Introduction

Future breeding for organic and low-input agriculture: integrating values and modern breeding tools for improving robustness

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Introduction

Organic production and also the attention for plant breeding for organic agriculture is still increasing in Europe. The question often raised is how much does plant breeding for the organic sector differ from modern plant breeding and does a ban on GMO also include refraining from molecular marker assisted selection (MAS)? In this paper I will first elaborate on the values in organic agriculture and it related systems approach as a central focus in organic agriculture and will then discuss in which way molecular marker assisted selection can be of use for plant breeding for organic and low-input agriculture.

Values and systems approach

The central values of organic agriculture are summarized in IFOAM (International Federation of Organic Agricultural Movements) four basic principles: health, ecology, fairness and care (IFOAM, 2005). The original, long term driving force behind organic farming systems was and is to support a stable crop growth by avoiding soil degradation through a management system that restores and maintains soil health as the basis for healthy crops, animals and humans. Soil fertility includes a good soil structure to allow roots to exploit a large soil volume, a good water holding capacity through improved level of soil organic matter. The organic fertilisers together with a wide crop rotation contribute to a diversity of soil organisms. In this sense sustainable soil management is considered the basis of a robust farming system. However a farming system should be designed in such a way that at all levels it can contribute to sustainable crop production. Napel et al. (2006) plea for a adaptation model rather than a control model if the focus is to support yield stability rather than yield as such, see figure 1. In the mainstream agriculture the 'control' model is the prevailing approach. The main focus is to protect crops from unwanted fluctuations influencing the production as much as possible by keeping away disturbances depending on continuous monitoring and direct intervention with chemical-synthetic crop protectants and to look for single solutions.

In the 'adaptation model' not optimising the financial income but stabilising crop production and income is the main focus. In this approach in which we can recognise the aims of organic farming approach, the goal is designing a site-specific farm system such that at all levels (plant, field, farm) can minimise the impact of sources of variation or disturbances, rather then ruling out the sources of variation.

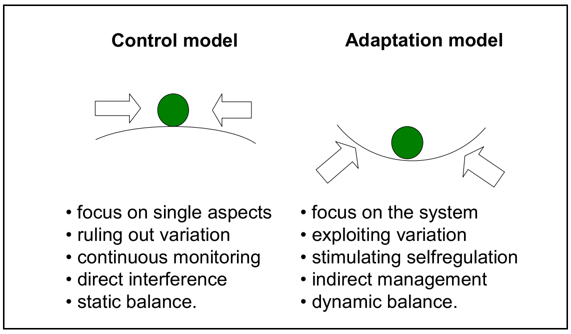

Figure 1.The control model versus adaptation model, adapted after Napel et al. (2006)

Besides increasing soil fertility and improving crop management to enhance disease suppression, also the choice of varieties can contribute to achieving yield stability. Many authors have discussed important crop traits to make crop robust and less vulnerable for unfavourable conditions. Not only disease resistances and field tolerance, but also other kind of traits is of importance such as a deeper rooting system to exploit larger soil volumes for resources, different plant features that contribute to early and late weed suppression. Another category of variety characteristics to enhance yield stability are focussed on exploiting genetic diversity in breeding approaches such as evolutionary breeding, or breeding for combinability in variety mixtures or crop mixtures in an intercropping system.

Breeding for resilience

Breeding for organic and low-input farming systems with a special emphasis on strategies that allow for more ‘robustness’ or ‘resilience’ in response to global change is a challenge. While organic and low-input agricultural systems are more exposed than conventional ones to heterogeneous environments, low nutrient availability and biotic as well as abiotic stress, global change might increase uncertainty in environmental conditions by producing drastic variation in climate, epidemic pressures, nutrient availability, etc. These changes could be considered an opportunity for the organic sector to develop original and innovative strategies for high level resilience or robustness. We will have to realize that certain plant traits such as deeper root system or nutrient efficiency can contribute to crop robustness, but that there are more mechanisms that support robustness in the broad sense which we have not yet fully explored to be able to optimise breeding programs for organic and low-input agriculture. We can learn from the ecological sciences to reconsider e.g. the use of biodiversity without ignoring the new tools coming from genomics.

