

Summary

In the past decades, wheat (*Triticum aestivum* L.) breeding on a global scale was strongly focused on grain yield improvement to limit starvation. The introgression of semi-dwarfing genes for example improved the harvest index, which is the ratio of grain yield to total aboveground biomass. Accompanied by the increased input of mineral nitrogen (N) and phosphorus (P) fertilizers and the application of pesticides, it resulted in considerable yield increase. Focusing on yield improvement, wheat breeders tended to neglect to breed for cultivars achieving high grain yields at low nutrient supply, which means using available nutrients most efficiently. This development might have resulted in a shift of the optimum nutrient level for wheat cultivation and thus led to cultivars with an increasing demand for nutrient supply. Arbuscular mycorrhizal fungi (AMF) can contribute to nutrient supply of plants under nutrient limited conditions. It is hypothesized that breeding under high input conditions might result in cultivars that lost the ability to form AMF symbiosis. Herefrom the question arose whether those modern cultivars selected for high input farming are suitable for growing under the nutrient restricted conditions in organic farming.

This study assessed the need of specific breeding programs for organic farming. The general hypothesis was that cultivars selected under organic conditions are better suitable for organic farming than cultivars selected under conventional high input conditions. Two one year field studies were carried out in a total of seven environments with eight to ten wheat cultivars. Wheat cultivars were assessed in organic and conventional systems of the DOK long-term field trial in 2007, where different farming systems are compared since 1978. In 2008 these cultivars were assessed under practical farming conditions (replicated on-farm trials) at three organically managed farms in different pedo-climatic regions. In contrast to the fertile DOK site on loess soil, the organic farms were located at more marginal sandy or sandy loamy soils with a lower inherent yield potential. The main objectives were (i) to compare yield, baking quality and several parameters of nutrient use efficiency of modern winter wheat cultivars derived from organic and conventional breeding programs as well as old cultivars in organic and conventional systems of the DOK long-term field trial, (ii) to compare the performance of a set of these cultivars at three on-farm trials at organically managed farms at more marginal sites, (iii) to analyse phenotypic stability of selected traits and (iv) to assess the root colonization with arbuscular mycorrhizal fungi (AMF-RC) and the correlation between AMF-

RC and nutrient concentration of P, Manganese (Mn) and Zinc (Zn) in plant tissue and in the grain, nutrient uptake and grain yield.

Grain yields were significantly higher under conventional than under organic conditions at the fertile DOK site in 2007. According to expectations, the conventionally bred cultivars achieved the highest yields under conventional conditions, whereas the organically bred cultivars could not outyield the conventionally bred cultivars in the organic systems. In contrast, the organically bred cultivars could slightly outperform the conventionally bred cultivars at the three marginal on-farm sites in 2008. Remarkably, the difference in grain yield was statistically significant at the lowest yielding site.

Baking quality parameters clearly increased from old to modern organically and conventionally bred cultivars in all test environments. Nitrogen use efficiency was higher under organic than under conventional conditions and increased with the year of release of the cultivars. Similar to the results obtained for grain yield, nutrient use efficiency of the organically bred cultivars was higher than of the conventionally bred cultivars at the marginal organic sites. However, this was not confirmed in the organic systems at the fertile DOK site.

No significant genotype x environment interactions for agronomically important traits were observed comparing the organic and conventional systems at the fertile DOK site in 2007. In contrast, significant interactions were detected among the three marginal on-farm trials in 2008 and in the combined analysis across all seven conventionally and organically managed sites. This emphasizes the importance of selection under the adequate target environments. Screening and selection should not only be performed under organic farming but various pedo-climatic conditions, including also more marginal soils.

Regarding the stability of grain yield and nutrient use efficiency, a cultivar suitable for organic farming should respond dynamically to the given environmental conditions. Such a dynamic behaviour would be expressed by a good performance under marginal conditions and a constant increase from the marginal sites to the fertile DOK sites. In contrast, a static stability is required for baking quality, i. e. the gluten index. For such a parameter, a genotype should achieve stable values across a wide range of environments. One organically bred cultivar was identified, which was stable for all three traits (yield, nutrient use efficiency,

baking quality) simultaneously. However, it was not possible to relate the stability to the different breeding categories.

A promising approach to improve nutrient use efficiency of wheat could be achieved by breeding for improved AMF symbiosis. Root colonization of AMF (AMF-RC) was significantly higher in the organic than in the conventional systems but did not differ among the ten wheat cultivars at any of the seven sites. In one organically managed system and in the unfertilized control at the fertile DOK site, a positive correlation between AMF-RC and shoot P concentration at tillering was measured. No such correlation was obtained in the conventional system at the DOK site and at the marginal sites. These results indicate that higher AMF-RC might contribute to shoot P supply under organic conditions. However, the measured effect of the AMF-wheat symbiosis was only observed in early growth stages and was not reflected in improved P-uptake or grain yield at harvest. No consistent correlations were observed between AMF-RC and Mn and Zn. Molecular studies on AMF-diversity of a larger set of cultivars grown under low input conditions could shed more light on the co-evolution of wheat and AMF during breeding programs.

In conclusion, this study strongly indicates the need for organic selection environments at least in later generations of wheat breeding when selection for grain yield takes place. This study could not confirm the hypothesis that modern conventionally bred wheat cultivars might have lost the ability to form AMF symbiosis during breeding for high input conditions.