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The critical point of conventionally bred soft wheat varieties in organic farming systems

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Abstract. Nowadays, wheat is the most important crop for organic farming systems. However, the varieties bred and tested in the conditions of organic farming systems are still missing, resulting in a very low level of yield in the Czech Republic (less than 50% of level of conventional yield in the same conditions). One reason is that the ideotype of the organically bred variety is different from that of the conventional. The varieties suitable for an organic farming system differ in many respects from those adopted in conventional farming. The first difference is obvious from the conventional tests of the varieties' value for use, taking only direct indicators influencing the main parameter (yield) into account. Generally speaking, the features to be tested can be divided into 4 groups: the morphological, biological, economic and quality parameters. The conventional varieties are bred in conditions characterised by an abundance of soluble nutrients, and therefore, their root systems are not adapted to an insufficiency or weaker bonding of nutrients. The competitiveness with weeds has also been ignored. Any conventional variety which has not had to confront strong weeds during the breeding process cannot be assumed to be competitive enough in the conditions of an organic agro-ecosystem. Resistance to diseases and pests can be similarly characterised. Varieties are protected by pesticides throughout the conventional breeding process. Because of the seasonal fluctuations in weather, we need a plastic and flexible variety. They also differ in their qualitative parameters.

Key words: organic farming, bread wheat, ideotype, variety

INTRODUCTION

Bread wheat is one of the most important food crops of conventional and organic farming systems (FAO, 2006). The efficiency of cultivation and yield of bread wheat varies in different parts of the world. Some organic farmers achieve only half the yield of conventional farmers; others provide almost the same yield (the organic yield is usually slightly lower) (Moudrý et al., 2007). There are many reasons; some organic farms in Austria and the Czech Republic may offer an explanation. Farms there exist in the same land-climatic condition and may be only tens of kilometres from each other, but, while Czech organic farmers achieve half the yield of their conventional counterparts, Austrians achieve 80-90% of the yield of the conventional farmers (Konvalina et al., 2007a). Perhaps the most important reason is that organic farming has a much longer tradition in Austria, where farmers use the principles and methods of organic agrotechnology much more effectively. A crucial factor is that the Austrian system of certification of organic varieties is better developed (Löschenberger & Lafferty, 2005). Austrian farmers mostly grow conventional varieties, but they have extensive information available on their reaction to low-input farming systems. According to many authors, the choice of variety is a crucial factor in efficient organic farming.

Modern cultivars of wheat do not satisfy all the requirements and demands of organic agriculture. Therefore, more attention should be given to the breeding of specific cultivars adapted to the agronomic conditions on organic farms and complying with the philosophy of organic farming (Lammerts van Beuren, 2002). Nowadays, new breeding programs are emerging because the conventional varieties of bread wheat have a very different genetic background (Kunz & Karutz, 1991). Lammerts van Bueren (2003) points out that, in order to avoid the use of chemical fertilizers and pesticides in organic agriculture, agro-ecological principles should be applied to enhance the self-regulatory capacity of the agroecosystems. Organic farmers require cultivars that can be multiplied and grown organically with no undue negative effect on the health and function of the agroecosystem (Kunz & Karutz, 1991). Cultivars should therefore have the ability to perform under a low input of organic fertilizers, a good root system, the ability to interact with beneficial soil microorganisms, suppress weeds, and to produce a healthy crop and healthy propagules (Lammets van Bueren et al., 2002, 2003).

MATERIALS AND METHODS

The facts published in this article are based on an extensive search of other projects, seminars and workshops organised in cooperation with scientists, breeders and organic farmers between 2005 and 2007 (see Konvalina et al., 2007c for details). Old prevailing arguments about the ’suitability’ of conventional varieties have been rebutted by the scientific community (see results of the European Project COST 860 for details) and by studies carried out by organic farmers (see http://www.cost860.dk for details). Many results are also based on a known working version of the ‘methodology’ for testing the suitability of varieties of bread wheat which was first defined, prepared and tested in field conditions and published as a complete methodology for use in organic and low-input farming systems in the climatic conditions of Central Europe by the authors of this article (for details, see Konvalina et al., 2007a).

