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Yield response to treatment with vesicular-arbuscular myccorrhiza (VAM) in a breeding population of barley

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Abstract
Vesicular-arbuscular myccorrhiza (VAM; *Glomus* spp.) are soil fungi that can colonize the roots of a number of commercially important crops, including barley, and are implicated in increasing the availability of nutrients to the host plant, particularly phosphorus (P). This has been shown to increase yields in the host crop. Barley has shown a differential response to increased yield after inoculation with VAM culture. Two barley cultivars with differential yield response to VAM treatment, Virden and CDC Earl, were crossed and 200 Recombinant Inbred Lines (RILs) were produced. Seeds of individual heads, from the parents and RILs, were treated with VAM or left untreated and planted as head rows in a Completely Randomized Design (CRD) in a soil low in nutrients and nearly devoid of native VAM. Grain and dry matter yield response indicated that VAM treatment produced a significant yield increase in CDC Earl and significant yield suppression in Virden. VAM-treated RILs demonstrated significant yield suppression, indicating that genetic improvement for this trait is unlikely in barley.

Introduction
Vesicular-arbuscular myccorrhiza (VAM; *Glomus* spp.) are fungi that can colonize the roots of a number of important crops, including barley (*Hordeum vulgare* L.) and provide benefits to the host plant by mobilizing nutrients from the soil, especially phosphorus (P; Jensen, 1982). The effectiveness of VAM has been demonstrated in the field for a number of crops (Jensen, 1984). This has led to the availability of commercial inoculants of VAM for field use (Bagyaraj, 1991). In barley, colonization by VAM appears to be at least partially dependent on genotype where some genotypes demonstrate enhanced biomass and grain yield while others do not (Boyetchko and Tewari, 1995). Developing new barley cultivars, with the ability to increase yield with VAM inoculation, would be advantageous to producers. This study utilizes a breeding population of barley, developed from two genotypes with positive and negative response to VAM inoculation, to determine the feasibility of breeding for improved VAM-mediated yield response in barley.

Materials and Methods
Using Virden (VAM-negative response) and CDC Earl (VAM-positive response) six-row barley cultivars, 300 manual crosses were made yielding 220 F1 seeds. Each F1 seed was then placed through four cycles of Single Seed Descent (SSD) producing a total of 220 Recombinant Inbred Lines (RILs). Remnant seed of the original parent material was also saved and multiplied along with the RILs. The 220 RILs were grown in single 3 m long rows, along with twenty four rows of each of the two parents. Three heads were selected, at random, from each row and individually manually threshed and stored in labelled envelopes. One half of the RILs and parent seed were treated with a commercial inoculum of vesicular-arbuscular micchoryza (VAM; Mikro-VAM®) according to manufacturer specifications (Mikro-Tek Inc., Timmons, ON, Canada). The remaining half were left untreated as served as the control group.

Each package of seed was sown in individual head rows in a Completely Randomized Design (CRD) and each row labelled accordingly. Head rows were sown on a medium-textured clay loam soil that had been deliberately sown to canola in the three previous crop years to eliminate most of the native VAM and reduce nitrogen (N) and phosphorus (P) levels to 30 and 20 kg ha^{-1}, respectively. Sixty kg ha^{-1} N, as urea, was added to the soil, prior to sowing, to allow for normal crop development. Potassium (K) was not limiting in this soil, being in excess of 300 kg ha^{-1} of native K. Levels of P were not augmented to allow for the expression of VAM activity in a low P soil.

Head rows were allowed to mature completely prior to the entire plants above-ground being harvested by hand. Entire rows were individually weighed, to the nearest 0.5 g, to obtain dry matter yield per row. Each row was then threshed in a stationary plot combine and the subsequent seed collected and weighed to the nearest 0.5 g. to obtain grain yield per row. An Analysis of Variance (ANOVA) was performed for both grain and dry matter yield using the PROC GLM of SAS (SAS Institute, 1988).

Results and Conclusions

The parent cultivars, CDC Earl and Virden, were chosen because they demonstrated differential responses to VAM treatment (Boyetchko & Tewari, 1995), with CDC Earl demonstrating a positive response and Virden having no, or a negative, response. The parent cultivars, Virden and CDC Earl, gave yield responses to VAM treatment that were expected. CDC Earl showed an increase in both dry matter yield (Table 1) and grain yield (Table 2) after treatment with VAM, whereas Virden showed reduced dry matter yield (Table 1) and a slight reduction (non-significant) in grain yield (Table 2).

The yield values for the RILs were intermediate to the parents (Tables 1 and 2), as would be expected for the quantitative traits of grain and dry matter yield. For dry matter yield, the RILs showed a response similar to Virden, which was a decrease in yield, albeit non-significant (Table 1). For grain yield, the RILs showed only a slight (non-significant) increase in yield (Table 2), with values closer to Virden than to CDC Earl. The results suggest that there would be no genetic improvement from a cross between these VAM responsive and non-responsive genotypes. Further evaluation with multiple genotypes may provide genetic gain for yield from VAM inoculation via recombination from genetic backgrounds differing from those in the present study.

Table 1. Average dry matter yield (g plot^{-1}) of inoculated vs. uninoculated (control) Virden, CDC Earl and RILs treated with VAM.

Source	Control	Inoculated	Standard Error	Significance	Response
CDC Earl	399.1	435.5	16.1	**	Increase
Virden	516.5	469.4	27.3	*	Decrease
RILs	450.1	436.7	19.0	ns	Decrease
Average	455.2	447.2			
Std. Error	34.0	11.1			
CV	7.5	2.5			

Table 2. Average grain yield (g plot^{-1}) of inoculated vs. uninoculated (control) Virden, CDC Earl and RILs treated with VAM.

Source	Control	Inoculated	Standard Error	Significance	Response
CDC Earl	128.2	140.8	6.1	**	Increase
Virden	97.8	97.6	8.5	ns	No change
RILs	117.4	119.6	4.3	ns	Increase
Average	114.5	119.3			
Std. Error	8.9	12.5			
CV	7.8	10.5			

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