Molecular marker assisted selection (MAS)

Breeding for resilience or robustness includes quantitative traits such as nutrient-efficiency, root architecture or polygenetic disease resistances. Such complex traits depend on more genes and are very much influenced by the environment. As low-input management of organic agriculture results in a larger influence of varying environmental conditions (in time and geographically) on crop performance, also the QTLs (Quantitative Trait Loci) may interact with environmental conditions and QTls found in one environment will not always be the ones found in another environment. However, plant geneticists consider molecular marker assisted selection for such complex traits a useful additional tool in plant breeding programs to make selection more efficient.

Standards for organic agriculture do not exclude the use of molecular markers, but still there is uncertainty whether molecular tools are in line with the values of organic agriculture. Use of genomics, e.g. molecular tools as easily associated with genetic modification which is banned in organic agriculture. Modern breeding techniques, including in-vitro techniques, have been discussed for many years in the organic sector not only for ecological but also for ethical reasons not wanting to violate the integrity of life (Lammerts van Bueren et al., 2003). The outcome so far is that breeding techniques applied on whole plant level are applicable, and techniques on cell (tissue) level as the lowest level of self organised life, are still under debate. More clarity is on the ban of techniques beyond cell level and interfering directly at DNA level, e.g. genetic modification, cell or protoplast fusion etc.

Organic and low-input farming conditions require breeding for robust varieties that contribute to resilience at all levels of the farming systems, which may be hampered by too much focus on the molecular level. The question therefore is how information and selection on molecular level can be integrated in an approach that takes all

levels of the crop production into account. Pros and contras for use of molecular markers in breeding for organic and low-input agriculture were the topic of a Eucarpia-Bioexploit plant breeding workshop in 2009. Through a SWOT analysis produced during the workshop the strengths, weaknesses, opportunities, and threats of the use of molecular markers were explored (Lammerts van Bueren et al., 2010). Clear strengths were identified, e.g. better knowledge about gene pool of breeding material, more efficient introgression of new resistance genes from wild relatives and testing pyramided genes. There were also common concerns among breeders aiming at breeding for organic and/or conventional agriculture, such as the increasing competition and investments to get access to marker technology, and the need for bridging the gap between phenotyping and genotyping especially with complex and quantitative inherited traits such as nutrient-efficiency. Integrating more disciplines such as agronomy and crop physiology in breeding research will provide ways to bridge that gap and to deal with the interaction between genotype, environment and management (Struik and Yin, 2009). Their approach, including QTL-based ecophysiological modelling, could provide the tools to breed for complex trait, such as nutrient-use efficiency, in a more efficient way making use of markers.
The extent to which MAS can be used efficiently in breeding for organic farming to complement or to replace part of the phenotypic selection will be highly dependent on the specific trait and the availability of markers that reflect the genetic basis of the special needs for organic farming. With respect to the organic sector there is a need to show and discuss with molecular scientists examples of 'good practices' of breeding and research projects with MAS approaches as well as to be updated on how new protocols may be adapted. This last aspect reflects the concern of the organic sector that the development and use of molecular markers often include the use of harmful chemicals and enzymes produced from genetically modified organisms. One of the opportunities is that the general development within molecular techniques is moving towards replacing harmful chemicals by alternatives that cause less damage to the lab-workers and the environment.

Discussion and conclusions

The question is whether we fully understand the plant characteristics or interactions with soil organisms that contribute to intrinsic robustness for achieving sustainable crop production. Napel et al. (2006) indicates that the adaptation model is closely linked with concepts such as a) robustness in the narrow sense, which can be defined as the ability to switch between underlying processes to maintain the balance, b) resilience, as the ability to regain the balance after a disturbance, and c) resistance, as insensitivity to disturbance. Napel et al. argue that none of the three concepts alone describes fully the adaptation model, but that robustness in the broad sense is minimal variation in a target feature following a disturbance, regardless of whether it is due to switching between underlying processes, insensitivity or quickly regaining balance. These authors also state that there are many unanswered questions regarding optimal utilisation of biological robustness mechanism and further research is needed. This will also apply to breeding research to support the development of varieties that enhance the intrinsic robustness in the cropping system.

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