Bases for the management of the AM symbiosis in cropping systems of the prairie

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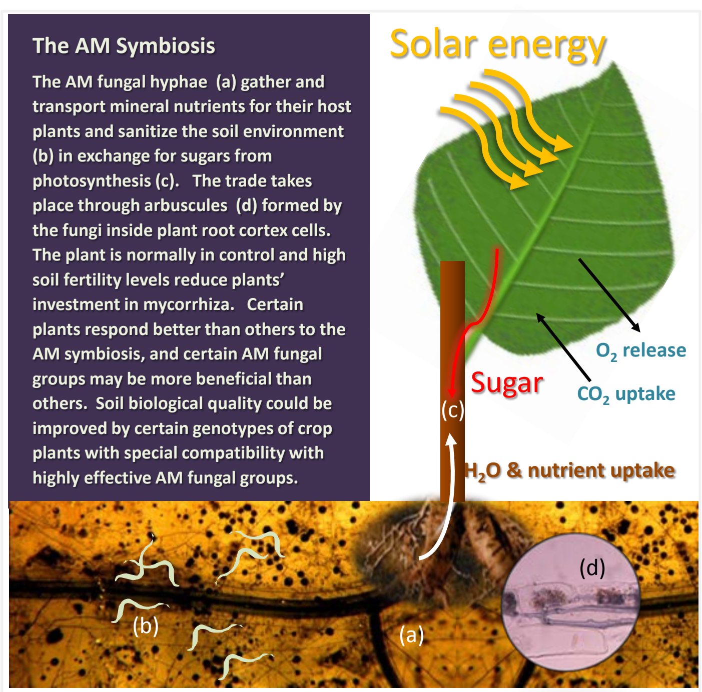
Keywords: Arbuscular mycorrhiza, AM fungi, MykePro, wheat, pea, lentil, soil biology management

Introduction

The innovative arbuscular mycorrhizal (AM) inoculant MykePro of Premier Tech Biotechnologies has raised interest and much questions on the AM symbiosis in crop plants since its release for use in prairie field crops in 2010. Effectively managing the AM symbiosis would improve the efficiency of cropping systems in reducing fertilizer inputs and promoting root health. Raising the quality of soil biology in crop production fields has become a research objective around the world. With MykePro, Canada is a step ahead in the development of high quality AM fungal inoculants. However, the management of the AM symbiosis in crop production must be integrated in the global farm production strategy.

A sound decision about adopting a technology can hardly be made without understanding its characteristics and conditions for its use. The purpose of this article is to provide basic information on AM symbiosis in crop plants and report observations relevant to the management of this symbiosis in prairie cropping systems.



Function and Regulation of the AM Symbiosis

Plants are the most successful living organisms on Earth because they possess a rare capacity to fulfil their energy and basic nutrition requirement through photosynthesis. Through photosynthesis, plants can harness solar energy and assimilate atmospheric CO_2, two resources available in practically unlimited supply. Photosynthesis gives plants important negotiation power and through evolution, plants have traded energy-rich carbon compounds for services with pollinators, seed dispersers, and antagonists of their pests. Plants also trade with providers of mineral nutrients such as N_2-fixers and mycorrhizal fungi. Nitrogen fixing symbiosis is restricted to a few plant families, whereas most land plant species, including many crop plants, form mycorrhizal symbioses.

Arbuscular mycorrhizal fungi are a component of the normal nutrient acquisition system of the major prairie crops, with the important exception of canola and mustard. Arbuscular mycorrhizal fungi are involved in the uptake and transport of soil mineral nutrients and water to roots, and their presence reduces the incidence of soil-borne diseases. These fungi are particularly important for the uptake of nutrients with low mobility in soil such as phosphorus. It is important to remember that AM fungi do not create plant available nutrients. In contrast to rhizobia, which transform atmospheric N into plant available ammonia, the AM fungi do not increase the pool of soil nutrients. They simply help plants take-up available nutrients and as such, complement rather than replace inorganic and organic fertilizing materials.

