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Response of old, new and organically bred winter wheat cultivars in different farming systems: concept and experimental layout in the DOK field trial

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Organic farming, organic breeding, winter wheat cultivars, arbuscular mycorrhizal fungi, nutrient acquisition potential

Abstract

Organic farmers often use winter wheat (Triticum aestivum L.) cultivars that have been bred under conventional high-input conditions. We test the hypothesis, whether old and organically bred cultivars are better adapted to low-input conditions through a better functioning of the symbiosis with arbuscular mycorrhizal fungi (AMF). Our aim is to assess the nutrient acquisition potential of old, new and organically bred winter wheat cultivars and to identify the role of AMF for nutrient uptake and growth. In October 2006, an experiment with 10 wheat cultivars was superimposed to all four field replicates of the DOK long-term experiment, comprising four different treatments with increasing nutrient input: unfertilized, biodynamic low and moderate intensity and conventional mineral system. Growth and harvest parameters such as plant density and length, growth habit, plant health, yield and grain quality will be assessed. Shoot and root samples were taken at tillering and flowering to analyse nitrogen and phosphorus content and AMF root colonization. In this paper, the current state of literature findings in the field of organic breeding is summarized and the experimental setup for variety testing in an existing long-term trial is outlined.

Introduction

Organic farmers often use the same wheat cultivars as conventional farmers. Most of these cultivars have been bred under and for high input conditions. In organic farming systems these cultivars cannot perform to the full extent of their high genetic potential because organic soils frequently do not deliver enough nutrients and fertilizers are limited. Better nutrient uptake efficiency would be of great value for organic farms and conventional farms producing under low-input conditions.

Nitrogen (N) and phosphorus (P) are usually the most limiting macro-elements in organic farming. A large part of P in soils is secluded in minerals and organic compounds, or heavily absorbed, and the supply of soil-N by mineralization is limited. The AMF symbiosis can positively influence plant growth and health. AMF are known to be strongly affected by the concentrations of soluble nutrients, specifically P, and plant genotype. This suggests a suppression of the AMF symbiosis with wheat

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cultivars obtained in selection programmes under high-input conditions. In addition, physiology and rooting of such cultivars may be adapted to high soil nutrient content. New cultivars may have a negative influence on AMF root-colonisation due to resistance introduced against fungal root pathogens.

In the current project we will test, whether old and organically bred wheat cultivars are better adapted to low-input conditions than conventionally bred cultivars through a better functioning of the AMF symbiosis. The aim is to assess nutrient acquisition potential and to identify the role of AMF on nutrient uptake and growth.

Review of the Science

Symbiotic relationships of wheat and AMF can play an important role for growth and productivity. There is clear evidence, that AMF colonization is affected by nutrient supply and AMF infection potential of the soil, as it has been shown in pot trials for P (Zhu et al., 2001). Highest values for shoot and root weights of wheat were measured for inoculated treatments in a pot trial with a soil low in P (Rubio et al., 2003). AMF symbiosis can lead to an increased uptake of P by plants. AMF hyphae could contribute up to 50-80% of total plant P-uptake in pot trials with wheat (Li et al., 2006).

AMF occurrence and diversity shows a strong dependence on the land use management. AMF root colonization in the DOK-trial decreased with increasing farming intensity. Colonization was highest in the unfertilized control and 30-60% higher in the organic than in the conventional farming systems. Similar results were found in additional pot experiments with field soils from the DOK-trial (Mäder et al., 2000). The results agree with Covacevich et al. (2007), where AMF colonization was highest in plants receiving no annual P supply compared to plants grown at elevated nutrient levels. Native AMF could contribute considerably to the P-uptake of field grown wheat, even at typical soil fertility levels (Schweiger et al., 1999). Oehl et al. (2003) compared the influence of low-, moderate- and high-input conditions on AMF occurrence and diversity. Numbers of spores were highest under low- and moderate conditions. A shift in the AMF diversity could be shown with highest species numbers in the organic field, which was part of the DOK-trial. Results from the DOK-trial also showed that older wheat varieties might have a higher capacity to take up P: Grains of an old wheat variety had a distinctly higher P-content than grains of two recently released varieties, suggesting wheat x variety x AMF interactions (Mäder et al. 2007).

