

**ROLES OF MYCORRHIZAL SYMBIOSIS IN GROWTH
AND PHOSPHORUS NUTRITION OF WHEAT IN A
HIGHLY CALCAREOUS SOIL**

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Summary

The overall objective of the work presented in this thesis was to investigate roles of arbuscular mycorrhizal (AM) fungi in growth and phosphorus (P) nutrition of wheat (*Triticum aestivum* L.) in a highly calcareous soil from the Eyre Peninsula, South Australia.

The soil used for this study is one of the main soil types used for wheat production in South Australia. It is severely P-deficient, but plant responses to conventional fertiliser application are poor. Although the total P and Colwell-extractable P contents of the soil are high, the resin-extractable P content is very low. Resin-extractable P is better able to predict P availability for plant growth than Colwell-extractable P. The soil is also strongly P-fixing. Moderate levels (about 20 mg kg⁻¹) of resin-extractable P for wheat could only be achieved by adding high rates (up to 100 mg kg⁻¹) of CaHPO₄ in this soil. A bioassay with wheat showed that it can be highly colonised by AM fungi in the soil. AM fungi have been shown to improve P nutrition of plants, particularly in nutrient poor soils. They may thus be important for wheat grown in the soil with low amounts of plant-available P such as the one used.

The first part of the work involved conventional pot experiments. Effects of AM fungi on wheat were compared between sterilised soil and non-sterile soil, sterilised soil inoculated with non-sterile soil or with *Glomus intraradices* or noninoculated, with different soil/sand mixes. Colonisation of wheat at 8 weeks was high, with about 75% of root length colonised for indigenous fungi and 55% for *Glomus intraradices*,

regardless of the soil treatments. Growth and P uptake of wheat were significantly increased by both indigenous fungi and *G. intraradices*, irrespective of soil/sand mixes. Effects of indigenous fungi on plant growth were larger in sterilised and inoculated soil than in non-sterile soil. In sterilised soil, increases of plant growth by AM fungi were higher with *G. intraradices* than with indigenous fungi. Dilution of the soil by mixing with sand reduced plant growth and P uptake of both AM and non-mycorrhizal (NM) plants.

In another experiment, responses of wheat to AM fungi and P supply were compared with those of clover. Plants were inoculated with four different AM fungi. Colonisation of wheat was lower than clover. Although suffering from P deficiency, NM wheat (6 weeks) grew relatively well with no added P (P0) and application of P at 100 mg kg⁻¹ (P100) increased the dry weight (DW). Shoot P concentrations increased with P application and there were positive effects of all AM fungi at P100. In contrast, NM clover (8 weeks) grew very poorly at P0 and did not respond to P application. Clover responded positively to all AM fungi at both P levels, associated with increases in P uptake. The results showed that responses of wheat to AM inoculation and P supply were quite different from those of clover, and emphasized the different abilities of the two species to access P in the very high P-fixing soil used.

Responses of two wheat cultivars (Brookton and Krichauff) to AM fungus (*G. intraradices*) were also evaluated with different P supplies at two developmental stages (vegetative and maturity). Colonisation by *G. intraradices* of both cultivars was well established at 6 weeks (~50% in P0 plants) and continued to increase up to

maturity (~70%), but decreased greatly at both harvests as P supply was increased (up to 150 mg P kg⁻¹). Addition of P significantly increased plant growth, grain yield and P uptake irrespective of cultivar and harvest time, and the optimum soil P for grain yield was 100 mg kg⁻¹. In both cultivars, a growth depression in AM plants occurred at 6 weeks at all P levels, but this disappeared at 19 weeks with added P. At P0, AM plants produced lower grain yield per plant, but with higher P supply, AM plants produced higher grain yields than NM plants. There was a significant positive effect of AM on grain P concentration at P0, but not at other P levels. Brookton was somewhat more P efficient than Krichauff, and the latter responded more to AM fungi. The results showed that responses of wheat to AM fungi and P supply changed during development. Growth depression induced by AM fungi in low P soil was overcome by addition of moderate amounts of P, resulting in significant increases in grain yield in AM plants.

