Plant Variety and Certified Seed in Organic Agriculture

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This article is dedicated to the memory of the late Dr Géza Kovács, organic plant breeding expert of the Agricultural Research Institute of the Hungarian Academy of Sciences (HAS), Martonvásár, Hungary, who was supposed to serve as one of the authors of this paper but died suddenly on June 21, 2012.

Abstract

Varieties well adapted to the local low input organic production systems are needed to be able to improve the success of organic farming, therefore an initiation of organic breeding is an up to date necessity. In organic breeding, the conventional breeding methods are the mainly used techniques, and the use of biotech methods, especially GMOs, is restricted. Besides yield, yield stability is the main target, and special attention is paid to quality and functional diversity of the fruit as well as to resistance to biotic and abiotic stresses. Landraces and old varieties that are well adapted to low inputs are of particular interest for organic farming and the conception of conservation varieties might contribute to this issue. The ultimate aim of organic agriculture is to use organic seed. If such seed is not available from the database of reproductive material maintained by each country, seed derived from the conversion period or from conventional production is acceptable, provided it is not treated in the way forbidden in organic agriculture. The status of the seed produced by organic farmers for their own use (farm saved seed) is much less restricted in organic as opposed to conventional agriculture.

Key words: organic agriculture, organic breeding, organic variety, organic seed

Introduction

Organic agriculture (OA) is continuously growing worldwide on land and farms in more than 160 countries as well as in the global marketplace (Wilier and Kilcher, 2011). OA is distinguished from conventional production in a number of specific features. An important principle of OA is that it strives to become a closed system, with the production and marketing of organic produce fully separated from conventional production. In other words, organic production aspires to separate from conventional production in all aspects, including cultivars and seed.

It was only in the early 1990s that plant breeding and seed production became priorities for organic growers mainly as a response to the mass use of GMOs and to the issue of intellectual property rights. The issue of selecting cultivars, seed and planting material for organic production used to be settled in the beginning by resorting to untreated seed of conventional cultivars produced under conventional conditions. The subsequent stage called for the seed and planting material of conventional cultivars to be produced by organic methods (at least for one year in the case of annual crops and two seasons in the case of perennial crops). The ultimate objectives are the use of organic seed and replacement of conventional cultivars by organic ones.

Organic plant breeding implies the development of organic cultivars that meet the requirements of organic production by employing accepted breeding methods (Berenji, 2004; Berenji, 2008b; Prodanović and Surlan-Momirović, 2006). Frequently cited evidence of need for specific cultivars in AO as compared to those for conventional agriculture was published by Murphy et al. (2007) (Berenji and Sikora, 2009).
Organic plant breeding

The term “plant breeding for organic” is probably much more adequate but “organic plant breeding” is adopted in different languages (“ökonemesites” in Hungarian, “organsko oplemenjivanje” in Serbian, etc.). To be considered as organic, a cultivar must meet specific requirements and it must be developed by methods different from those employed in conventional breeding (European Consortium for Organic Plant Breeding 2001, 2005).

Organic breeding is performed under organic conditions and under control of certified control agencies. The objective of the latter is to ascertain that only acceptable breeding methods are used.

Excellent overviews on organic plant breeding and seed production are available (Adam, 2005; Berenji, 2008c; Gaile, 2005; Ceddia and Cerezo, 2008; Lammerts van Bueren, 2003; Lammerts van Bueren and Myers, 2012; Lammerts van Bueren et al., 2003; 2007; Murphy et al., 2004; Löschenberger et al. 2008; Miedaner et al., 2008; etc.).

Organic breeding objectives

Lammerts van Bueren and Myers (2012) gave a detailed summary of differences in plant ideotype between high input conventional and low-input organic cropping systems (table 1).

Table 1. Differences in plant ideotype between high input conventional and low-input organic cropping systems (Lammerts van Bueren and Myers, 2012, p. 7).

