Can arbuscular mycorrhizal fungi enhance plant nitrogen capture from organic matter added to soil?

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1. Background & Objectives

Several studies have shown that arbuscular mycorrhizal (AM) fungi are involved in plant nitrogen (N) uptake from inorganic sources. In addition, the AM fungi may be important in plant N capture from decomposing organic matter (OM), but their role is still unclear (Hodge et al., 2010). The present work tested the hypothesis that AM symbiosis can affect durum wheat (*Triticum durum*) N acquisition from OM added to soil, either by directly or indirectly influencing OM decomposition.

2. Materials & Methods

A pot experiment was conducted in a climate-controlled glasshouse (25/19°C day/night temperature; 16 h photoperiod). A complete randomized factorial design with four replicates was adopted. Treatments were: i) AM symbiosis, inoculation of soil with *Glomus mosseae* (+Myc) and uninoculated control (–Myc); ii) organic matter (OM), soil amended with 4.6 g ^{15}N-enriched maize leaves (C:N ratio 22.6:1) per kg of soil (+OM) and unamended soil (–OM). Each pot was filled with 600 g of a quartz sand:soil mixture (2:1). Soil properties were: clay 20% and sand 37%; pH 8.1 (soil:water 1:2); 1.04% organic C; 1.05‰ total N. The soil mixture was steam-sterilised. Before starting the experiment, a soil filtrate was inoculated to normalise the microbial community. Three wheat plants (cv Simeto) per pot were grown. During the experiment, each pot received 5 ml of a modified Hoagland's solution (with no phosphorus and 10% N) once every 5 days. The dry weights of wheat shoots and roots were recorded 9 weeks after the emergence of the crop and both fractions were analyzed for total N and ^{15}N enrichment using an elemental analyzer–isotope ratio mass spectrometer. The activity of two soil proteolytic enzymes was measured: caseinase (a measure of the protein hydrolysis to monopeptides) and BAA-protease (a measure of amino acid deamination). Wheat roots were stained with 0.05% trypan blue in lactic acid and AM infection was measured using the grid intersect method (Giovannetti and Mosse, 1980). The recovery of the applied ^{15}N in wheat was calculated according to Allen et al. (2004). An analysis of variance was performed according to the experimental design.

3. Results & Discussion

No AM root infection was found in the –Myc treatment. The addition of OM to soil markedly decreased both plant growth and total N uptake and, at the same time, increased the caseinase and BAA-protease activities (Table 1), which suggests an increase in soil microbial activity. Because soil microorganisms outcompete plants for nutrients over short timescales, the depressive effect of OM on plant growth and N uptake may have been caused by the higher sequestration of available inorganic N and other nutrients by microorganisms in +OM. On average, mycorrhizal wheat yielded 20% more biomass and 15% more N than non-mycorrhizal control. Several studies have shown that AM symbiosis improves plant growth and nutrient uptake especially when plants are grown under nutrient-limiting conditions (Azcón et al., 2001). Through AM fungi, plants can better scavenge the soil volume, which enhance their ability to absorb the available N. In addition, as suggested by Hodge et al. (2000), AM fungi could enhance N uptake by host plant being more effective than non-mycorrhizal roots in competing with soil microorganisms for inorganic N. The microbial activity

(both caseinase and BAA-protease) was significantly higher in +Myc than –Myc in either +OM and –OM treatments. This should have involved an increase in soil N availability from OM. However, the ^{15}N recovery fraction from the added OM was markedly lower in +Myc than –Myc treatment. Two mechanisms can be invoked to explain such result: firstly, AM fungi could have acquired N from decomposing OM in the form of amino acids and retained this element primarily for their own growth and metabolism (Hodge and Fitter, 2010). Secondly, mycorrhizal plants are more effective than non-mycorrhizal plants to take up inorganic N; this probably limited N availability in soil, thus forcing soil bacteria to rely on organic compounds for satisfying their N demand, which limited the release of N from OM (Schimel and Bennett, 2004).

Table1. Effects of AM symbiosis (AMS) on total plant biomass, total plant N uptake, ^{15}N recovery fraction from added organic matter (OM), AM root infection, and caseinase activity and BAA-protease activity in wheat grown in soil amended with OM (+OM) or without OM (–OM).

Organic matter (OM)	AM symbiosis (AMS)	Total plant biomass [g per pot]	Total plant N uptake [mg per pot]	^{15}N recovery fraction from added OM [%]	AM root infection [a)] [%]	Caseinase activity [μg Tyr g^{-1} h^{-1}]	BAA-protease activity [μg NH_4^+ g^{-1} h^{-1}]
–OM	–Myc	1.00	9.78	–	–	1.026	1.887
	+Myc	1.13	10.96	–	32.8	1.235	2.510
+OM	–Myc	0.79	7.68	6.36	–	1.328	2.114
	+Myc	1.01	9.03	3.93	35.1	1.609	3.323
F test [b)]	OM	**	**	–	***	*	***
	AMS	***	*	***	–	*	***
	OM × AMS	ns	ns	–	–	ns	*

[a)] not applicable to –Myc treatments;
[b)] ns = not significant; *, ** and *** significant for $P < 0.05$, 0.01 and 0.001, respectively.

4. Conclusion

Although AM fungi increased soil N mineralization rates and total plant N uptake, they strongly reduced wheat N recovery from OM. This suggests that AM fungi have marked effects on competition between plants and bacteria for the different sources of N in soil.

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