Competitiveness-Shifts from Weeds to Crops Using Arbuscular Fungi

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Abstract

Arbuscular fungi (AF) colonize *ca.* 80% of terrestrial plant roots and typically improve their growth by enhancing nutrient uptake, reducing disease severity and/or imparting resistance to abiotic stress. Therefore, AF-colonized crop cultivars exhibit early vigor and superior growth compared to cultivars not colonized by AF. However, routine AF inoculation of crops is limited because of their obligate nature. Nevertheless, there are strategies that can be readily adopted by growers to exploit the indigenous AF community. Our project aimed at determining the relationship between the mycorrhizal dependency of crops and crop competitiveness against weeds. The mycorrhizal dependency of eight barley and eight wheat cultivars on an AF mixture resembling that of an indigenous AF community was evaluated in natural soil. There were significant differences between the cultivars in their response to AF. The most and least mycorrhizal cultivar (based on biomass) were evaluated for their competitiveness against wild oat at four crop:weed density levels (1:0.5; 1:1; 1:2; 1:4) in soil with and without the AF mixture. Results showed that the most AF dependent cultivar in both crops exhibited superior growth and competitiveness against wild oat up to a level of 1:1 crop:weed density. This confirms that mycorrhizal dependency is partially linked to crop competitiveness against weeds and that the choice of cultivar may be a strategy which can enhance crop competitiveness while reducing chemical herbicide use.

Introduction

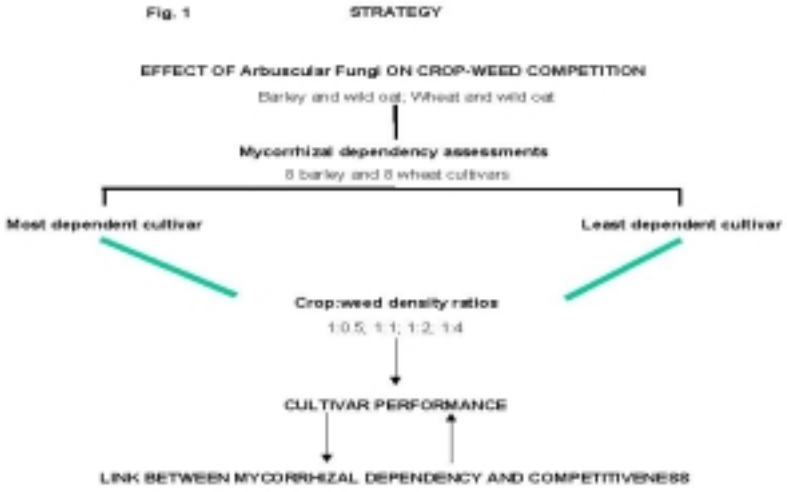
Weed control using chemical herbicides in Canada costs millions of dollars annually. The sole use of herbicides may still be an issue of contention because of their residual effects in soil and their negative effects on non-target organisms. In recent years, research efforts have been directed towards the development of integrated weed management programs including the use of naturally occurring soil microorganisms. This weed management approach appears to be more ecologically friendly and sustainable.

Arbuscular fungi (AF) are soil fungi that associate with most crops and typically enhance plant growth. The AF are considered to be generalists because of their obligate nature, but often prefer one host plant (or cultivar) to another (Boyetchko and Tewari, 1995; Hetrick et al. 1995; Xavier and Germida, 1997, 1998). This preferential association for the associated crop generally means enhanced plant benefits such as higher productivity, improved nutrient acquisition, and disease

control. Hence, a plant or cultivar that is more dependent on AF may be more competitive than a host that is relatively less dependent on AF. Mycorrhizal dependency of a host plant is defined as the percentage increase in aboveground shoot biomass over that of an uninoculated control.

Project Objective: To assess the influence of AF on the competition between cereal crops and wild oat.

Rationale: This project was accomplished using a strategy consisting of two components (Fig. 1). The rationale for this strategy was that AF improve plant vigor and health, and as a result, mycorrhizal plants can compete more effectively against weeds. Improvements in mycorrhizal plant vigor and health are ensured by AF-mediated enhancements in nutrient uptake and disease suppression. However, not all plants enjoy these benefits. Plants or cultivars that have a more intimate association or are more dependent on AF appear to have a clear advantage over plants and cultivars that are less dependent on AF.