<table>
<thead>
<tr>
<th>Conventional</th>
<th>Organic</th>
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<tbody>
<tr>
<td><strong>Above-ground traits</strong></td>
<td></td>
</tr>
<tr>
<td>Performs well at high population density</td>
<td>Optimal performance at lower densities</td>
</tr>
<tr>
<td>Increased harvest index</td>
<td>Increased harvest index, but not as dramatic as for conventional production</td>
</tr>
<tr>
<td>Erect architecture and leaves, shortened plant stature</td>
<td>Taller plants, spreading canopy to be productive in low input situations</td>
</tr>
<tr>
<td>Weeds controlled by herbicides</td>
<td>Weeds limited by competition (plant height, spreading architecture), plants tolerate cultivation</td>
</tr>
<tr>
<td>Yield is maximized with high level of inputs</td>
<td>Maximized sustainable yield achievable with input of nutrients from organic sources</td>
</tr>
<tr>
<td>Pest and disease resistance to specific complex of organisms; need for resistance to diseases of monoculture systems</td>
<td>Pests and pathogens of monoculture potentially less severe, pathogen and pest complex differ; induced resistance relatively important; secondary plant compounds important for pathogen and pest defence</td>
</tr>
<tr>
<td><strong>Rhizosphere traits</strong></td>
<td></td>
</tr>
<tr>
<td>Root architecture unknown</td>
<td>Exploratory root architecture; able to penetrate to lower soil horizons</td>
</tr>
<tr>
<td>Adapted to nutrients in readily available form</td>
<td>Adapted to nutrients from mineralization - not readily available; need for nutrient use efficiency; responsive to mycorrhizae</td>
</tr>
<tr>
<td><strong>Legume-specific traits</strong></td>
<td></td>
</tr>
<tr>
<td>Nitrogen production by rhizobia of lesser importance</td>
<td>Rhizobia more important; discrimination against infective rhizobia important for N acquisition</td>
</tr>
<tr>
<td><strong>Harvest and marketing traits</strong></td>
<td></td>
</tr>
<tr>
<td>Improved labour efficiency</td>
<td>Incorporate traits that improve working conditions</td>
</tr>
<tr>
<td>Improved processing, packing, and shipping efficiency</td>
<td>Improved nutrition, taste, aroma, and texture</td>
</tr>
<tr>
<td>Crop shaped by mechanical harvest constraints</td>
<td>Traits priorities set jointly by researcher and farmer</td>
</tr>
</tbody>
</table>
Adaptability and stability. The breeding of conventional cultivars strives for cultivars possessing maximum adaptability. Organic breeding has two approaches to adaptability. About 30% of organic produce comes from local production and is devoted to local markets, which requires cultivars adapted to specific local conditions. The larger part of organic produce, about 70%, is distributed via supermarket chains. That production calls for widely adapted organic cultivars. It can be seen from the above that adaptability of organic cultivars depends on the actual situation, but, unlike the modern conventional breeding, organic breeding also takes into account the adaptability to specific local conditions. Generally speaking, in the case of organic cultivars, stability is even more important than adaptability (Berenji, 2009). To serve the need for better adaptability of cultivars intended for OA special breeding methods, “shuttle breeding” is invented for example (Kovács, 2011). Shuttle breeding refers to breeding during which the breeding material is successively moved from one environment to another in order to build in wide adaptability into the breeding material as well as into the final product, i.e. the new cultivar. Such cultivars are especially well adapted to organic conditions by expressing wide adaptability to various environmental typical to OA. In spite of the occasional pessimism prompted against such breeding methods based on the expectation that shuttle breeding will result unacceptably high genetic and phenotypic variation of the resulting cultivars, practical experience suggest that it is possible to achieve wide adaptability combined with variability which does not exceed the limit expected according to the DUS standards for registration of a new plant variety.

Genetic variability. The requirement for the existence of genetic variability in organic cultivars is based on the fact that genetic variability of a cultivar improves its adaptation to environmental conditions. Simultaneously, crop heterogeneity slows down the spread of pests and diseases, serving as a substitute for the banned synthetic pesticides for control of diseases and pests. There is no set value, but the desired level of polymorphism within an organic cultivar is estimated at 10-20%. This polymorphism is intended to be useful not only as a tool in control of pests and diseases but also as the genetic basis for higher adaptability of organic cultivars (Berenji, 2011a, 2011b).