RESULTS AND DISCUSSIONS

Can the ideotype of ‘the conventional variety’ be suitable for the organic farming system?

The varieties suitable for organic farming system differ in many respects from those adopted in conventional farming. The first difference is obvious from the conventional tests of use value of the varieties, taking into account only direct indicators influencing the main parameter (yield). Generally speaking, the features to be tested can be divided into 4 groups: the morphological, the biological, the economic and quality parameters (Konvalina & Moudrý, 2007b). Most of the morphological features are not usually tested in the conventional farming system; only plant length is taken into consideration. However, other features have an effect on the degree of total yield in a low-input farming system. In respect to biological features, all the important factors are tested and evaluated in varied conditions. Regarding economic features, considerable stress is placed on the testing and evaluation. However, some important features for organic varieties are not taken into account. Density of spike may serve as an example; a less dense spike can increase the resistance to fungal diseases but affects the spike in an indirect way (the spike gets dry easily) and the total productivity can be improved by the length of the spike and higher TGW. Better assimilation of sunlight and better distribution of nutrients in the plant can also lead to positive outcomes. Concerning the quality parameters, maximum levels of quality are now achievable. The particularity of organic varieties (e.g. the different composition of storage proteins) is nevertheless not taken into consideration. The choice of variety determines the flavour, which should always be taken into account (Konvalina, 2007a). In 2001, the testing of varieties in the organic farming system was initiated in Austria, the only country in the European Union to do so. According to Austrian studies, many of the results of conventional tests are not applicable to organic farming (e.g. the efficient use of nitrogen, suppression of weeds, rapid mix test) (Konvalina, 2007a). A number of the varieties recommended in the conventional system are no longer grown in the organic farming system.

Concerning the critical points of conventional and certified bred varieties of wheat, there are 4 groups of problems (Wolfe, 2006) and they determine each other. They are the following: the efficiency of absorption and use of nutrients, competitiveness against weeds, resistance to diseases and pests, degree and stability of the yield and the qualitative parameters of production (See Table 1).

Nutrient uptake and utilization efficiency

Organic farming is a system using a limited quantity of nutrients (especially nitrogen) and serial applications of nitrogen (Köpke, 2005). The ability or lack of ability to absorb nitrogen in early spring is an important issue in growing winter varieties of cereals in an organic farming system; cold wet soil is characterized by a low degree of microbial activity. The mineralization of nutrients (especially nitrogen) is limited in this period (Moudrý, 2003). The efficient absorption of nitrogen is also an important factor; it provides good-quality production and development of plants in the early stages of growth. (Steinberger, 2002). Varieties must be adapted to the lower inputs of nutrition into the agroecosystem (Lammerts van Bueren, 2002).

A wide range of studies has been carried out in the last few years; their common purpose has been to determine the changes in efficiency of varieties during the breeding process, and changes in the efficiency of the exploitation of nutrients. Muurinen et al. (2006) studied the efficiency of the exploitation of nitrogen in wheat, oat and barley, bred in Finland between 1909 and 2002. Modern varieties of wheat and oat were more efficient than older ones: they absorbed more nitrogen and were able to use it more efficiently. It was not so with barley. They also point out that the improvement in the efficiency of absorption and use of nitrogen was caused by the more efficient use of the absorbed nutrients in a plant, not the increased ability of absorption of nutrition by the root system.

