease tolerance. As a next step an adapted protocol for Value for Cultivation and Use (VCU) testing has been developed and applied in official VCU trials for organic spring wheat in the Netherlands, from 2001 onwards.
It is described how organic breeders search to take the intrinsic value and integrity of the cereal plant into account in more consciously developing an eye for the genotypic and phenotypic integrity of wheat. They have done so by investigating the basic characteristic of wheat and its potential spectrum of appearances by studying different gene bank accessions in relation to their region of origin. One of the typical questions one can ask in relation to the integrity of wheat is: what is typical of cereals as cultivated plants compared to their wild relatives, such as grasses. Or what are characteristic elements in the growth dynamics and morphology of wheat compared to other cereals such as barley? This investigation has resulted in the idea that most typical for cultivated plants is the ability to build up and ripen 'fruits'. Organic breeders, therefore, searched for those wheat plant types that can optimally perform their ripening ability under organic conditions. Growth dynamical aspects of such plant types are described.
The obstacles in organic seed production of spring wheat are not so much the availability of quantities but more of seed quality. Organic farmers experience disappointing seed emergence rates, especially under cold and wet spring conditions. Due to the VCU testing trials in the Netherlands this was confirmed with some varieties showing problems in the organic fields, while emergence was normal with chemically treated seeds in the conventional fields. Because of the EU regulation 2092/91 more and more organically produced seed will be used that has been untreated during seed production, and risks of contamination with seed-borne diseases such as Fusarium and Septoria will therefore require more attention in the future. This requires more effort to develop strategies to avoid seed-borne diseases, seed treatments and threshold values for contamination on organically produced wheat seed.

By introducing the concept of naturalness, the organic sector challenges the plant breeder to develop additional and new approaches for organic plant breeding and propagation. It can

open new perspectives for improvement of organic varieties in directions that hardly received attention until now.
In describing the complexity of the organic farming system from the non-chemical and agro-ecological points of view two main areas became apparent where organic farming systems differ most significantly from conventional farming systems: the soil fertility management and the disease and pest management. This implies a greater need for 'reliable' varieties, which means varieties with a greater buffering capacity and flexibility to cope with such conditions, compared to conventional farming systems. Currently organic farmers put more emphasis on higher yield stability than on higher yields. This thesis shows that this implies more than merely a sum of potential resistance traits against pests and diseases, as often is merely thought from the non-chemical way of thinking. From an agro-ecological point of view, farmers look for an organic crop ideotype with several additional plant architectural and other growth dynamical aspects of the plant that can direct and indirect contribute to yield stability and reduce the risks of quality and yield loss.

In the short and middle long run, organic crop ideotypes per crop and per market segment can help to select the best available varieties among existing varieties which can also be propagated organically. Progress for more yield stability can be gained by developing adequate variety mixtures among the self-fertilising species, such as wheat. For the middle long term, adapted protocols for testing varieties can enlarge the chance that new varieties with interesting traits for organic farming can be admitted to the market. For the long term optimisation of organic farming, the proposed new concepts and strategies need to be explored to be able to profit from as much functional diversity at all levels of farm management: farm, field, crop and gene levels. The limited area of organic agriculture will be the bottleneck for economic interest in establishing specific breeding programmes for organic farming systems, especially concerning small crops and low-yielding but important crops such as cereals.
A role for the government is to support public-private research and pre-breeding activities, and to invest in new strategies that renew the genetic base for breeding programmes and for (re)new(ed) variety concepts. Co-operation at the European level should be the basis for regional diversification and adaptation. Exploring and establishing new variety concepts with more functional genetic variation will not succeed when the adaptation of regulations for registration of new varieties and breeders' rights based on the pure-line theory will not be discussible. 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 input of nutrients and chemical pesticides. The needs in conventional agriculture can only be simultaneously served if the government's policy with regard to fungicides and herbicides will become stricter in the future.