Strategy: Assess (i) the mycorrhizal dependency of several barley and wheat cultivars with and without an AF mixture that mimics the indigenous AF population in Saskatchewan soils, and (ii) whether mycorrhizal dependency is a determinant of crop competitiveness against weeds.

Model: Barley (*Hordeum vulgare* L.) and wild oat (*Avena fatua* L.); Wheat (*Triticum aestivum* L.) and wild oat.

Materials and methods
Barley:
Experiment 1: The **mycorrhizal dependency of barley** (*Hordeum vulgare* L.) cultivars (Candle, Condor, CDC Dolly, CDC Earl, Falcon, Harrington, AC Lacombe, Virden) was determined in a growth chamber study with and without an AF mixture that mimics the indigenous AF population in Saskatchewan soils. Plants were grown for 90 d and harvested. The treatments were replicated three times and the experiment was repeated. Plant parameters

such as shoot and root dry weight, N and P content of the aboveground shoot matter and percentage AF-colonized root were assessed.

Experiment 2: The **competitiveness of barley cultivars** CDC Earl (not dependent on AF) and Virden (most AF-dependent) with and without added AF were evaluated at crop:weed density ratios of 1:0.5, 1:1, 1:2 and 1:4 against wild oat (*Avena fatua* L.) in field soil containing indigenous AF. Plants were grown with or without an AF mixture for 11 weeks and harvested. Plant parameters such as shoot and root dry weight, N and P content of the aboveground shoot matter and percentage AF-colonized root were assessed.

Treatments: Three factors: 2 cultivars (Earl and Virden); 2 AF treatments (with and without) and 4 crop:weed density ratios (1:0.5, 1:1, 1:2, 1:4). This experiment was repeated and replicated (n=3).

AF inocula: The following AF species were obtained from the INVAM culture collection: *Glomus clarum* (Nicolson and Schenck), *Glomus etunicatum* (Becker and Gerdemann), *Glomus intraradices* (Schenck and Smith) and *Glomus mosseae* (Nicolson and Gerdemann) Gerdemann and Trappe. Four grams (31 AF propagules / 50 g) of an inoculant mix containing all four AF species listed above.

Wheat:

Experiment 1: The **mycorrhizal dependency of wheat** (*Triticum aestivum* L.) cultivars (Oslo, Columbus, Thatcher, Genesis, Red fife, Marquis, Katepwa, Merlin) was determined in a growth chamber study with and without an AF mixture that mimics the indigenous AF population in Saskatchewan soils. Inoculation, plant growth conditions, plant harvest and data processing were identical to that of the barley mycorrhizal dependency study described earlier.

Experiment 2: The **competitiveness of wheat cultivars** Katepwa (not dependent on AF) and Marquis (most AF-dependent) with and without added AF were evaluated at crop:weed density ratios of 1:0.5, 1:1, 1:2 and 1:4 against wild oat (*Avena fatua* L.) in field soil containing indigenous AF. Inoculation, plant growth conditions, plant harvest and data processing were identical to that of the barley competitiveness study described earlier.

Treatments: Three factors: 2 cultivars (Katepwa and Marquis); 2 AF treatments (with and without) and 4 crop:weed density ratios (1:0.5, 1:1, 1:2, 1:4). This experiment was repeated and replicated (n=3).

AF inocula: Same as for barley.

Project Summary

Mycorrhizal dependency of barley cultivars: Significant differences exist between cultivars (Xavier et al. 2002). Virden was the most AF-dependent, whereas Earl was the least dependent on AF, and hence selected for crop-weed competition studies. Growth increases were generally associated with increases in nutrient uptake.

Evaluation of AF-inoculated barley competitiveness against wild oat: AF-inoculated Virden had greater shoot biomass compared to uninoculated Virden and Earl with or without AF at a crop:weed ratio of 1:0.5 (Fig. 2a). There was a corresponding decrease in the shoot biomass of wild oat competing with barley at this ratio (Fig. 2b). This suggests that the AF community exhibited a preferential affinity for Virden than Earl. In general, the AF-inoculated plants appeared to be more competitive than uninoculated plants.

