Effect of mycorrhizal inoculation on the yield averages of winter wheat (*Triticum aestivum* var. Mv Nádor) under farm conditions

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Abstract

The effect of mycorrhizal inoculants on a winter wheat cultivar (*Triticum aestivum* var. Mv Nádor) was tested under modified farm conditions near Nagyhörcsök in 2016. The soil of the experimental field was a chernozem with lime deposits (WBR classification: Calcic Chernozem) with a mean humus content of 2.73%, AL-soluble P_2O_5 and K_2O values of 181 mg/kg and 149 kg/kg and a $pH_{(KCl)}$ of 7.27. The mycorrhizal inoculant contained spores of *Rhizophagus irregularis* (previously *Glomus intraradices*) and *Glomus mosseae*. In some of the treatments mineral fertiliser was applied at a rate of 130 kg/ha N, 78 kg/ha P_2O_5 and 60 kg/ha K_2O in addition to the soil inoculation. Both mycorrhizal inoculation and mineral fertiliser application were found to have a significant effect on the yield level (at the $p<0.05$ level). The mean yield of the inoculated treatments was 8.91 t/ha, compared with a mean of 8.50 t/ha for the non-inoculated treatments. Plots given mineral fertiliser treatment had a mean yield of 9.23 t/ha, while those given no mineral fertiliser yielded only 7.75 t/ha. The yield-increasing effect of mycorrhizal inoculation was only manifested on plots where no mineral fertiliser was applied. Plant protection treatments were the same on all the plots. There was no difference between the treatments in terms of plant pathological parameters.

Keywords: mycorrhizal inoculation, *Glomus intraradices*, wheat, yield average.

Összefoglalás

Mikorrhiza oltóanyag hatását vizsgáltuk egy őszi búza fajtára (*Triticum aestivum var.* Mv Nádor) módosított üzemi körülmények között Nagyhörcsök mellett, 2016-ban. A kísérlet talaja mészlepedékes csernozjom (WBR besorolás: Calcic Chernozem) volt, az átlagos humusztartalom

2,73%, az AL-oldható P_2O_5 és K_2O értékek 181 mg/kg és 149 mg/kg, a $pH_{(KCl)}$ 7,27. A mikorrhiza oltóanyag *Rhizophagus irregularis* (korábban *Glomus intraradices)* és *Glomus mossa* szaporítóegységeket tartalmazott. A talajoltás mellett a kezelések egy részében műtrágya kezelést is alkalmaztunk 130 kg N/ha, 78 P_2O_5 kg/ha, 60 K_2O kg/ha adagban. Eredményeink szerint a mikorrhiza oltásnak és a műtrágya kezelésnek egyaránt szignifikáns hatása volt a termés mennyiségére ($p<0,05$ szinten). A mikorrhiza oltást kapott kezelések termésátlaga 8,91 t/ha volt, ami magasabb, mint az oltatlan kezelések átlaga (8,50 t/ha). A műtrágyakezelést kapott kezelések termésátlaga 9,23 t/ha, a műtrágyát nem kapott kezeléseké 7,75 t/ha volt. A mikorrhiza oltás termésnövelő hatása csak a műtrágyakezelést nem kapott parcellákban érvényesült. A növényvédelmi kezelések egyformák voltak minden kezelésnél. A növénykórtani jellemzőkben nem volt a kezelések között különbség.

Kulcsszavak: mikorrhiza oltás, *Glomus intraradices*, búza, termésátlag.

Introduction

Under natural conditions the mycorrhizal fungi living in symbiosis with plant roots make a substantial contribution to the nutrient uptake of the plants. In addition to this direct effect, mycorrhizal fungi also have indirect effects, including the amelioration of the soil structure (Rillig and Mummey, 2006), interactions with other soil-borne microorganisms (Veresoglou et al., 2016) and protection against plant pathogens (Azcón-Aguilar and Barea, 1996). There are various types of mycorrhizas, but 85–90% of angiosperms form arbuscular mycorrhizas (AM). Under intensive agricultural production conditions AM fungi are of much less significance. The reduction in the number of plant species found on a given area (mono- and dicultures), the regular disturbance of the soil, the use of mineral fertiliser and the application of fungicides all lead to a decline in the number and activity of mycorrhizal fungi. On areas constantly used for agricultural production the number of mycorrhizal fungal propagules is greatly reduced (Posta, 2013).