Low input production. Conventional crop production is characterized by high inputs among which most important are mineral fertilizers, synthetic pesticides for disease, pest and weed control, etc. Characterized by low inputs, OA calls for cultivars adapted to such conditions. Therefore, organic cultivars strive for high efficiency of nutrient uptake and utilization, which is best achieved by breeding for a powerful root system that develops intensively and reaches deep into the soil. As the results of different investigations show, detectable differences in nutrient use efficiency exist for different crops like winter wheat (Dawson et al., 2011) and other crops.

Yield vs. quality. As a rule, organic production is mostly lower yielding than the conventional one. Depending on the crop in question, yield reductions range between 10-30%. As a compensation for reduced yield, in organic cultivars priority is given to quality and functional diversity, i.e. specific features of the fruit: taste, odour, nutritive value (dietetic value, digestibility), morphological characteristics (appearance, colour, size, shape, skin thickness), post-harvest characteristics (delayed maturation, long shelf life), etc.

Weed control. Since herbicide application is banned, one of the main mechanisms of weed control in organic production is competitiveness of organic cultivars, i.e. their capacity to inhibit weeds. This is achieved by larger foliage which improves shading, intensive tillering, rapid initial growth, etc. The modern conventional cultivars do not need such characteristics because in conventional production weeds are effectively controlled by synthetic herbicides.

Resistance to diseases and pests. In principle there is no large difference between the organic and conventional cultivars in this respect. The essential difference is that the requirement for resistance is more pronounced in organic cultivars. Since the use of pesticides is ruled out, the potential range of diseases and pests to which resistance should be incorporated is much wider in the case of organic cultivars. Another aspect is the nature of resistance. Instead of monogenic vertical resistance (which is frequently used in conventional cultivars), in the case of organic cultivars emphasis should be placed on polygenic horizontal resistance.
**Reproduction.** In accordance with the principles of organic production, each cultivar must maintain its natural reproduction capacity during reproduction cycles. It means that in the course of reproduction, each cultivar should preserve its original genetic and phenotypic characteristics. This requirement is especially important in the case of hybrid cultivars when used in OA.

**Participatory Plant Breeding.** Cooperation of farmers with breeders and their direct participation in breeding process i.e. Participatory Plant Breeding (PPB) is of special importance for organic plant breeding. The basic ideas of PPB in OA as described by Osman and Lammerts van Bueren (2002) are to facilitate communication between farmers and professional plant breeders, develop variety ideotypes best suited to the needs and environment of OA as the result of this cooperation, farmers and traders to be invited to evaluate existing and newly bred varieties during field visits, during which a lively platform for discussions is given as breeders are confronted with the performance of their own varieties and seeds of their colleagues. Examples of successful application of PPB in OA are broccoli (Renaud et al., 2010), cereals (Murphy et al., 2004, 2005), etc.

**Plant genetic resources.** In organic breeding, the importance of plant genetic resources (PGRs) comes to full expression. The main idea behind the establishment of plant gene banks has been the prevention of genetic erosion and obliteration of old varieties, local populations and wild relatives, i.e., the prevention of genetic erosion (Penčić et al., 1997). Collections in gene banks are valuable genetic bases for selection of genotypes in the course of development of organic cultivars. Old varieties and local populations (landraces), which are well adapted to local conditions, are of prime importance for organic plant breeding. The term “Conservation varieties” was first introduced in the EU Directive 98/95/CE, which included the policy objective of “conservation” in the core of seed legislation (Farm Seed Opportunities, 2009). In this way PGRs can legally contribute to the agro-biodiversity in OA (Berényi, 2002; 2003; 2011).

**Breeding methods.** Besides the different principles and targets, organic breeding differs from conventional one in the applied methods. Compared with methods employed in conventional breeding, organic breeding imposes certain limitations in the choice of methods for development of variability and further selection (Lammerts et al., 1999). The methods are divided into permitted, conditionally permitted and banned (Table 1).

