Weeds promote the development of arbuscular mycorrhizal fungi in organic wheat fields

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Abstract

Understanding the effect of aboveground plants on arbuscular mycorrhizal fungi (AMF) in organic agriculture is of great importance in developing more efficient and sustainable agricultural systems. This study was conducted to evaluate the effect of weeds on AM and the effect of AMF on wheat (Triticum aestivum L.) grain quality in organically managed weed-free and weedy fields. The soil microbial profile was characterized using phospholipid fatty acids (PLFA) analysis. The presence of weeds increased the proportion of AMF; however, this increase did not alter the quality of wheat grain grown with sufficient soil phosphorus (P).

Introduction

Arbuscular mycorrhizal fungi (AMF) have attracted researchers' attention due to their ubiquitous distribution and beneficial effects on symbiotic host plants. Phosphorus (P) uptake enhancement is a well-known benefit of AMF (Smith and Read, 2008). Organic fields tend to have a larger AMF community than conventional fields (Oehl et al., 2004).

Although weed pressure has resulted in economic loss, some studies have emphasized the importance of aboveground species for maintaining soil mycorrhizal communities under conventional practices (Kabir and Koide, 2000). However, the relationship between weeds and AMF under organic management fields is still poorly understood.

The present study was conducted 1) to understand the role of weeds on the maintenance and promotion of AMF communities, and 2) to determine the effect of AMF on wheat grain quality in organically managed fields.

Material and methods

This study was conducted in 2010 and 2011 at the University of Alberta research farm, Edmonton, AB, Canada (55^o 34' N, 113^o 31' W). Fertility levels were adequate for wheat cultivation in both years, albeit with low N levels. The field has been organically managed since 1999. Plant residues from prior years were disc-harrowed in the field several weeks before seeding. A single tillage operation was also performed to control initial weed emergence prior to seeding. Thirteen Canadian spring wheat cultivars (*Triticum aestivum* L.) were seeded in a split-plot design with four replications. Weed treatment (weed-free and weedy) was the main plot effect and wheat cultivar was the subplot. Weed-free plots were maintained by daily hand-weeding throughout the wheat growing seasons to avoid soil surface disruption, while no weed control was applied in the weedy treatment.

Weed samples were collected from a quadrat in each plot when wheat vegetative growth was completed. Wheat yield samples were collected at their maturity. The samples were stored in a dryer at 40 °C for at least 48 h before measurement.

Soil samples for a microbial community analysis were collected twice during the wheat growing season (1st: May, 2nd: September). Soil samples were analyzed to characterize soil microbial communities using phospholipid fatty acid (PLFA) analysis (Hannam et al., 2006). Indicator PLFAs were used to calculate the relative contribution (as % of total microbial PLFA) of several soil microbial groups (i.e. gram-positive bacteria, gram-negative bacteria, actinomycetes, AMF).

Wheat grain nutrient contents were analyzed using a standard HNO_3 H_2O_2 method (Zn, Mn, Cu, K) and the Kjeldhal method (P). Grain protein content was recorded using near-infrared reflectance (NIR) spectroscopy.

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All collected data were tested to meet the assumptions of ANOVA prior to analysis. The data were analyzed using the PROC MIXED procedure (version 9.2, SAS® Institute, 2008) of SAS. They were analyzed as a randomized complete block design in a split-plot arrangement. For PLFA analyses, all PLFA data were transformed using arcsine square-root transformation prior to the analyses. Pearson's correlation coefficients were computed to examine correlations among grain nutrients, weed dry biomass (WDB), total biomass production (TBP: wheat grain + weed dry biomass) and soil microbial communities.

Results

The weedy treatment had a greater percentage of AMF (Weedy: 3.4 %, Weed-free: 3 %), wheat grain yield (Weedy: 3.94 t ha^{-1}, Weed-free 4.79 t ha^{-1}), weed dry biomass (Weedy: 2013 kg ha^{-1}, Weed-free: 7 kg ha^{-1}), total biomass production (Weedy: 5.86 t ha^{-1}, Weed-free: 4.8 t ha^{-1}) and manganese (Weedy: 34.1 ppm, Weed-free: 31.9 ppm) relative to the weed-free treatment at $p < 0.05$. However, levels of phosphate and protein were not affected by the weed treatment.

There was a moderate positive correlation between weed dry biomass and the percentage of AMF in the weed-free treatment; however, weed dry biomass did not correlate with AMF in the weedy treatments (Table 1). Zinc and potassium were negatively correlated with the proportion of AMF only in the weedy treatment (Table 1). However, there was no discernible difference in the levels of grain nutrients related to the presence of AMF.

Our study also observed an increase in AMF over the wheat growing season in both treatments (Figure 1). The increase of AMF was greater in the weedy treatment than in the weed-free treatment (Weedy: from 2.9 % to 3.9 %, Weed-free: from 2.8 % to 3.1 %), while gram-negative bacteria decreased over the growing season (Weedy: from 13 % to 12 %, Weed-free: from 12.8 % to 11.9 %).