Additional approaches were used to help determine the roles of AM fungi in wheat growth and nutrition. The effects of plant density were tested, as it was expected that increasing density might decrease the negative effects of AM fungi on wheat growth. Large growth depressions were induced by both *G. intraradices* and *Gigaspora margarita* in wheat grown at low density, although % colonisation by *G. intraradices* was higher than by *Gi. margarita*. With increasing plant density, the growth depressions were smaller, indicating that competition modulates growth responses. Although there may be effects due to competition for soil P, it is clear that with increasing plant biomass per unit soil volume, the AM fungal biomass did not

increase in proportion; in fact, hyphal length density decreased. Accordingly, costs of AM in terms of organic carbon loss per plant decreased with increasing plant density, thus mitigating the growth depression. The results add to the increasing body of evidence that mycorrhizal growth responses of plants grown singly may not apply at the population or community level as in crops.

Two compartmented pot systems were used to examine whether the fungal hyphae deliver the P into the plants even in the absence of positive growth responses. An experiment in which plants were constricted in a mesh bag, but hyphae of AM fungi could explore a large soil volume was carried out. Results suggested that AM fungi helped the plants acquire P, although mesh bags did not remove AM growth depression. The experiments in which AM fungi were supplied with ^{32}P in a small soil compartment to which only hyphae had access showed that a considerable amount of P was delivered to wheat plants via AM fungi. The original aim was to calculate the percentage of total P entering the plants via the AM pathway. However, realistic values were not obtained probably because of difficulties of determining plant-available P and uneven distribution of hyphae in the soil. It is also possible that plants and AM fungi access different P pools.

This study demonstrated the potential roles of AM fungi in growth and P nutrition of wheat grown in the highly calcareous soil from the Eyre Peninsula, South Australia. Further studies on the effects of the interactions between AM fungi and wheat in the field are needed to assess the contribution of AM fungi to plant nutrition.

Publications and presentations from this thesis

Journal paper

Li HY, Zhu YG, Marschner P, Smith SE, Smith FA. 2005. Wheat responses to arbuscular mycorrhizal fungi in a highly calcareous soil differ from those of clover, and change with plant development and P supply. *Plant and Soil* (In press).

Conference posters

Li HY. 2005. Roles of arbuscular mycorrhizal fungi in growth/yield and phosphorus nutrition of wheat. Workshop of Centre for Soil-Plant Interactions (CSPI), Waite Campus, The University of Adelaide. February 15-17. (Abstract for oral presentation).

Li HY, Smith SE, Dickson S, Smith FA. 2004. Mycorrhiza-induced plant growth depressions are mitigated by increasing plant density that lowers fungal demands on photosynthesis. International Congress on Rhizosphere - Perspectives and Challenges, Munich, Germany. September 12-17. (Poster).

Li HY, Marschner P, Smith FA, Smith SE. 2005. Wheat grown in a highly calcareous soil benefits from phosphorus uptake by arbuscular mycorrhizal fungi. The Annual Conferences of the Australian Society for Biochemistry and Molecular Biology, the Australia and New Zealand Society for Cell and Developmental Biology and the Australian Society of Plant Scientists (ComBio 2005). Adelaide, Australia. September 25-29. (Poster).

Declaration

I declare that this work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution. To the best of my knowledge and belief, this thesis contains no material previously published or written by another person, except where due reference has been made in the text.

I consent to this copy of my thesis, when deposited in the University Library, being made available for loan or photocopying.

Signed

July 2005

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I know not what I appear to the world, but to myself I seem to have been only like a boy playing on the sea-shore, and diverting myself in now and then finding a smoother pebble or a prettier shell, whilst the great ocean of truth lay all undiscovered before me.

If I have been able to see further, it was only because I stood on the shoulders of giants.

Isaac Newton