Ericson (2006) states that modern varieties provide higher efficiency in absorption and use of nutrients than land races (various amounts of industrial fertilizers). This is valid for conventional farming systems. However, this statement is more ambiguous for natural low-input farming systems. Gorny (2001) states in his study that land strains of baking wheat provide a higher efficiency in the absorption and use of nitrogen than modern European varieties in low-input farming systems. He clarifies the reason for this in his study. Slafer et al. (1990) studied 6 varieties of baking wheat which had been bred between 1912 and 1980 and found out that the ability of the root system to absorb nitrogen did not improve during the growing and flowering season of the breeding process. The breeding caused an increase in the grain yield thanks to a change of the harvest index, the harvest index of nitrogen and the increasing number of grains. The change in the harvest index was greater than the change in the harvest index of nitrogen; it led to a 'dilution' of nitrogen and a lower concentration of nitrogen in the grain. As a result, the varieties bred in conditions of an abundance of soluble nutrients (especially nitrogen) are not able to absorb nutrients from less accessible bonds, but use the accessible nutrients more efficiently, and thus need fewer accessible nutrients. This fact supports conducting the breeding process in the conditions of the organic farming system, and the selection of tribes with greater potential.

The studies of wheat varieties by Baresel et al. (2005) also support this idea. They found the conditions of organic farming widely varied and dissimilar to the conditions of conventional farming. The varieties adapted to the conditions of conventional farms may not have been adapted to the conditions of low-input farming. The efficient genotypes (those able to absorb and use nitrogen in the first stages of their growth) are more suitable for the organic farming system. Most modern varieties do not achieve the required baking quality in low-input conditions but are successfully grown and applied in farming systems which are characterized by high inputs of nutrients. They provide a low degree of interaction between genotype and the environment. On the other hand, old cultivars and biological varieties contain more protein in grains (in both organic farming and conventional systems). A higher proportion of protein is usually connected with a lower level of yield (Ericson, 2006).

A well-developed root system, responsive to the interaction with the soil edaphone in a positive way, is crucial to the efficient absorption of nutrients (Lammerts van Bueren, 2002). The growth of roots is more important than the growth of upper phytomass in a soil characterized by a lower concentration of accessible nitrogen. On the other hand, the shape of the root system is influenced not only by the soil structure, but also by the proportion of nutrients and water in the soil, by a genetic factor (Fitter, 1991, Fitter & Stickland, 1991) and by the selection of varieties which provide a high level of yield in the conditions of conventional farming, but with negative consequences (Siddique et al., 1990). This means that the selection of suitable varieties for low-input farming system should be applied in the conditions of organic farming (Lammerts van Bueren, 2002).

The selection of an efficient root system, adapted to the absorption of nutrients from the soil, should take into account the limited competitiveness of varieties for the assimilates and a good position of the roots. A long and deep root system with numerous small young roots forms a better and richer branching with more capillary roots. The deep roots assure a sufficient absorption of water and nutrients from the deeper layers of the soil profile (Köpke, 2005).

The interaction between the root system and the other soil organisms (bacteria, fungi) is a key aspect of the agroecosystem: it increases the extent of mineralization of nutrients (Lee & Pankhurst, 1992; Mäder et al., 2000). Hetrick et al. (1993) realised that modern varieties of wheat responded less to mycorrhizal symbiosis. The interaction between microorganisms and roots is determined by genetic factors; nowadays, this factor is not taken into consideration in the breeding process.

Weed suppression

Weed plants are one of the main factors limiting the level of agricultural yield. Because of the availability of herbicides in the last 50 years, the competitiveness of field crops to weeds has been overlooked. The relationship between the cultured and the weed plant was supposed to be negative. However this relationship could contribute to the formation of a stable agroecosystem (Lammerts van Bueren, 2002) as the weeds can play a positive role (Wolfe, 2002). We cannot consider the cultured plant as naturally competitive to weed plants, because it has not confronted any important competitive weed during the breeding process. Modern conventional varieties are not selected in accordance with their indirect morphological or biological features; however, these features - the shape of a tuft, the length of a plant or the position of leaves - contribute to increased competitiveness. Nevertheless, the competitiveness of the currently bred conventional varieties can be tested in the conditions of an organic farming system. Sufficient tillering is one of the complex of characteristics responsible for high competitiveness against weeds (Kruepl et al., 2006), as is selection (Köpke, 2005). The architecture of a plant has an important effect also (length of stalk, percentage of leaves, position, compactness and shape of leaves) (Regnier & Ranke, 1990). Medium to tall varieties are the most suitable in this respect (Moudrý, 2003). Kunz & Karutz (1991); Eisele & Köpke (1997); Müller (1998) and Köpke (2005) also point to the higher competitiveness of the taller varieties. However, the taller varieties also cause problems such as lodging (Kruepl et al., 2006). Fast growth of the plant in the first stages of life is crucial as it allows an early achievement of a high LAI value. A planofile position of leaves (>45º) in the first stages of growth assures a higher degree of coverage of the soil surface and a deterioration in the growing conditions for weeds, although in poor nutritive situations, this can also lead to the slower development of the plants. An erectofile position of leaves is a more favourable feature for the later stages of the plant's growth (Hoad et al., 2005). The competitiveness of plants also depends on the speed of columning, LAI, capacity of the upper phytomass and the height of plants in the DC 31-75 stage (Köpke, 2005).