Fig. 2a. **Total shoot dry weight of barley competing against wild oat**

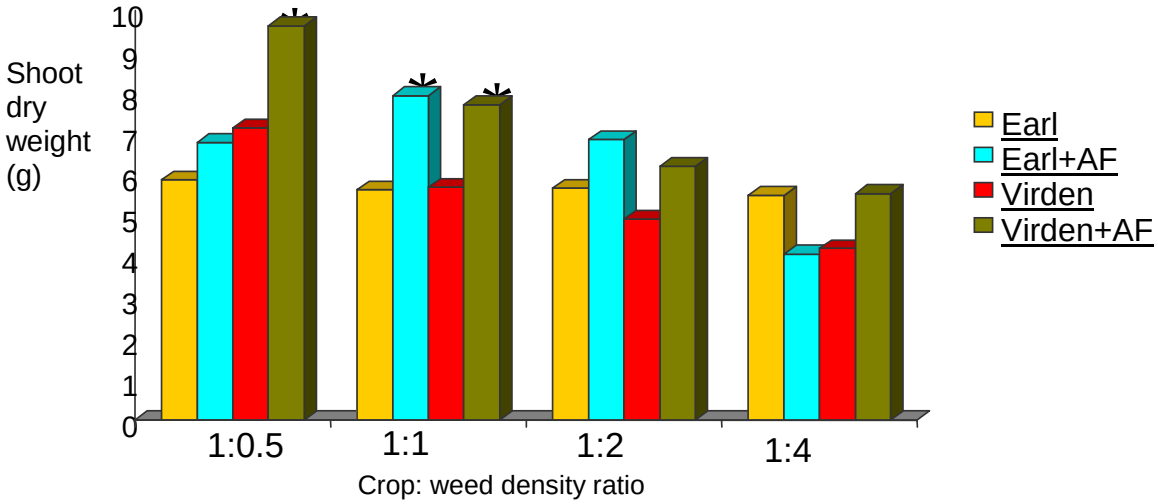
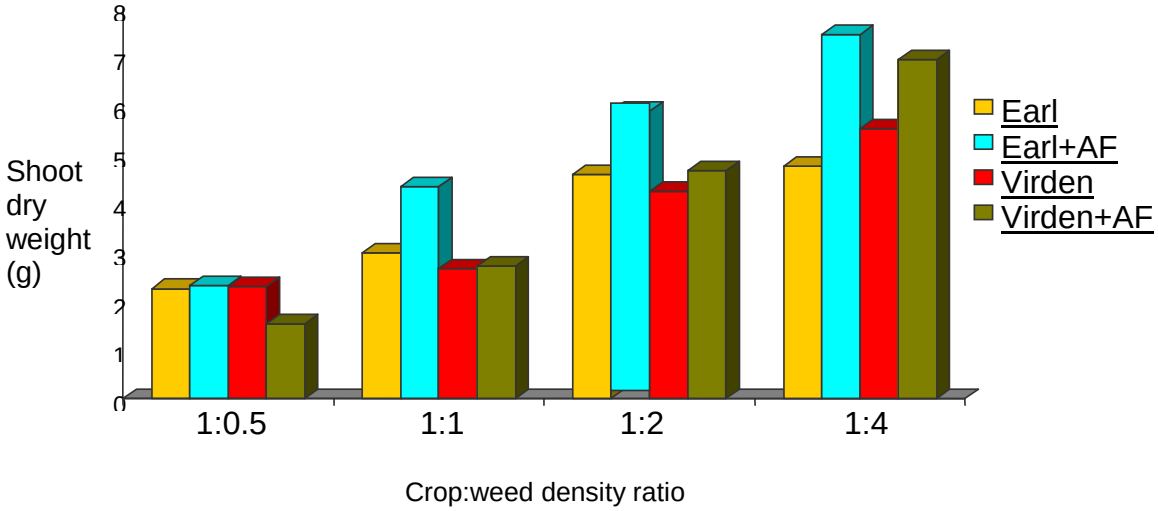


Fig. 2b. **Total shoot dry weight of wild oat competing against barley**



Mycorrhizal dependency of wheat cultivars: Cultivars varied significantly in their dependency on AF for growth (data not shown). No cultivar exhibited a positive response to AF inoculation. Growth increases were generally associated with increases in nutrient uptake. Marquis and Katepwa were more representative of growth trends and hence selected for crop-weed competition studies.