The advantages of mycorrhizal fungi are obvious to crop producers, so the possibility of inoculating soils with these fungi has long been the subject of research. A number of reviews and meta-analyses have been published, most of which report on the yield increases demonstrated in field crops such as maize and winter wheat (Lekberg and Koide, 2005; Lehmann et al., 2012; Treseder, 2013; Pellegrino et al., 2015). The effect of mycorrhizal inoculation depends on the available nutrient content of the soil, the type of cultivation, (mineral) fertilisation, the use of plant protection agents (particularly fungicides) and the weather (Posta, 2013). The relationship between the available phosphorus content of the soil and the level of mycorrhization has been examined in depth (Treseder, 2013; Suriyagoda et al., 2014). Most authors observed a yield-increasing effect in the case of low-input crop production (Pellegrino et al., 2015), but Cozzolino et al. (20113) also demonstrated a yield-increasing effect in maize when the treatment was combined with the application of NP or NPK fertiliser. After evaluating the results of 38 field experiments, Pellegrino et al. (2015) reported that AM fungal inoculation led to a mean yield increase of 20%. However, the transferral of these results is complicated by the fact that only three of the locations tested were in Europe and here too only the effect of naturally-occurring fungal associations was examined. The aim of the present work was to determine whether mycorrhizal inoculation resulted in a yield increase in winter wheat (*Triticum aestivum* var. Mv Nádor) under field conditions on 1 ha plots with fertile soil (calcic chernozem) using the technology normally applied in Hungary.

Material and method

The field experiment was set up on calcic chernozem soil in the neighbourhood of Nagyhörcsök, Hungary. The soil characteristics were as follows: upper level of plasticity according to Arany 43, mean humus content 2.73%, AL-soluble K_2O and P_2O_5 149 mg/kg and 181 mg/kg, respectively, $CaCO_3$ 5.05 m/m%, $pH_{(KCl)}$ 7.27. The soil analysis was performed in the Soil Protection Laboratory, Velence. The preceding crops on the experimental area were sunflower (2015), maize (2014) and peas (2013).

The mycorrhizal inoculant used in the experiment was the Aegis Sym Irriga microgranulate manufactured by Italpollina. This contains several mycorrhizal fungi, principally *Rhizophagus irregularis* (previously *Glomus intraradices*) and *Glomus mosseae* species. The inoculant has a concentration of 1,400 spores/g and the recommended dose is 1–2 kg/ha (internet 1).

The treatments (mineral fertiliser+mycorrhizal inoculant, mineral fertiliser alone, mycorrhizal inoculant alone, no fertiliser or inoculant) were applied in three replications. The mineral fertiliser dose was 130 kg/ha N, 78 kg/ha P_2O_5 and 60 kg/ha K_2O and the plot size 10,000 m² (40×250 m), arranged in a strip-split-plot design. All the plots were given the soil preparation and plant protection normal under farm conditions. The sunflower crop in the previous year was harvested on 31 Aug. 2015, followed on 1 Sept. by disking and on 14 Sept. by the application of basic potassium fertiliser to the fertilised plots. The seedbed was prepared using a seedbed cultivator on 20 Oct. The mycorrhizal inoculant was applied on 21 Oct. as recommended by the manufacturer using plant protection machinery, where the spraying device followed a short disk fitted with a bladed cylinder at a maximum distance of 20 m. Sowing took place on 26 Oct. As the seed was sown within 7 days of inoculation the conditions were ideal for colonisation. Ammonium nitrate (34%) was applied to the fertilised plots on 3 Nov. and Nitrosol (30%) on 22 Nov. Plant protection treatments were performed on 5 Apr. and 9 May. Samples were taken with the plot combine at harvest on 12 July.

