ARBUSCULAR MYCORRHIZA OF WINTER WHEAT UNDER DIFFERENT DURATION OF ORGANIC FARMING

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Abstract

The effect of continuous organic farming (OF) on the arbuscular mycorrhizal fungi (AMF) of winter wheat (*Triticum aestivum*) was investigated in a greenhouse pot trial. Representative soil samples were taken from 5 farms in the "Weinviertel" region, northeast of Vienna, Austria. On each farm three sites with a different duration of OF were selected for soil sampling; wheat was used as test plant. The mycorrhizal colonization (MC), root length density (RD) and the mycorrhizal colonized root length density (MD) were evaluated for the wheat roots. The majority of the wheat plants indicated an increasing MC and MD with increasing duration of OF. Based on our results we assume that a conversion period from conventional to OF of approximately 15 years is needed to establish a stable population of AMF, with all their considerable potential benefits for the host plants, and their contribution to maintaining soil fertility and structure.

Introduction/Problem

Arbuscular mycorrhizal fungi (AMF) are a main component of the soil edaphon in most agroecosystems. These obligate mutualistic symbionts colonize the roots of the majority of crop plants (Smith et al. 1997). AMF can efficiently absorb mineral nutrients (George et al. 1995) by their extended hyphal network, especially from nutrient-poor soils, and deliver them to their host plants in exchange for carbohydrates. AMF can also enhance the host plant's resistance to root pathogens (Azcon-Aguilar et al. 1996) and its tolerance of abiotic stresses, such as drought (Subramanian et al. 1995). Furthermore, AMF play an important role in the formation of stable soil aggregates that allow water and air infiltration and prevent soil erosion (Miller et al. 2000). Because of these beneficial effects it is a challenge to develop AMF management strategies applicable for sustainable low-input but productive agricultural systems such as OF (Hamel 1996, Klironomos et al. 2000). Industrial farming practices are apparently detrimental for AMF, as recent studies indicate that AMF performance is declining with agricultural intensification (Ryan et al. 1994; 2002). However, little is known about how the duration of OF affects AMF. Therefore, we performed a study about the effect of the duration of OF on the root colonization of wheat by AMF.

Methodology

On five farms (A-E), three field sites with a different duration of OF on each were selected for this study. They are all located in the so-called "Weinviertel", an area northeast of Vienna extending to the border with the Czech Republic. The climate of the region is temperate, with an annual precipitation of about 650 mm and an annual average temperature of about 9.0°C. The soils on the five farms (A: Haplic Phaeozem; B and C: Eutric Cambisol; D: Haplic Chernozem; E: Luvic Chernozem) developed from loess, a wind-blown sediment of silty texture deposited during the last ice age. The agricultural use of the soils is arable land with OF in accordance with the Austrian guidelines corresponding to EU regulation 2092/91, from 7 to 19 years on average without applying mineral fertilizers or synthetic pesticides. Fertilization was based on green manuring by various legumes, the application of composted plant residues produced on the farm, and horse manure. The previous crops and soil management by tillage was the same for every plot.

Soil samples (four replicate plots per field site) were taken after the harvest of the crop plants and tillage in September 2000. At each plot, two soil blocks (30 x 30 cm) were taken with a spade to a depth of 30 cm. The soil samples from each plot were mixed and sub-samples were used in a greenhouse pot trial with 4 replicates. Because of its importance as cash crop in arable OF, wheat (seed density 200 kg ha^{-1}) was used as trap plant for colonization with autochthonous AMF. The soil parameters (pH, available P) were measured in the laboratory of the Austrian Agency for health and food safety (AGES), Vienna, according to standard methods. The trap cultures were kept in a greenhouse under natural light from October 2000 till May 2001.

For vernalisation, a cold temperature treatment before flowering (Thomas 1993) was necessary, therefore the trap cultures were placed outside the greenhouse for some days in January. Four soil cores (30 cm^3, sampling depth 20 cm) were taken at the shooting of the wheat plants from each pot for the extraction of roots in May 2001.

Cereals show the highest uptake rates of P until shooting (Römer *et al.* 1986) and the rate of root growth is in accordance with the hyphal growth rate of the AMF hyphae. The wheat roots were separated from the adhering soil by a hydropneumatic elutriation system (Gillison´s Variety Fabrication Inc., USA) through a sieve with a mesh of 560 µm (Smucker *et al.* 1982). The root length density (m_{root} m^{-3}_{soil} RD) was determined according to the method of Giovanetti *et al.* (1980). Roots were stained according to the method of Vierheilig *et al.* (1998) and the mycorrhizal colonization (% MC) was determined under a light microscope according to the method of McGonigle *et al.* (1990). Considering that plants can compensate for a low MC due to a low colonization potential in the soil by a higher density of their root system, RD was multiplied by MC to obtain the mycorrhizal colonized root length density ($m_{colonized\ roots}$ m^{-3}_{soil} MD), a more reliable parameter for the determination of a significant MC of a plant root system (Amijee *et al.* 1989). The data obtained for RD, MC and MD were divided into 3 groups of different duration of OF (long-term, mid-term, short-term) and subjected to a one way ANOVA. The mean values of four replicate pots were compared using Tukey's multiple range test (P<0.05).