A number of authors also point out that competitiveness is determined by a good ability to absorb nutrients in low-input farming conditions. Varieties must be adapted to the negligible use of nitrogenous fertilizers and be able to cover the soil as fast as possible (Kunz & Karutz, 1991; Eisele & Köpke, 1997; Müller, 1998). Although aleopatic secretions may also influence the growth of rye and oat, studies indicate that they do not affect wheat (Köpke, 2005). Nevertheless, other research results rebut this fact; they point out that the aleopatic potential may lead to a reduction in yield and quality (Regnier & Ranke, 1990).

Disease resistance

A plant's health depends primarily on preventive measures, which can mean the creation of optimum conditions for growth, prevention against stressors, and accounting for the natural toleration of plant competitors. Several diseases occur not because of poor growing conditions, but because of an imbalance between the plant and environmental conditions; this can lead to an imbalance in the metabolism processes, and the attraction of insects, fungal and bacterial diseases (Tamis & Van den Brink, 1999).

The main selection criterion for good breeding is not the level of resistance; it is rather the ability of a specific plant to create a certain level of yield and quality in spite of the pressure of infectious diseases (Lammerts van Bueren, 2002). The resistant plant should not be just resistant, but its morphological features should also guarantee its resistance in conditions of higher infection. This fact is not taken into consideration in the selection process of conventional varieties. However, it is one of the reasons for the reduced resistance of conventional varieties, which are without any chemical protection against fungal diseases, as the following examples show: the occurrence of *Septoria nodorum* is influenced by a plant's architecture (Kunz, 1983), in that the transfer of spores from leaves to spikes by raindrops may be reduced by a longer distance between spike and flat leaf (Köpke, 2005); tall plants are more resistant (Kunz, 1983) and *Fusarium* spp, an infection of spikes, is influenced by the distance between spike and flat leaf (Engelke, 1992).

Yield stability and product quality

In the best organic farms, yield is about 20-30 % lower than the conventional (Moudrý, 1997; Mäder et al., 2002; Lammerts van Bueren et al., 2002). The quality and stability rather than quantity of the yield are the main priorities for organic farming. In general, farmers need to grow ‘reliable’ and ‘solid’ varieties which are able to tolerate potential fluctuations in the weather and the potential pressure of diseases; they must in any case be able to provide sufficient yield of grains and straw. The target variety should be bred to provide a lower but stable yield. The selection of the conventional varieties is based on yield level and is carried out in uniform conditions. According to the results of tests carried out by organic farmers, conventional varieties which provide a high yield are not as efficient as organic varieties in marginal areas. The suitability of the conventional varieties may be tested in the conditions of the organic farming system where relatively stable varieties providing a high yield can be selected.

A variety may be characterized by specific features due to the interaction between genotype and environment; a favourable factor may be that such varieties can be marketed as a regional product,, based on the fact that its flavour adds special features and character to the variety (Lammerts van Bueren & Hulscher et al., 1999).

The high baking quality of the organic varieties is characterized by the proportion and total content of crude protein, high value of the Zeleny - sedimentation value, flour binding capacity and flour yield, falling number and test weight. Achieving optimal baking quality of wheat is complex; the breeding of such varieties (to a high quality) is a long and difficult process (Fossati et al., 2005).