Table 1: Pearson correlation coefficient of WDB, TBP and grain nutrition with soil microbial communities at the second soil sampling

				Weed-free				
	WDB	TBP	Zn	Mn	Cu	K	P	Pro
Gram+	-0.36**	-0.42**		-0.34*				-0.41**
Gram-	0.31*	0.34**		0.28*				0.36**
Actino		0.37**						
AMF	0.4**							
				Weedy				
	WDB	TBP	Zn	Mn	Cu	K	P	Pro
Gram+	-0.32*	-0.29*		-0.28*		0.49**	-0.32*	-0.57**
Gram-			-0.28*			-0.41**	0.36**	0.46**
Actino				-0.31*			-0.31*	
AMF			-0.38**			-0.43**		

*,**= significant at the 0.05, 0.01 probability levels.
Gram+: Gram-positive bacteria, Gram-: Gram-negative bacteria, Actino: Actinomycetes, WDB: Weed dry biomass, TBP: Total biomass production, Pro: Protein

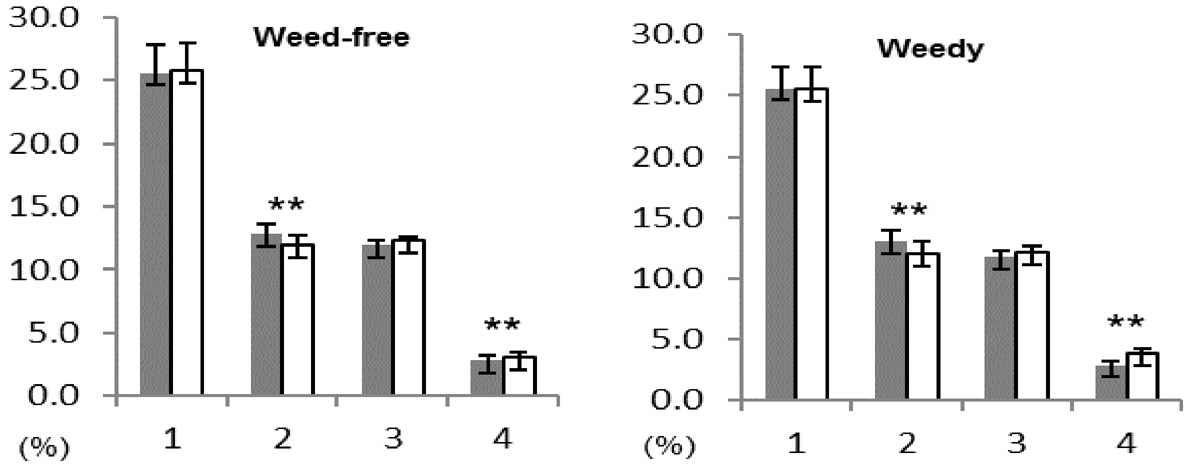

Figure 1: Mean proportion of soil microbial communities in the weed-free and the weedy treatments in two different samplings

Grey bars denote first sampling time (May) and white bars represent second sampling time (September). 1: Gram-positive, 2: Gram- negative, 3: Actinomycetes, 4: AMF.
**= significant at the 0.01 probability levels. Bars indicate standard errors of the means.

Discussion

These results indicated that the presence of weeds supported a substantial increase in AMF over the growing season. Interestingly, we observed a positive correlation between AMF and weed dry biomass only in the weed-free field. This indicated that the substantial increase in AMF did not occur continuously with the growth of aboveground vegetation. The increase may have reached a marginal point at which symbiotic nutritional exchange became imbalanced due to intensification of light and nutritional competitions among aboveground spices (Facelli et al., 1999).

As in a previous study (Liu et al., 2000), AMF did not alter wheat grain quality under sufficient soil P conditions (2010:134 kg ha^{-1}, 2011:63 kg ha^{-1}). The total aboveground biomass and soil P status are important factors in controlling AMF benefits for host plants. Further studies on the behavior of AMF at various aboveground crop and weed densities may contribute to the development of efficient organic agricultural practices.

References

Facelli E., Facelli J. M., Smith S. E. & McLaughlin M. (1999): Interactive effects of arbuscular mycorrhizal symbiosis, intraspecific competition and resource availability on *Trifolium subterraneum* cv. Mt. Barker. New Phytologist. 141, 535-547.

Hannam K. D., Quideau S. A. & Kishchuk E. B. (2006): Forest floor microbial communities in relation to stand composition and timber harvesting in northern Alberta. Soil Biology & Biochemistry. 38, 2565-2575.

Kabir Z. & Koide R.T. (2000): The effect of dandelion or a cover crop on mycorrhiza inoculums potential, soil aggregation and yield of maize. Agriculture, Ecosystems & Environment 78, 167-174.

Liu Y., Hamel C., Hamilton R. I., Ma B. L. & Smith D. L. (2000): Acquisition of Cu, Zn, Mn and Fe by mycorrhizal maize (*Zea mays* L.) grown in soil at different P and micronutrient levels. Mycorrhiza. 9, 331-336.

Oehl F., Sieverding E., Mäder P., Dubois D., Ineichen K., Boller T., & Wiemken A. (2004): Impact of long-term conventional and organic farming on the diversity of arbuscular mycorrhizal fungi. Oecologia. 238, 574-583.

Smith S.E. & Read D.J. (eds.) (2008): Mycorrhizal Symbiosis. 3rd ed. Elsevier Ltd. London. Middleton.