<table>
<thead>
<tr>
<th>Status</th>
<th>Method for variability induction</th>
<th>Breeding method</th>
</tr>
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<tbody>
<tr>
<td>Permitted</td>
<td>Intraspecific crossing</td>
<td>Mass selection</td>
</tr>
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<td></td>
<td>Backcrossing</td>
<td>Individual selection</td>
</tr>
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<td></td>
<td>Bridge crossing</td>
<td>Pedigree method</td>
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<td></td>
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<td>SSDM (Single Seed Descent Method)</td>
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<tr>
<td></td>
<td></td>
<td>Use of molecular markers</td>
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<tr>
<td>Conditionally permitted</td>
<td>Somatic embryogenesis</td>
<td><em>in vitro</em> selection</td>
</tr>
<tr>
<td></td>
<td>Embryo culture</td>
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<td></td>
<td>Ovary culture</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>in vitro</em> fertilization</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Anther culture</td>
<td></td>
</tr>
<tr>
<td>Banned</td>
<td>Interspecies hybridization</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Protoplast fusion</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Irradiated mentor pollen</td>
<td></td>
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<tr>
<td></td>
<td>Induced mutations</td>
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<td></td>
<td>Genetic modifications</td>
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</table>

Generally speaking, organic breeding accepts only „natural“ methods, i.e. those applied at the level of plant and possibly those applied at the level of integral cell. Biotechnological methods on DNA
level, which are used at an increasing rate in conventional breeding, have almost unanimously been banned from organic breeding.

**Genetic modifications.** Since 1993 the Basic Standards for Organic Production and Processing of the International Federation of Organic Agriculture Movements (IFOAM) include a strict ban on genetically modified organisms (GMOs) (Anonymous 2005). Since 1999, also the EU Regulation for organic agriculture 2092/91/EC prohibits the use of GMOs and the products obtained through the use of GMOs in organic produce. GMOs are therefore legally and morally not acceptable in organic agriculture. As a consequence, not a single country in the world permits the use of genetically modified organisms or their derivatives in OA.

In a position statement, the IFOAM argued why such a ban is justified (IFOAM 2002). There are three categories of reasons:

1. Environmental and health risks. In IFOAM's perception such risks are inherently associated with the reductionistic approach of gene technology.

2. Socio-economic aspects. These include the fact that freedom of choice for farmer and consumer is threatened by the risk of contamination of organic produce with genetically modified material when the two types of crops have to co-exist and the fact that intellectual property rights and economic independence are threatened by large-scale use of GMOs.

3. Incompatibility with biological principles of sustainability. This is the most arguable issue in debates between opponents and proponents of the organic position on GMOs. Verhoog (2007) analysed the different arguments used against GMOs in organic agriculture in details. It seems that the ban is more ethical than scientific in nature and it is based on the opinion that the modern biotechnological methods present risks for the environment and human health, that they lead to monopoly of multinational companies thus infringing the free seed trade, etc. (Berenji, 2005).

The ban also includes the genetic material to be used for breeding, which in its pedigree should not contain a single component that is in any way associated with genetic modification. In EU, registered organic cultivars must be tested in accredited laboratories to prove that they had not been genetically modified. The contradiction of banning genetic modifications in OA is in that transgenic plants resistant to pests or diseases had been modified precisely for that reason, to increase the level of plant protection without synthetic pesticide application. However, molecular scientists have recently tailored and upgraded gene technology by developing techniques that make these modern plant breeding techniques more efficient and simultaneously more acceptable to the general public, such as cigenesis (Rommens 2004; Schouten et al. 2006a, b; Rommens et al. 2007). A cigenesis product is a transformed plant that only contains genes that are innate to the species or to a small group of crossable species. In spite of these facts, cigenesis is, similar to transgenesis, excluded from the list of breeding methods permitted for organic plant breeding (Lammerts van Bueren et al., 2008; Myskja, 2006).