Organic methods of farming may have negative effects on the technological value, especially in the case of the crucial crude protein content (Moudrý & Prugar, 2002). The proportion of crude protein in grain is reduced because of the reduced availability of soluble nitrogen (Krejčířová et al., 2006). The composition of storage proteins also changes: there are more protoplastic proteins (albumins and globulins) (Krejčířová et al., 2007), which increase the nutritive value of grain.

Table 1: Criteria for organic plant breeding and propagation strategies derived from the non-chemical and agro-ecological approach) (according to Lammerts van Bueren, 2002).

Criteria	Desirable variety characteristics
The efficiency of absorption and use of nutrients:	Adaptation to low, organic inputs and fluctuating nutrient dynamics, efficient in capturing water and nutrients, their uptake and their use; deep, intensive root architecture; ability to interact with beneficial soil microorganisms.
Weed suppression:	Plant architecture for early soil cover and more light-competitiveness.
Crop health:	Durable resistance, field tolerance, plant morphology, combining ability for crop or variety mixtures, capable of interaction with beneficial microorganisms.
Product quality:	High processing/baking quality, good taste, high storage potential.
Yield and yield stability:	Maximum yield level and yield stability under low, organic input.

CONCLUSIONS

The importance of organic farming has been increasing worldwide. However, the selection and breeding of suitable varieties for the organic farming system have been disregarded. According to most viewpoints, the ideotypes of an organic and conventional variety are very different. The suitable conventional varieties cannot be assumed to be as suitable in the organic farming system, for several reasons. The conventional varieties are bred in conditions characterised by an abundance of soluble nutrients, and therefore, their root systems are not adapted to an insufficiency of nutrients or weaker bonding of nutrients. The competitiveness to weeds has also been ignored. A conventional variety which has never confronted strong weeds during the breeding process, cannot be assumed to be sufficiently competitive in the conditions of an organic agro-ecosystem. Resistance to diseases and pests can be similarly characterised. In the conventional breeding process, varieties are protected by pesticides throughout the growth period. Thanks to the harmony of the production process, the pressure of diseases and pests is usually lower in the organic farming system. On the other hand, a variety unable to provide the required level of yield without pesticides is vulnerable. Because of seasonal fluctuations in weather, we need a flexible variety. Can the conventional variety, having been bred in conditions of an abundance of nutrients and instruments of plant protection, be stable and flexible enough? Yes, it can. But it must be a variety which is bred and grown in particular regional land-climatic conditions. However, the varieties imported from distant areas are characterised by different features and different qualitative parameters. Concerning the qualitative parameters of production, the conventional varieties grown in organic farming conditions are characterised by a low proportion of nitrogenous elements in grain (less than 10 %). It could be better to breed directly for a lower yield level in a variety (about 10-20 %) which could then achieve better qualitative parameters.

Organic farming cannot avoid modern conventional varieties. The system certifying conventional varieties for organic farming therefore plays an important role (see the Austrian example). Breeding of organic varieties remains an important task for the future. The selection of suitable tribes with regard to the qualities necessary for an organic variety could be a good solution at the beginning of the breeding process. The formation of clear organic breeding processes would be the next important step; it would close the cycle of the development of organic farming which began with conventional seeds which were then reproduced in the organic farming system. A certification system of the conventional varieties for organic farming system has already been introduced; specialised regional breeding stations will be established in the future and the breeding process will be transmitted directly to the organic farms (participatory breeding). Stable and flexible varieties will be created which will be adapted to regional conditions and which will be able to provide an abundance of food in weaker years (characterised by strong fluctuations in weather).

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REFERENCES

Baresel, J.P., Reents, H.J &Zimmermann, G. 2005. Field evaluation criteria for nitrogen uptake and nitrogen efficiency. In: Lammerts van Bueren, E.T., Goldringer, I. & Østergård, H. (eds), *Organic plant breeding strategies and the use of molecular markers*. ECO PB, Driebergen, p. 49-54.