Wheat yield worldwide increased rapidly, especially during the second half of the last century due to an increased use of chemical fertilizers, and pesticides (Ceccarelli, 1996) and the introduction of semi-dwarf cultivars (Manske et al., 2002). Wheat breeding was targeting the improvement of nutrient use efficiency; especially of N and P. Little is known about the influence of the nutrient level during breeding on the performance of cultivars under low- and high-input conditions. Brancourt-Hulmel et al. (2005) assessed the efficiency of low- *vs.* high-input selection environments to improve wheat for low-input conditions. They concluded, that breeding programmes targeting low-input environments should include low-input selection environments to maximise selection gains. Results in barley could show a genotype x environment interaction. High-yielding lines selected in high-yielding environments showed lower yields on farmers' fields (Ceccarelli et al., 1996). Wheat cultivars differ in their ability to form AMF symbiosis (Hetrick et al., 1995). There is evidence that wheat cultivars bred before 1900 and the beginning of the intensive chemical fertilization were more responsive to AMF than modern cultivars (Hetrick et al., 1992). Hetrick et al. (1996) found a relationship between AMF root colonization and biomass only in responsive wheat cultivars. Average yield of wheat during 21 years was only 20 % lower in the

organic systems of the DOK-trial depending on the variety (Mäder et al., 2007). This supports the hypothesis of a cultivar x AMF symbiosis x farming system interaction.

Materials and methods

A field trial experiment with 10 wheat cultivars was performed in the DOK-trial with organic and conventional land use management (Mäder et al., 2002). Two organic systems (BIODYN 1 and 2), a conventional system (CONMIN) and an unfertilized control plot (NOFERT) were included, differing mainly with respect to fertilization strategy and the concept of plant protection management. The organic systems stand for mixed farms with arable land and livestock, CONMIN for a stockless conventional system. Level of fertilization increased gradually from NOFERT to BIODYN 1, BIODYN 2 and CONMIN. This concept may show a correlation between AMF symbiosis and the level of fertilization. The field experiment is designed as a randomized block with four replicates. Wheat cultivars were sown in October 2006.

Winter wheat cultivar experiment in the DOK trial and selected varieties

Ten subplots with winter wheat cultivars were sown in each DOK-plot (5 m x 20 m) in the described four treatments and in all four replicates, resulting in 160 subplots (3 m x 1 m). Plots of BIODYN 1 were adjacent to BIODYN 2, plots of NOFERT adjacent to CONMIN. Cultivars were sown marginal in each plot, with five subplots at the inner and the outer side, with a border of 0.50 m between two cultivars. Sowing density was 420 seeds m^{-2} according to the usual local level. Cultivars with different breeding history were chosen for the field trial:

- Old cultivars: Rouge de Bordeaux (France, 1840), Mont Calme 245 (Switzerland, 1926), Probus (Switzerland, 1948)
- Conventionally bred cultivars: Titlis (Switzerland, 1996), Antonius (Austria, 2003), Caphorn, (France, 2001), DI 9714 (France, not registered)
- Organically bred cultivars: Scaro (Switzerland, 2006), Sandomir (Germany, not registered, Composite Cross Population (Great Britain, not registered)

Except for the composite cross population (CCP), they had to be of bread wheat quality and suitable for the growing conditions in Therwil (Basel, Switzerland). By including four Swiss cultivars (one in each breeding group) it will be possible to trace the development of cultivars with a similar genetic background, adapted to the local conditions in Switzerland during the last century. The field experiment aims to observe different agronomic growth and harvest parameters, nutrient uptake and the occurrence of AMF symbiosis during the growing season. At the beginning of the experiment, soil parameters were analysed and the number of AMF spores were counted. Samples of roots (soil core Ø 4 cm, 20 cm deep) and shoots were taken at tillering and flowering to measure nutrient uptake and for AMF assessments. During the growing season plant density was counted, plant length measured, plant growth stages, pests and diseases were recorded. Harvest took place at the end of July. We are now working on the analysis of the harvest samples: Yield of grain and straw, thousand seed weight and hectolitre weight will be measured. Additional following quality parameters of the grain will be measured: falling number, quantity and quality of protein (Zeleny). Furthermore we will analyse macro-and micro-nutrients in shoots, grain and straw to trace the relocation of nutrients. Analysis of harvest parameters showed the same ranking of yields for all varieties and treatments, whereby conventionally bred varieties had the highest yields. No statistical interaction between

varieties x treatments was found (2-way ANOVA). On the meeting we will present agronomic performance of the varieties and selected quality parameters.

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