Evaluation of AF-inoculated wheat competitiveness against wild oat

AF-inoculated Marquis had greater shoot biomass compared to uninoculated Marquis at a crop:weed ratio of 1:0.5 (Fig. 3a). In contrast to barley, wheat did not otherwise respond to AF inoculation. In addition, there was no corresponding decrease in the weight of wild oat plants competing against Marquis (Fig. 3b). At the lower crop:weed ratios, there appeared to be a non-specific enhancement of growth in AF-inoculated plants that gradually declined.

Fig. 3a. **Total shoot dry weight of wheat competing against wild oat**

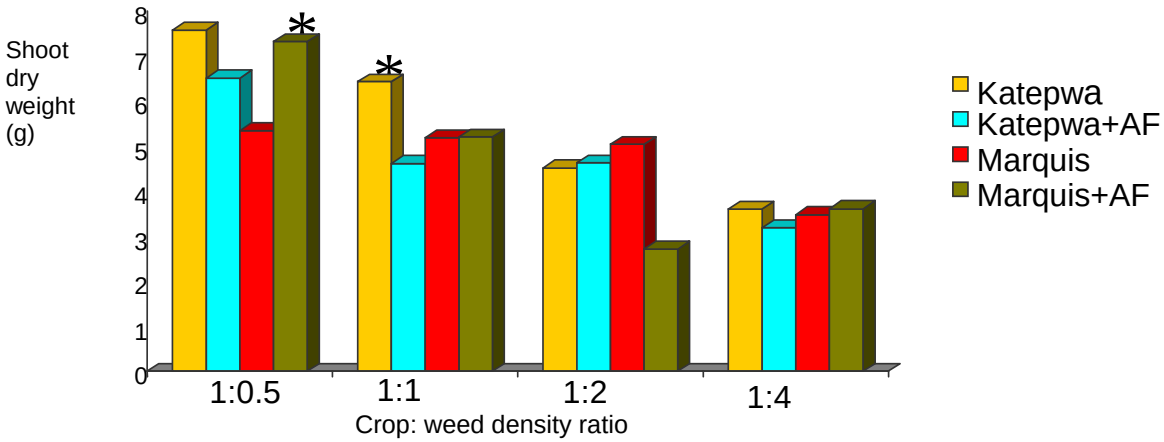
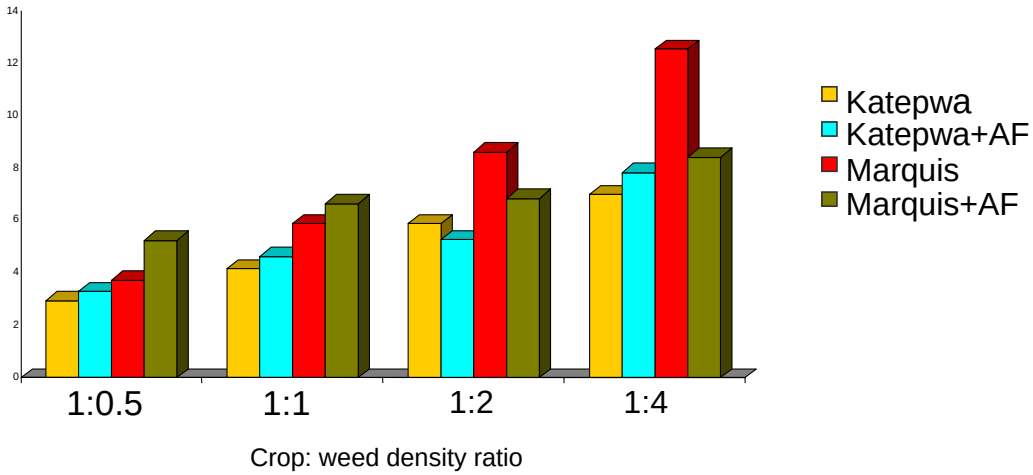


Fig. 3b. **Total shoot dry weight of wild oat competing against wheat**



Conclusions

- Naturally occurring AF communities can be manipulated to enhance crop competitiveness against weeds by choice of crop and crop cultivar.
- Crop competitiveness appears to be linked to mycorrhizal dependency.
- Cropping practices that alter AF diversity and function can be integrated into Integrated Pest Management programs as an additional tool for effective weed control.

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