Eisele, J.A. & Köpke, U. 1997. Choice of cultivars in organic farming: new criteria for winter wheat ideotypes. *Pflanzenbauwissenschaften* **2**, 84-89.

Eenglke, F. 1992. *Ertrag und Ertragsbildung von Winterweizen, Winterrogen und Winteriticale im Organischen Landbau-Aswertung von Sortenversuchen in drei Versuchenjahren*. Thesis (Ph.D.) - Faculty of Agriculture, University of Bonn Bonn, 1992, 103 p. (in German).

Ericson, L. 2006. Nutrient use efficieny. In: Donner, D. & Osman, A. (eds) *Handbook cereal variety testing for organic and low input agriculture*. Louis Bolk Institute, Driebergen, p.N1-N8

FAO, 1996. *The state of world´s plant genetic resources for food and agriculture*. FAO, Rome, 336 p.

Fitter, A.H. & Stickland, T.R. 1991. Architectural analysis of plant root systems – architectural correlates of exploitation efficiency. *New Phytology* **118**, 375-382.

Fitter, A.H. & Stickland, T.R. 1991. Architectural analysis of plant root systems - influence of nutrient supply on architecture in contrasting plant species. *New Phytology* **119**, 383-389.

Fossati, D., Kleijer, G. & Brabant, C. 2005. Practical breeding for bread quality. In: Lammerts van Bueren, E.T., Goldringer, I. & Østergård, H. (eds), *Organic plant breeding strategies and the use of molecular markers*. ECO PB, Driebergen, p. 31-35

Gorny, A.G. (2001). Variation in utilization efficincy and tolerance to reduce water and nitrogen supply among wild and cultivated barleys. *Euphytica* **117**, 59-66.

Hetrick, B.A.D. & Wilson, G.W.T. 1993. Mycorrhizal dependence of moder wheat cultivars and ancestors: a synthesis. *Canadian Journal of Botany* **71**, 512-518.

Hoad, S., Neuhoff, K. & Davies, K. 2005. Field evaluation and selection of winter wheat for competiviness against weeds. In: Lammerts van Bueren, E.T., Goldringer, I., Østergård, H. (eds), *Organic plant breeding strategies and the use of molecular markers*. ECO PB, Driebergen, p.61-66

Konvalina, P. & Moudrý, J. jr. 2007b. Choice of species and varieties of wheat for organic farming. *Research for rural development* **9**, 22-29.

Konvalina, P., Stehno, Z. & Moudrý, J. 2007c. Ideotype and variety testing of wheat for organic and low input agriculture. *Lucrati stiintifice* **50**, 241-247.

Konvalina, P., Zechner, E. & Moudrý, J. 2007a. *Plant breeding and variety testing of wheat (Triricum aestivum L.) for organic and low input farming*. JU ZF v Č. Budějovicích, 131 p. (in Czech)

Köpke, U. 2005. Crop ideotypes for organic cereal cropping systems. In: Lammerts van Bueren, E.T., Goldringer, I. & Østergård, H. (eds), *Organic plant breeding strategies and the use of molecular markers*. ECO PB, Driebergen, p.13-16

Krejčířová, L., Capouchová, I., Petr, J., Bicanová, E. & Kvapil, R. 2006. Protein composition and quality of winter wheat from organic and conventional farming. *Žembdirbysté **93***, 285-296.

Krejčířová, L., Capouchová, I., Petr, J. & Faměra, O. 2007. The effect of organic and conventional growing systems on quality and storage protein composition of winter wheat. *Plant Soil Environ*. **53**, 499-505.

Kruepl, C., Hoad, S, Davies, K., Bertholdsson, N. & Paolini, R. 2006. Weed competitivness. In: Donner, D, Osman, A. (eds), *Handbook cereal variety testing for organic and low input agriculture*. Louis Bolk Institute, Driebergen, p.N1-N8

Kunz, P. 1983. Entwickungsstufen bei Gerste und Weizen - ein Beitrag zu einem Leitbild für die Züchtung. *Naturwissenschaft* **39**, 23-37.

