

Organic plant breeding – A general overview

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Introduction

The share of agricultural land and farms managed following guidelines of organic agriculture increased continuously in the last two decades. Today organic farming is practiced in more than 130 countries of the world. In the 27 member states of the European Union 4% of the land is under organic management (Willer et al. 2008). As likely as not this upgrowth will continue since the growth rates of the global organic food and beverages market increased exceptionally the last few years, and have pushed over the worth of € 30 billion in 2006. Still Europe and North America are experiencing undersupply in some food categories (Organic Monitor 2006). With the Council Regulation (EEC) 2092/91 on organic production regulations concerning organic seeds became effective. However, these regulations do not include specifications of plant breeding and seed production methods and/or techniques. Today's organic agriculture still relies mainly on varieties derived from conventional breeding programmes. The current growth of organic agriculture poses the risk that due to not available alternatives the sector will turn more and more to conventional methods in order to keep up with the growth of the market. The 'conventionalisation phenomena' already affect almost all actors of organic production (Kratochvil et al. 2005, De Wit & Verhoog 2007). Hence, concerning breeding the calls for more 'organic' in breeding programmes are emerging.

Breeding techniques

A vision on organic plant breeding and its consequences in regard to breeding techniques was elaborated by Lammerts van Bueren et al. (1999). Two years later a dossier on plant breeding techniques was edited by the Research Institute of Organic Agriculture (FiBL) (2001) judging the suitability of the different breeding and multiplication techniques for organic agriculture. One outcome of the discussion were the IFOAM Plant Breeding Draft Standards (Table 1).

Table 1: Plant Breeding Draft Standards suitable and permitted for organic plant breeding (IFOAM 2005)

Variation induction techniques	Selection techniques	Maintenance and multiplication
<ul style="list-style-type: none"> • combination breeding • crossing varieties • bridge crossing • backcrossing • hybrids with fertile F₁ • temperature treating • grafting style • cutting style • untreated mentor pollen 	<ul style="list-style-type: none"> • mass selection • pedigree selection • site-determined selection • change in surroundings • change in sowing time • ear bed method • test crossing • indirect selections • DNA diagnostic methods 	<ul style="list-style-type: none"> • generative propagation • vegetative propagation <ul style="list-style-type: none"> - partitioned tubers - scales, husks, partitioned bulbs, brood bulbs, bulbils - offset bulbs etc. - layer, cut and graft shoots - rhizomes • meristem culture

Not allowed in organic plant breeding are techniques of genetic engineering. The interpretation of genetic engineering, however, is sometimes in a grey zone. Protoplast fusion for example is considered to be not suitable for organic breeding by the IFOAM guidelines, while it is not considered genetic manipulation by the EU regulation on organic farming.

Therefore, varieties derived from protoplast fusion need not to be labelled (Billmann 2008, Lammerts van Bueren 2008). A similar discussion is ongoing with novel breeding techniques, i.e. intra-, fami- and/or cisgenesis (Nielsen 2003, Schouten et al. 2006, Lammerts van Bueren et al. 2007). Contrary to cell fusion, however, these techniques are not excluded by the EU directive (2001/18/EC) on genetically modified organisms and, therefore, they are banned from organic agriculture.

In various European countries some organic actors elaborated and approved additional guidelines besides the IFOAM draft standards for organic varieties. In Austria the ARGE Bio-Landbau generated a negative list of not allowed methods. This list is in accordance with the IFOAM draft standards, but also excludes bread wheat introgressions into varieties of spelt wheat (Surböck et al. 2003). In Switzerland the organic umbrella organization BioSuisse generally banned hybrid varieties from organic cereal production with the exception of maize (Voegeli 2006). The criticism on hybrid varieties was outlined by Arncken & Dierauer (2006). Recently, the Association of Biodynamic Plant Breeders (www.abdp.org) released standards for certified biodynamic plant breeding. In addition to the IFOAM guidelines these standards explicit ban hybrid breeding irrespective of the hybridization method, the production of double haploid varieties or polyploidisation, and protoplast/cytoplasm fusion. The use of hybrid or double haploid varieties as parents for a biodynamically bred variety, however, is allowed.

