Effects of soil inoculation with arbuscular mycorrhizal fungi on plant growth and nutrient uptake of some Mediterranean species grown under rainfed field conditions

Saia, S., Ruisi, P., Amato, G., Di Miceli, G., Frenda, A.S., Giambalvo, D.
Dipartimento dei Sistemi Agro-Ambientali, Università degli Studi di Palermo, Italy

1. Background & Objectives

Low-input farming systems often suffer nutrient deficits that limit plant performance. The symbiosis between plants and arbuscular mycorrhizal (AM) fungi efficiently promotes plant growth and nutrient uptake, especially in growth-limiting environments (Smith and Read, 2008). AM symbiosis seems to be particularly efficient for the acquisition of low-mobility nutrients such as phosphorus (P), magnesium, and zinc, although it traditionally has been considered irrelevant for plant nitrogen (N) nutrition. However, there is increasing evidence that AM symbiosis plays a significant role in plant N capture, especially under conditions of stress (such as water and nutrient stress). These benefits mainly have been observed in pot studies; field studies have often produced contradictory results (Kaschuk et al., 2010). The present work evaluated the effect of a multi-species AM fungi soil inoculum on the biomass uptake of P and N in two cereals, oat (*Avena sativa*) and barley (*Hordeum vulgare*), and two legumes, lentil (*Lens culinaris*) and fenugreek (*Trigonella foenum graecum*), all grown in the field.

2. Materials & Methods

A field trial was conducted under rainfed conditions at Pietranera farm, Sicily, Italy (37°33′N – 13°30′E, 170 m a.s.l.), on a Vertic Haploxerept. The topsoil (0–40 cm) characteristics were: clay 50%, silt 23%, sand 27%; pH 8.0 (1:2 H_2O); 1.27% organic matter; 83 ppm available P; and 0.76‰ total N. The climate of the experimental site is semiarid Mediterranean. The experimental design was a split plot with four replicates. The main treatment was plant species: oat, barley, lentil, and fenugreek. The sub-plot treatment was soil inoculation: the application of a commercial inoculum containing nine species of AM fungi and non-inoculated soil. The previous crop was durum wheat (*Triticum durum*). In the first week of December 2010 all crops were sown using the seed rate for each plant species that is usually adopted by farmers in the growing environment. No fertilizer was applied and all plots were hand-weeded during the entire crop cycle. In the first week of May 2011, all crops were cut to 2-cm stubble height. Total fresh and dry weights were determined and a sub-sample was taken and analyzed for total N and P. Root samples were also collected and stained with 0.05% trypan blue in lactic acid. The percentage of root AM infection was measured according to Giovannetti and Mosse (1980). An analysis of variance was performed according to the experimental design.

3. Results & Discussion

On average, the addition of AM fungi inoculum to soil significantly increased biomass production (+14.1%) without affecting P and N concentration, thus producing a significant increase in plant P and N uptake (+8.3% and +12.7% on average, respectively; Table 1). Several studies have shown that AM symbiosis can increase plant P uptake in P-limited environments; although our experiment was performed in P-rich soil, we observed a significant increase in P acquisition by plants. Given the low N availability (a result of both low soil N content and N uptake by the field's prior cereal crop), the observed growth increase in AM-inoculated oat and barley is probably related to increased plant uptake of N as a result of the symbiotic relationship. The effect of AM fungi inoculation on plant N uptake was evident in lentil (+30% compared to the non-inoculated crop), but not in fenugreek. AM symbiosis may have allowed lentil—a slow-growing and low-yield species that usually suffers abiotic stresses such as nutrient and water deficiency (Materne and Siddique, 2009)—to increase its tolerance to biotic and abiotic stresses. This enhanced plant growth resulted in a higher demand for N, which was satisfied through increased N_2 fixation. Other studies (Saia et al., 2010) have shown that AM fungi positively affect the N_2 fixation of field-grown forage legumes, particularly when grown under drought conditions. We used a genotype of fenugreek that has good tolerance to biotic and abiotic stresses and that gives reasonable yields under low-input cultivation conditions, which may explain why it benefitted less from the AM symbiosis.

Table 1. Effect of arbuscular mycorrhizal (AM) fungi soil inoculation on above-ground biomass, phosphorus (P) and nitrogen (N) concentrations in tissue, and P and N uptake in two cereal and two legume species (S) grown in the field.

Plant species (S)	Soil inoculation with AM fungi (AM)	Biomass	P concentration	P uptake	N concentration	N uptake
		[Mg DM ha^{-1}]	[‰]	[kg ha^{-1}]	[%]	[kg ha^{-1}]
Barley	Inoculated	9.45	1.33	12.6	0.91	86.0
	Non-inoculated	8.45	1.44	12.2	0.85	71.5
Oat	Inoculated	7.93	1.49	11.7	1.10	86.3
	Non-inoculated	6.76	1.59	10.7	1.05	70.6
Lentil	Inoculated	6.06	1.96	11.8	2.47	150.3
	Non-inoculated	4.80	2.11	10.1	2.43	115.6
Fenugreek	Inoculated	7.24	2.11	15.3	2.36	169.4
	Non-inoculated	6.88	2.09	14.5	2.45	168.8
F test [a)]	S	*** (0.85) [b)]	*** (0.15)	*** (1.8)	*** (0.12)	*** (16.7)
	AM	***	ns	*	ns	*
	S×AM	ns	ns	ns	ns	* (12.4)

[a)] ns = not significant; * and *** significant for $P < 0.05$ and 0.001, respectively;
[b)] Fisher's Protected LSD for P=0.05 are shown in parentheses.

4. Conclusion

Our results show that soil inoculation with AM fungi increases both growth and nutrient uptake in cereal and legume species typical of the Mediterranean environment to varying degrees among species. From a practical point of view, inoculation with AM fungi can be a valuable option for farmers to improve the sustainability of the agro-ecosystem as it is an environmentally friendly approach for the increase of crop nutrient uptake.

References

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