Kunz, P. & Karutz, C. 1991. *Pflanzenzüchtung dynamisch-die Züchtung standortpflangepasster Weizen und Dinkelsorten*. Dornach, Forschungslabor an Goetheanum, 164 p.

Lammerts van Bueren, E.T. 2002. *Organic plant breeding and propagation: concepts and strategies*. Thesis (Ph.D.) - Wageningen University, Wageningen, 198 p.

Lammerts van Bueren, E.T., Hulscher, M., Jongerden, J., Haring, M., Hoogendoorn, J., van Mansvelt, J.D. & Ruivenkamp, G.T.P. 1999. *Sustainable organic plant breeding*. Louis Bolk Instituut, Driebergen, 60 p.

Lammerts van Bueren, E.T., Struik, P. C., Tiemens-Hulscher, M. & Jacobsen, E. 2003. Concepts of intrinsic value and integrity of plants in organic plant breeding and propagation. *Crop Science* **43**, 1922-1929.

Lee, K.E. & Pankhurst, C.E. 1992. Soil organism and sustainable productivity. *Australian Journal of Soil Research* **30**, 855-892.

Löschenberger, F. & Lafferty, J. 2005. Breeding scheme for organic winter wheat. In: Lammerts van Bueren, E.T., Goldringer, I. & Østergård, H. (eds), *Organic plant breeding strategies and the use of molecular markers*. ECO PB, Driebergen, p. 88

Mäder, P., Edenholfer, T., Bolter, A., Wiemken, A. & Niggli, U. 2000. Arbscular mycorrhizae in a long-term field trial comparing low-input (organic, biological) and high-input (conventional) farming systems in a crop rotation. *Biology and fertility of Soils* **31**, 150156.

Mäder, P., Fliessbach, A., Dubois, D., Gunst, L., Fried, P. & Niggli, U. 2002. Soil fertility and biodiversity in organic farming. *Science* **296**, 16941697.

Moudrý, J. 2003. Field production. In: Urban J. & Šarapatka, B. (eds), *Organic farming*. MŽP, Praha, p. 103-126.

Moudrý, J. & Konvalina, P. 2007c. Differences between organic and conventional farming systems in Czech Republic. *Lucrati stiintifice* **50**, 282-289.

Moudrý, J. & Prugar, J. 2002. *Bioproducts*. MZe, Praha, 60 p.

Műller, K. J. 1998. From word assortments to regional varieties. In: Wiethaler, C. & Wyss, E. (eds), *Organic plant breeding and biodiversity of cultural plants*. NABU/FiBL, Bonn, pp. 81-87

Muurinen, S., Slafer, G.A. & Peltonen/Sainio, P. 2006. Breeding effects on Nitrogen Use Efficiency of Spring Cereals under Northern Conditions. *Crop Science* **46**, 561-568.

Regnier, E.E. & Ranke, R.R. 1990. Evolving strategies for managing weeds. In: Edvars, C.A. (ed), *Sustainable agricultural systems*. Soil and Water Conservation Society, Ankeny/Lowa, p. 174–203.

Siddique, K.H.M., Belfort, R.K. & Tennant, D. 1990. Root-shoot rations of old and modern, tall and semidwarf wheats in a Mediterranean environment. *Plant and Soil* **121**, 89–98.

Slafer, G.A., Andrade, F.H. & Feingold, S.E. 1990. Genetic improvement of bread wheat (Triticum aestivum L.) in Argentina: relationship between nitrogen and dry matter. *Euphytica* **50**, 63 –71.

Steinberger, J. 2002. *Züchtung für den Ökolandbau*. Bundessortenamt, Hannover, p. 142.

Tamis, W.L.M. & van den Brink, W.J. 1999. Conventional, integrated and organic winterwheat production in the Netherlands in period 1993–1997. *Agriculture, Ecosystems and Environment* **76**, 47–59.

Wolfe, M.S. 2002. Plant breeding, ecology and modern organic agriculture. In: Lammerts van Bueren, E.T., Wilbois, K.P. (eds), *Organic seed production and plant breeding*, ECO PB, Berlin, p.18–25