**Hybrid cultivars.** The place and role of hybrid cultivars in organic breeding and production have not been fully elucidated. Because of genetic segregation of hybrids, hybrid cultivars do not fit the requirement asking each cultivar to be reproducible without changes in their original genetic makeup. Presently, a compromise has been adopted which permits hybrid cultivars to be used in organic production if they are fertile and if sterility in the course of hybrid seed production had not been induced by chemical means. Of course, hybrid seed must be produced under organic conditions. However, hybrid parents pose a problem in hybrid seed production under organic conditions. Because of inbreeding depression, viability of parent lines is reduced to a minimum (called inbreeding depression), which negatively affects their performance under low input conditions of organic seed production. An opinion has also been voiced that the process of development of parental inbred lines is „unnatural” and against the principles of OA. There are indications that three-way (TWC) and double cross (DC) hybrids will be exploited in the organic production instead of single cross (SC)
hybrids which dominate the conventional production. Also, it seems reasonable to assume that open-
pollinated cultivars will be preferred in OA over hybrid cultivars.

**Induced mutations.** Organic breeding permits neither direct nor indirect use of genetic material containing induced mutations. A difference between induced mutations and genetic modifications is that the latter can be efficiently identified while the former cannot. There is no methodology capable of distinguishing spontaneous from induced mutations. This is another proof that the limitations in the choice of methods for organic breeding are often more due to ethical than scientific reasons. Organic plant breeding does not permit the use of silver nitrate, silver thiosulphate, synthetic hormones, antibiotics and colchicine.

**Approval of organic cultivars.** In principle, there is no difference between the procedures of approval of organic and conventional cultivars. Still, organic cultivars possess certain specific characteristics which are reflected on the procedure of cultivar approval. VCU tests for organic cultivar must be conducted under conditions of organic production DUS tests are mandatory for organic cultivars just as for conventional ones. When assessing uniformity, note should be taken of genetic variability left intentionally in organic cultivars. Due to a persistent shortage of organic cultivars, possibilities have been considered at the EU level to simplify the procedure of registration of appropriate conventional cultivars for use in organic crop production (Rey et al., 2008). This intent has sprung from practical experience that there is a number of conventional cultivars that may be successfully grown under organic conditions. The lack of a list of cultivars recommended for organic production makes a correct choice of cultivars difficult.

Patenting organic breeding material or organic cultivars is not permitted. This decision is based on the assumption that patenting could restrict free exchange of seed between farmers or breeders. Another consideration, which is a cornerstone of the principles of organic production, is that it is „unethical to patent living organisms“.

**Ethics of organic plant breeding.** A new concept related to organic plant breeding is the ethics of plant breeding. It is based on the IFOAM basic principles (Principle of health, Principle of ecology, Principle of Fairness and the Principle of care) as a guide for the evolution of OPB (Lammerts van Bueren, 2010). The concept is based on the fact that the values of OA and, therefore, its norms and standards are process orientated rather than product orientated. Part of the concept is the idea of respect about the integrity of life and the concept of the natural (naturalness) in OA (Verhoog et al., 2003).

**Organic seed production**

Quality seed and planting material are basic prerequisites for successful crop production. These prerequisites are equally valid for conventional and organic production. Although the basic principles of conventional and organic seed production do not differ in essential aspects, the latter includes a range of specific features which have to be enforced in order to meet the requirements particular not only for organic produce in general but also for organic seed. The currently accepted concepts of use of certified seed in organic production distinguish two seed categories (Berenji, 2008a): (1) seed produced by methods of organic production and (2) organic seed.

**Seed produced by methods of organic production.** This category includes seed and planting material which have been multiplied under organic conditions for at least one generation (in the case of annual crops) or at least two generations (in the case of perennial crops). Seed and planting material originating from fields that are being converted from conventional to low-input methods (conversion period) are not considered as organically produced unless the seed or planting material used for this production had already been produced by organic methods.
**Organic seed.** Seed and planting material are considered organic if they have been produced by organic methods and the seed or planting material used for this production had already been produced or multiplied by organic methods.