Resident AM Fungi and Organic and Conventional Wheat Productivity in the Prairie

Advances in molecular biology has given us powerful tools to track the AM fungi residing in cultivated soils. A survey of 72 organically and 78 conventionally managed wheat fields revealed the influence of management on the composition of resident AM fungal communities of cultivated prairie soils. Organic wheat crops were colonized to a higher level by AM fungi than conventional crops, as expected. However, in contrast to expectation, the productivity of organic wheat was inversely related to the abundance of AM fungi, whereas conventional wheat was positively related with the abundance of AM fungi of the genus *Claroideoglomus*. The similarity in the amounts of N and P taken up by organic and inorganic crops indicated that despite reducing plant productivity, the AM fungi performed well as nutrient providers in organic systems where N and P fertility of the soil was only 37% and 48% that of conventional systems, on average, at the beginning of the growing season. Lower amounts of C in wheat plant tissues was responsible for the lower productivity of organic wheat. The reason for reduced C levels in organic wheat remains unclear. Increased C translocation to roots in support for higher mycorrhizal activity in low soil fertility and water-limited photosynthesis in wheat under organic management due to the drying effect of soil tillage, are two reasons that could explain the relatively low C content of organic wheat plants.

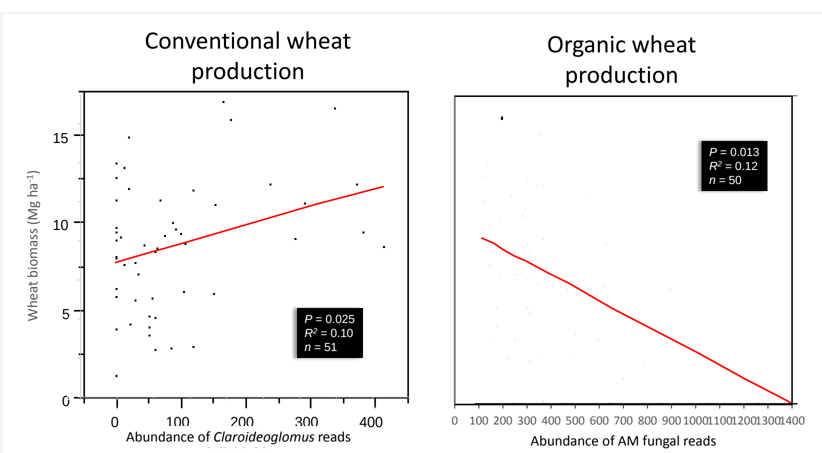


Fig. 1. Relationships between wheat biomass production and AM fungi residing in cultivated soil under conventional and organic management, in the Canadian prairie.

We conclude that resident *Claroideoglomus* may positively influence conventional wheat production and that organic wheat may be more nutritious because of the inability of wheat plants to adjust its photosynthesis to the high C demand of associated AM fungi, under the low soil fertility conditions resulting from the imposition of organic certification rules.

Genetic Variation in the Response of Wheat Genotypes to the AM Symbiosis

On the short-term, the value of studying the AM symbiosis of wheat lies probably more on the importance of the land area planted with this crop than on the potential benefits that this crop may derive from the symbiosis. Wheat and other small grain cereals, belong to the sub-family Pooideae of the Poaceae, a group of related species that form, but do not respond to the AM symbiosis. Wheat cultivars selected for their special compatibility with the most effective groups of AM fungi would improve the biological quality of the soil, with positive impact on the whole cropping system. However, the capacity of wheat to support resident AM fungi should not translate into reduced yield.

Theoretically, selecting wheat genotypes under high soil fertility conditions where plants do not use the AM symbiosis, as it is currently practiced, could lead to the release of cultivars with impaired AM symbiotic regulation. In a greenhouse experiment we tested 32 wheat cultivars of the historical set of SPARC-AAFC breeding program and found three cultivars with ineffective AM symbiotic regulation. Hercules, Wascana, and Eurostar grew smaller with than without MikePro, under soil fertility conditions favourable to AM symbiotic development. It is true that results obtained in the greenhouse do not necessarily reflect the reality of the field. However, it may be safe to grow these cultivars under good soil fertility conditions.