Results and brief discussion

In a first step, the determined parameters were compared for the three sites investigated on each of the five farms. The MD of wheat grown in the soil of the farm Alt Prerau was significantly increased after 16 and 13 years of OF compared to 9 years. Wheat grown in the soil of the farm Herrnleis showed a significantly increased MD after 17 and 11 years of OF compared to 6 years. No dependence of the MD of wheat on the year of conversion from conventional to OF could be found in the soil of the farm Neubau. The MC of the wheat roots of all treatments was approximately 35%, a relatively high value compared to the other treatments. The duration of organic farming on this farm ranged from 13 to 22 years. This long duration of OF even on the most recently converted site presumably was beyond the time needed for the establishment of a stable AM population, and can be regarded as the reason for the lack of effect of the conversion date on this farm. The MD of wheat grown in the soil of the farm Obersiebenbrunn was not significantly different between the longest (25 years) and the shortest (9 years) duration of OF. Interestingly, the MD of wheat was lowest in the soil with a medium-term duration (18 years) of OF, which was due to the relatively high RD. The MD of wheat grown in the soil of the farm Spillern was significantly increased after 11 years of OF.

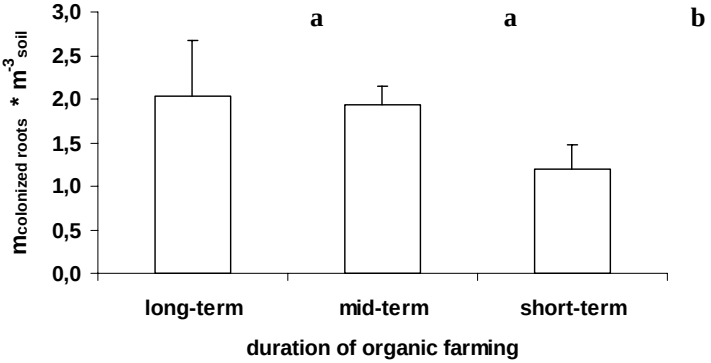
In a second step, the determined parameters were compared over all the five farms. Therefore, the field sites of each of the farms were pooled in three groups of different duration of organic farming: (long-term, medium-term and short-term OF, with an average duration of 19 years, 13 years, and 7 years of OF, respectively) (Tab. 1).

Tab. 1: Overview concerning the MC, RD and the MD of winter wheat (*Triticum aestivum*) within the groups as affected by the duration of organic farming.

Duration of Organic Farming	MC (%)	RD (m m^{-3})	MD (m m^{-3})
long-term (∅ 19 yr)	31 ± 7 a	6,4 ± 0,9 a	2,0 ± 0,6 a
medium-term(∅ 13yr)	30 ± 2 a	6,3 ± 0,6 a	1,9 ± 0,2 a
short-term (∅ 7yr)	17 ± 2 b	7,2 ± 1,3 a	1,2 ± 0,3 b

Values for determined parameters are shown with standard deviation (±), Treatments within one column with the same letter are not significantly different according to Tukey's multiple range test (P < 0.05).

Wheat plants grown in the pots with the soil from the plots with a medium- and long-term duration of OF maintained a significantly higher level of MC (Tablel 1) and MD (Figure 1) than in the short-term group. No differences were found in the RD of the wheat plants across the different treatments. No differences were found in the yield of wheat in the trial (data not shown).



Bars are shown with standard deviation error of means, treatments with the same letter are not significantly different according to Tukey's multiple range test ($P < 0.05$). Short-term.∅ 7 years, medium-term.∅ 13 years, long-term ∅ 19 years of organic farming

Fig. 1: Mycorrhizal colonized root length density (MD) of winter wheat (*Triticum aestivum*) within the groups as affected by the duration of organic farming.

Already more than 60 years ago, Sir Albert Howard (1943), one of the most important figures in the development of the organic movement, suggested that "the presence of an effective mycorrhizal symbiosis is essential to plant health". The potential benefits of OF to soil fertility and soil microorganisms such as AMF has been shown in numerous investigations (e.g. Foissner *et al.* 1986, Lee *et al.* 1992, Liebhart *et al.* 1989, Limonard *et al.* 1989, Hole *et al.* 2005). Of high significance, therefore, is the enriched humus content due to organic fertilization, especially with composted farmyard manure and soil management with reduced (conservation) tillage. Several observational studies have assessed differences between colonization levels and spore populations in differently managed agricultural systems (Sattelmacher *et al.* 1991, Douds *et al.* 1995 & 1999, Mäder *et al.* 2000, Oehl *et al.* 2003, 2004 & 2005).

To our knowledge, the MC, RD and MD of cereal crop plants have not been investigated over a broad range of OF duration. In two (Alt Prerau and Spillern) of the five investigated organic farms we found an increase of the MC after at least 11 and 13 years of continuous OF, respectively. Werner (1997) already found a significantly higher MC in an apple orchard (*Malus domestica*) after 2 years of continuous OF, probably due to the higher occurrence of highly mycorrhizal accompanying weeds and complementary herbs. In the pot cultures with soil samples from the farm Obersiebenbrunn we found an increase of the MC after 20 years of continuous OF, whereas no differences concerning the MC of wheat in the pot cultures from the farm Neubau were found. That could be due to the relatively high duration of continuous OF (at least 13 years) and the relatively high MC (>30%) in all treatments. In this case, the reestablishment of the soil organisms probably already had taken place within 13 years. In the comparison over all the farms, we found a significantly higher MC of wheat plants after at least 13 years continuous OF. The divergence to the shorter duration of OF causing a significantly higher MC in the comparison within the farms in relation to the comparison over all five farms is probably due to the relatively high MC of wheat in the pots with the soil trials of the farm Neubau, which increased the standard deviation.

Conclusions

For the majority of the wheat plants in our investigation we found an increasing MC and MD with longer duration of OF. Highly probable reasons responsible for our results are the rejection of easily soluble mineral fertilizers and artificial agro-chemicals such as pesticides and fungicides, as well as the establishment of a stable autochthonous soil organism community. Based on our results we assume that approximately 15 years is needed after conversion from conventional to OF to establish a stable population

of AMF, with all their potential benefits for the host plants and their contribution to maintaining soil fertility and soil structure.

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