It is important to note that the above two definitions make distinction inside the concepts of organic cultivars and organic seed. Both seed produced by organic methods and organic seed may be produced from conventional cultivars. Still, organic seed produced from organic cultivars is the ultimate target.

**EC Council Regulation (EEC) No 2092/91 of 24 June 1991** is a pioneer regulation dealing with the subject of seed and planting material for organic production. Starting from 1 January 2000, use of seed and planting material originating from organic production became mandatory. Since most member countries were not prepared for consistent implementation of this regulation, **Commission Regulation (EC) No 1452/2003 of 14 August 2003** postponed the obligation to 1 January 2004. As this deadline was not practically realizable either, the regulation foresaw the use of conventional seed, but only the seed untreated by synthetic preparations, in the following cases: 1) if a plant species is not represented by a single cultivar in the organic seed database; 2) if seed and planting material had been ordered but could not be delivered on time; 3) if varieties from the organic seed database turn out to be unsuitable, it is legitimate to propose to replace them with conventional seed of other cultivars, and 4) if the seed is intended for trials planned to be organized on a small scale or for maintenance of a cultivar. If the above requirements are met, it is necessary to contact the agency in charge and apply for permission prior to seeding or planting. Permits are issued on case-to-case basis and they are valid for one year only.

EU countries are obliged to maintain organic seed and planting material databases. These databases function as a virtual market for organic seed and planting material.

Compared with conventional crop production, organic production is relatively limited in spite of the relatively high demand for organic seed. There are a small number of seed producers and a limited number of available cultivars. The EU organic market is relatively well-provided with cereal seed, but there are recurrent shortages of organic vegetable seed and fruit tree and grapevine planting materials.

Because of small quantities involved, the price of organic seed is exorbitant when compared with conventional seed. Of course, this affects the price of organic produce (Berenji and Sikora, 2010; 2011a, 2011b).

The technology and technique of organic seed production have not been fully developed. Due to a shortage of reliable information and experience, growers are compelled to resort to their own experience, which makes this production risky and more expensive.

As a consequence of specific requirements of OA, in the first place the ban of synthetic pesticides for control of diseases and pests in the field and for seed treatment, organic seed frequently fails to meet quality standards imposed for the conventional seed. This problem is solved in some EU countries by adapting quality standards for organic seed, or practically by lowering the criteria for the organic seed. Studies are under way aimed at developing new methods of seed treatment with physical, chemical and biological agents that meet the requirements of organic production (Divéky-Ertsey and Tóbiás, 2008).

A viable solution to the problem of organic seed quality is to multiply organic seed or planting material outside the intended production region. This practice increases the probability that these two distant regions do not share the same diseases and pests, which will in turn make the produced seed healthier (Velema, 2004).

The importance of germination energy and viability of seed is greater in organic than in conventional production. Possibilities of increasing the germination energy and viability of organic seed are currently investigated. A frequent cause for low germination energy and viability is non-uniform maturity of individual seeds that comprise a seed lot. Insufficiently mature seed has low germination energy and viability. In the course of seed maturation, chlorophyll is gradually degraded and the green colour of seed turns into the colour characteristic for the plant species in question. By analyzing individual seeds by the chlorophyll fluorescence (CF) method, it is possible to separate seed fractions with less chlorophyll and improved germination energy and viability. The CF method has shown to efficiently improve organic seed quality of several crops (Jalink et al., 1998).
Generally speaking, the supply of organic cultivars and organic seed lags behind the actual expansion of organic production. Both organic plant breeding and commercial production of organic seed are in their very beginning. A similar situation can be seen in many other countries. Scientists, professionals and practitioners are tasked to urgently devise solutions for satisfactory supply of the market with organic cultivars and organic seed and planting material.

References


IFOAM World Board (2002). Position on genetic engineering and genetically modified organisms. PO1, IFOAM, Bonn.


Osman AM, Lammerts van Bueren ET (2002). Bringing farmers, traders and plant breeders together to develop better suited varieties. 14th IFOAM Organic World Congress, p. 310, Victoria, Canada.