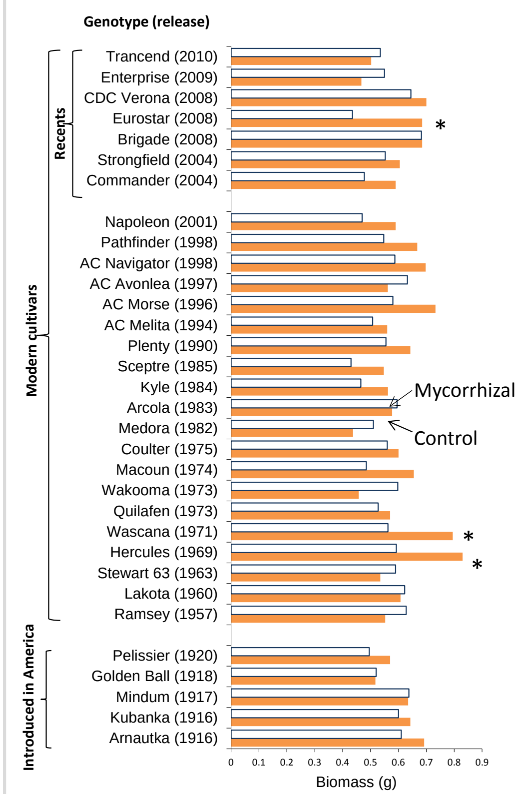


Fig. 2. Biomass of the durum wheat cultivars of SPARC's historical set, as influenced by AM inoculation and low soil fertility in the greenhouse. Mineral N fertilizers were developed after World War II, and the practice of abundant soil fertilization in plant breeding programs was implemented after this time. Bars are the means of four replicates, and stars indicate differences significant at $\alpha = 0.05$ between mycorrhizal and non-mycorrhizal treatments.

Soils and Crops Influence the Success of AM Inoculation

It is known that pea and lentil respond generally well to the AM symbiosis and that wheat is usually unresponsive. We confirmed this information in a greenhouse experiment that also tested the influence of four soil types on plant response to inoculation with four AM fungal strains isolated from cultivated soils of these types, i.e., from a Brown, Dark Brown, Black, and Dark Gray Chernozem. Pea was generally most responsive to the AM fungi, although lentil responded best in the Dark Gray soil. Wheat did not respond or responded negatively to inoculation with AM fungi, consistent with our previous results. Certain AM fungal strains triggered better growth responses in certain soils than in others, but such soil-AM strain interaction was only detected in lentil. Thus, our hypothesis that an AM fungi works effectively only in certain soil types was poorly supported. It is possible that only one highly effective strain could be sufficient to effectively inoculate crops in all Chernozems of the prairie, simplifying the management of the AM symbiosis of crop plants through inoculation.

In Cuba, where much research efforts have led to the effective management of the AM symbiosis of crop plants through inoculation, crops are inoculated with different highly effective

AM fungal strains based on soil type. The large diversity of soil types found in Cuba may explain the fact that the strains introduced in soil through inoculation function well only in certain soil environments in Cuba, but not in the Canadian prairie where soils are more uniform. In fact, we observed that the AM fungal communities are relatively similar among different great groups of Chernozems in the prairie. However, differences were observed between AM fungal communities living in Chernozems and Vertisols, suggesting that one highly effective AM fungal strain may not function adequately in Chernozem and in Vertisols, Luvisols, or Solonetzs.

Take Home Message

The AM fungi residing in cultivated prairie soils seem to contribute positively to conventional wheat production despite the fact that wheat is not a plant species known to respond to the AM symbiosis. Pea and lentil respond better than wheat to the AM symbiosis. Thus a response to AM inoculation is more likely to be seen in pea and lentil than in wheat, and purchase of AM inoculants should be targeted to pulses rather than to wheat.

Further Reading

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