Mycorrhizae reduce carbohydrate reserves of wheat

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Abstract

The impact of arbuscular mycorrhizal fungi (AMF) on water soluble carbohydrates (WSCs) in wheat roots, leaves and stems at the start of stem elongation was investigated in an experiment in southern NSW. The wheat was grown with and without P-fertiliser, following either linola or fallow. Colonisation by AMF was reduced by fallow and P-fertiliser. High AMF colonisation did not enhance uptake of P, but did correspond with a 14% reduction in stem WSC concentrations. While this reduction was not reflected in yields, perhaps due to high post-anthesis dry matter accumulation, the study suggests the carbon costs of high AMF colonisation may sometimes outweigh nutrient-uptake benefits, potentially lowering yields.

Key Words

arbuscular mycorrhizal fungi, water soluble carbohydrates, parasitism

Introduction

Arbuscular mycorrhizal fungi (AMF) colonise the roots of most crops. These fungi are obligate symbionts, receiving all energy as host-plant carbon compounds. The fungi are estimated to use 4-20% of the host's total carbon budget (1). In return for carbon, AMF provide the host with nutrients, generally P and Zn. The AMF-host relationship is mutualistic when the benefits for the host of nutrient provision outweigh the carbon-costs, but AMF may be parasitic when either no nutrients are supplied or the nutrients do not overcome a growth limitation (1). A recent two-year crop sequence experiment in southern NSW found AMF had no impact on nutrition of wheat prior to anthesis, although the fungi did greatly enhance Zn-uptake post-anthesis (2). In this paper we report the impact of AMF on water soluble carbohydrates (WSCs) and crop dry matter in this experiment. WSCs are the main store of non-structural carbohydrates in wheat shoots and are primarily fructans. Non-structural carbohydrate pools have previously been shown to respond strongly to AMF colonisation (1).

Methods

Wheat was grown in 2001 at Junee, NSW, in a soil with low available P (10 mg/kg Colwell), with or without 20 kg/ha of P as triple superphosphate, following either linola or fallow (2). There were 4 replicates. Soil water was uniform at sowing. At the start of stem elongation (Sept. 4) all shoots, and roots to 100 mm depth, were removed from two 0.32 m^2 quadrats in each plot. A subsample of roots was assessed for AMF. Shoots were divided into stems and leaves and, along with remaining roots, freeze-dried, weighed and ground. Shoot P was determined using X-ray fluorescence spectrometry, N using mass spectrometry and WSCs analysed colourimetrically (3). At maturity, all crop biomass was removed from two 0.32 m^2 quadrats in each plot, oven-dried and total crop dry matter and grain yield measured.

Results

AMF colonisation was reduced by P-fertiliser and fallow (Table 1). The concentration of shoot P was higher when P was applied, but unaffected by previous treatment. Concentrations of WSCs were greatest in stems and tended to be higher after fallow than linola. The root-shoot ratio of WSC concentrations was higher after fallow when P-fertiliser was applied. Stem and leaf N concentrations were unaffected by treatment or P-fertiliser. Crop dry matter and yield were increased by P-fertiliser, but unaffected by previous treatment.

Table 1. Characteristics of wheat crops 109 days after sowing and aboveground dry matter and grain yield at maturity. Means annotated with the same superscript did not differ significantly at p<0.05 (Students t-test).

	No P-fertiliser applied		P-fertiliser applied	
	Linola	**Fallow**	**Linola**	**Fallow**
AMF (% of root length colonised)	65[a]	46[b]	25[c]	12[c]
Shoot P (%)	0.22[a]	0.22[a]	0.34[b]	0.32[b]
Stem WSC (%)	32.4[a]	37.0[b]	30.8[a]	36.0[b]
Leaf WSC (%)	18.5[a]	19.3[a]	12.3[b]	16.3[ab]
Root WSC (%)	5.6[ab]	7.3[bc]	5.3[a]	8.6[c]
Root:shoot WSC concentration ratio	0.23[a]	0.27[ab]	0.25[a]	0.32[b]
Total aboveground WSC (g/m^2)	23[a]	25[ab]	41[bc]	54[c]
Stem N (%)	2.3	2.1	2.3	2.1
Leaf N (%)	4.0	3.7	4.3	3.9
Dry matter 109 days after sowing (t/ha)	0.94[a]	0.95[a]	1.98[b]	2.10[b]
Dry matter at maturity (t/ha)	7.1[a]	8.2[a]	11.1[b]	11.7[b]
Grain yield (t/ha)	2.8[a]	3.3[a]	4.9[b]	4.8[b]

Discussion

The greater AMF colonisation after linola than after fallow indicates increased inoculum levels following a host. It is difficult to separate the impacts of AMF on WSC concentration from those, independent of AMF, of P-fertiliser and previous treatment. For instance, N-uptake may influence WSC storage (3). However, the lower WSC concentrations after linola are consistent with the hypothesis of loss of assimilates to parasitic AMF and are consistent with the carbon-cost of AMF indicated in other studies (1). While low-P status promoted a similar increase in AMF colonisation, there was no accompanying decrease in WSCs. This may reflect conflicting impacts on WSCs: a reduction in WSC concentration due to increased AMF, offset by an almost equal accumulation in WSC due to reduced growth. Dry matter within each P-level mirrored WSC concentrations but the differences were not significant and grain yields after consideration of the effect of P-fertiliser were not closely related to AMF colonisation or WSC concentrations. While

retranslocation of pre-anthesis WSC stores may contribute a large proportion of grain yield when there is little photosynthesis after anthesis because of terminal drought (3, 4), in this experiment, more than 3 t/ha of dry matter was added to all treatments after the start of anthesis (2).

Positive growth responses to AMF have been reported for wheat crops in southern QLD (5). No such responses have been found in southern NSW and Victoria (2, 6), perhaps because low autumn/winter soil temperatures restrict the ability of AMF to take-up nutrients (2, 7). Thus the impact of AMF on crop yields in these regions may range from negligible to negative, with greatest negative impact in seasons where pre-anthesis WSC stores constitute a significant component of yield. Perhaps the positive yield response of wheat to preceding non-AMF canola in the absence of root pathogens in these regions may reflect reduced AMF colonisation. Further research is underway.

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