Breeding goals

Varieties bred by conventional breeding programmes are generally not unsuitable for organic agriculture. Disease resistance, yield, nutrient efficiency, tolerance to abiotic stress and end-use quality are important characteristics for both production systems. For organic varieties, however, the emphasis of some traits is different. While soil-borne and root diseases can be controlled by adequate crop rotation, resistance against some foliar and seed-borne diseases is much in demand. In addition organic varieties demand specific characteristics usually not necessary for conventional breeds, e.g. weed competitiveness is highly beneficial to suppress both undesirable weeds and volunteer plants (Surböck et al. 2003, Wolfe et al. 2008).

Naturally, yield is important in regard to economic revenue. For organic varieties, however, the benefits have to be seen within the whole crop rotation and the closed cycle system. Therefore, taller varieties might be favoured due to better weed suppression, higher yields of straw used for bedding and/or plant remains for organic manure. Due to highly variable conditions in organic farming yield stability is ranked higher. Yield stability is especially important for crops which play vital roles in organic farming, but for which only a few small breeding programmes are existing and the breeding progress is low, e.g. legumes and specialty crops. Combining yield and stability into a single parameter of yield reliability might be meaningful (Eskridge 1990, Annicchiarico 2002).

High end-use quality is an important characteristic for organic varieties. In trading the same quality parameters than for conventional produces are used to determine quality and price. However, limits of certain parameters are sometimes different, e.g. lower protein contents are accepted for organic wheat for bread making. In recent years nutritional quality amended technological end-use quality and breeding programmes for added quality values were initiated. Varieties biofortified with vitamins, minerals and phytochemicals should provide healthier foods. Genotypes with higher concentrations of these health beneficial compounds are often limited in yield. Therefore, such varieties could be more suitable for organic production. Furthermore, it's a general belief that organic farming would produce healthier foods than conventional farming. Whereas breeding for nutritional value is still at the beginning and often influenced by great genotype by environment interaction, the advertising of health benefits of such products is already commonplace.

Breeding strategies

Wolfe et al. (2008) defined organic agriculture by three market types, i.e. global, regional and local market. These market types are served differently by varieties from three different sources: breeding programmes for (i) conventional agriculture, (ii) organic agriculture or (iii) within organic agriculture. Varieties originally bred for conventional agriculture but which perform well under organic management still capture the greatest part of organic seeds. 'Pure' organic varieties, i.e. varieties which were selected and propagated in all breeding steps under organic conditions, are still very rare and often only of local importance. In the last decade several breeding programmes for organic agriculture were established by conventional breeders. Their fate will largely depend on cost recovery. The organic movement would need a tremendous increase of varieties selected under organic conditions. It can be assumed that organic programmes are more expensive, since more breeding goals have to be considered. On the other hand, the market for organic varieties is still relatively small. Various models how to finance organic breeding were discussed in an international workshop (Osman et al. 2007). Breeding strategies have to consider cost effectiveness. Various strategies such as indirect selection, decentralised and participatory approaches, composite crosses/evolutionary bulk breeding including 'older' varieties with valuable 'organic' traits, shifting between organic and conventional programmes (Suneson 1956, Löschenberger et al. 2008, Wolfe et al. 2008) could help to keep the costs for organic programmes low. For wheat it was demonstrated that many characteristics are highly correlated between organic and conventional low-input management. Yield, some quality traits, N use efficiency and weed suppression, however, did not rank satisfactorily consistent (Oberforster et al. 2000, Kempf 2002). Breeding strategies for organic agriculture have also to consider that a high genotype by environment interaction can not be only present between organic and conventional environments but also within organic subsystems. Considering organic traits and/or goals could be advantageous also for conventional breeding programmes. Climate change, fertilizer crisis and increasing costs for energy will adjust conventional agriculture to lower inputs Burger et al. (2008) demonstrated that including organic test sites into conventional programmes can increase the chances of detecting broadly adapted genotypes. Combining various breeding strategies and including 'organic characteristics' at the very beginning of breeding could lead to a greater number of better adapted organic varieties in the nearest future. Besides increasing the number of organic varieties of major crops it of equivalent importance to strengthen breeding programmes of minor, but for organic agriculture important crops, such as legumes and forage crops.

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