The first plant protection treatment on 5 Apr. consisted of a 0.75 l/ha dose of FalconPro fungicide (active ingredients: spiroxamine, tebuconazole and prothioconazole) and a 0.15 l/ha dose of the herbicide Sekator OD (active ingredients: amidosulfuron and iodosulfuron) with the adjuvant Silwet Star (0.1 l/ha). On 9 May a 2 l/ha dose of the fungicide Cherokee (active ingredients: cyproconazole, propiconazole and chlortalonyl) was applied, using the same adjuvant.

The plots were scored from the plant protection point of view on a total of 15 occasions, on 15 Nov., 30 Nov. and 15 Dec. 2015 and on 29 Jan., 14 Feb., 28 Feb., 5 Mar., 24 Mar., 9 Apr., 29 Apr., 15 May., 28 May., 10 Jun., 25 Jun. and 10 Jul. 2016.

The weather conditions in 2016 were ideal for wheat production.

Results

As the weather in 2016 was favourable for wheat production and there were no plant protection problems, the usual high yield averages, often ranging from 7–10 t/ha, were recorded on the experimental field. The wheat yields obtained in the fertiliser and mycorrhizal treatments are shown in Table 1.

Table 1. Mean yields obtained for the winter wheat cultivar Mv Nádor in the mineral fertilisation and mycorrhizal inoculation treatments

Treatment	Mean yield (deviation) [t/ha] without inoculation	Mean yield (deviation) [t/ha] with inoculation
Without fertiliser	6.96 (0.27) N=3	8.54 (0.20) N=3
With fertiliser	9.27 (0.33) N=6	9.27 (0.29) N=3

N: number of replications

The t-tests performed on the data revealed a significant difference between the inoculated and non-inoculated treatments on plots given no mineral fertiliser. Two-way analysis of variance was also performed on the yield data, the two factors being mycorrhizal inoculation and mineral fertilisation. The results showed that both factors had a significant effect on the wheat yield. The mean yield was 7.75 t/ha (deviation 0.90) on non-fertilised plots and 9.27 t/ha (deviation 0.30) on fertilised plots. Without mycorrhizal inoculation the mean yield was 8.50 t/ha (deviation 1.19), rising to 8.91 t/ha (deviation 0.45) after inoculation.

All the plots were given the same plant protection treatment, and no difference was observed from the plant protection point of view between the plants on the inoculated and non-inoculated plots.

Discussion

Two-way analysis of variance revealed that mycorrhizal inoculation had a significant effect on the yield of winter wheat under field conditions, but this effect was only manifested on plots given no mineral fertiliser. Inoculation had no yield-increasing effect on fertilised plots. No scientific papers were found in which mycorrhizal inoculation was reported to result in a perceptible increase in yield on large plots of nutrient-rich soil under normal farm conditions. All the yield-increasing effects described in the literature, e.g. by Cozzolino et al. (2013), were obtained on small plots where the soil had lower (1.7%) humus content and lower (12 mg/kg) $NaHCO_3$-soluble P content, not under farm conditions.

Intensive crop production with a high level of mineral fertilisation has been underway for several decades on the area used for the present experiment. This explains why the number of mycorrhizal fungal propagules had dropped to such an extent that a single mycorrhizal inoculation was sufficient to cause a detectable increase in plant growth and yield. From the plant protection point of view there was no difference between the various treatments.

In practice the cost of mycorrhizal inoculation and the more modest increase in yield must be weighed against the cost of fertilisation and the greater increase in yield to determine which is the more profitable option.

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internet 1: http://www.mezogazdasagibolt.hu/termek/ITALPOL2151/aegis-sym-irriga-05-kg-mikrogranul-tum

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