Influence of Pulse Crops on Arbuscular Mycorrhizal Fungi in a Durum-Based Cropping System

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Abstract

Pulses are an important component in crop rotations in southern Saskatchewan. Besides their capability to fix nitrogen, pulse crops establish a symbiotic relationship with arbuscular mycorrhizal fungi, which have been shown to increase nutrient and water uptake through hyphal extensions in the soil. This 2 year study is designed to evaluate the impact of pulses in crop rotations on the biodiversity of AMF communities and their dynamics. Plant N and P uptake and the available soil N and P pools under a durum crop are also measured to assess if there is any correlation with AMF communities. The sampling and analysis is completed on the durum phase of the rotation with preceding crops of pea, lentil, chickpea, canola and durum. The final results will be explained by: (1) the size, nature, and physiological state of the soil microbial community and (2) the nature of the preceding crop residues. Preliminary results from the 2004 season indicate that higher plant P uptake is related to AMF colonization, while no significant change was detected in the soil N and P pools.

Introduction

Pulses are an important component in crop rotations in southern Saskatchewan. Conservation tillage in the brown soil zone of Saskatchewan typically includes a combination of cereals, pulses, and oilseeds in the cycle. The benefits that pulse crops contribute to a rotation are not completely understood. Previously benefits were mostly attributed to their ability to fix N, but the non-N benefits are not well understood (Stevenson and van Kessel 1996). Besides their capability to fix nitrogen, pulse crops establish a symbiotic relationship with arbuscular mycorrhizal fungi (AMF).

Arbuscular mycorrhizal fungi help the plants take up nutrients and water, while the plant supplies the fungi with carbon derived from photosynthesis. AM fungi can increase uptake through hyphal extensions in the soil. The fungi work by colonizing the root and then extending hyphae out into the soil. Hyphae have the ability to increase soil-root

contact, increase exploration in micropores, extract water, and improve water holding capacity (Auge et al. 2003). The extraradical hyphae provide contact between the AM fungi and the host, thereby contributing to nutrient uptake in the soil (Miller and Jastrow 2000). The fungal hyphae (2-5_m diameter) are smaller than root hairs (10-20_m diameter) so have the ability to penetrate soil pores that are inaccessible to non-mycorrhizal roots (Marulanda et al. 2003). Since water, N and P are often limiting factors for plant growth on the Brown Chernozemic soils in the semiarid region of Saskatchewan, increased levels of AMF in the soil may decrease fertilization and disease management costs. Increased water infiltration, decreased soil erosion, and better soil aeration stemming from improved soil aggregation are other AMF-derived benefits.

The function and abundance of AMF are influenced by a combination of environmental and plant factors. The environmental factors include the soil type, temperature, pH, moisture, and dissolved nutrients. The plant factors comprise of the species, age, and biomass of the particular plant (Bever et al. 2001). The soil conditions are constantly changing, in addition fluctuations in temperature and plant growth result in changes in the microbial community. Seasonality also plays a large role in determining the microbial community composition.

Crop rotation encourages diversity of the AM fungi community (Douds et al. 1993). Strongly mycorrhizal crops such as pulses with no till cropping systems promote AMF diversity and increased soil inoculum levels. Crops that are highly mycorrhizal dependent (i.e. legumes) have shown substantial differences in dry weight of roots and shoots, root length and overall colonization, and P uptake per plot in inoculated plants compared to non-inoculated (Shibata and Yano 2003). The use of AM field inoculum is not currently practical (Saito and Marumoto 2002) since it has not always been beneficial and predictable (Rayan and Graham 2002). Production of AMF inoculum is complicated because of an inability to grow in a pure culture and its dependency to be multiplied on living roots (Budi et al. 1998). The best option for increasing inoculum levels is by manipulation using plants promoting AMF symbiosis.

The objectives of this study are to: 1) assess the impact of pulses in crop rotations on the biodiversity of AMF communities and their dynamics and 2) measure the plant available N and P pools in soil under a durum crop, and assess any correlation with AMF communities. It is expected that pulse crops will increase the biodiversity and dynamics of AMF communities under a subsequent durum crop and there will be an increase in plant N and P uptake which cannot be explained by changes in the soil N and P pools. The effect of pea, lentil and chickpea on soil biological and biochemical factors will be evaluated through microbial community profiling and examination of nutrient inputs of the preceding crop of pulses, canola, or a subsequent durum wheat crop.

Materials and Methods

The experiment is a two year field plot study (2004 and 2005), conducted at the South Farm of the Semiarid Prairie Agricultural Research Centre, in Swift Current on 5 year old plots. It is located in the Brown soil zone on a Swinton Silt Loam. Three repetitions of

five treatments: pea-durum, lentil-durum, chickpea-durum, canola-durum and durum-durum are being compared (Table 1) in 5 x 24 m plots[1]. The durum monoculture is included in the study since it once represented the best management practice under conventional tillage.

Table 1. Crop varieties used in this study are commonly grown in southern Saskatchewan.

Crop	Variety	Inoculant
Durum	cv. Avonlea	n/a
Canola	Argentine	n/a
Lentil	Sovereign	Nitragin C
Pea	Handel	Nitragin C
Chickpea	Myles	Nitragin GC

Crops are fertilized each year to equalize soil fertility among treatments, as determined by soil tests. For durum plots the total N level is equalized to 65 lbs/ac. This is calculated as 65 minus amount of N in top 24 inches as determined by fall soil sampling. Phosphorous (11-51-0) is routinely applied with seed at approximately 40lbs/ac.

Table 2. Variables used as indicators of soil quality in this field experiment and methods used for their evaluation.

Experiment	Sample	Evaluation	Method
Anion Exchange Membranes	Soil	N and P dynamics	Modified from Ziadi et al. 1999
NH_4/NO_3	Soil	Point in time available N	KCl extraction (Maynard and Karla, 1993)
Mineralizable N	Soil	N made available over growing season	Incubation extraction (Campbell et al. 1993)
Resin P	Soil	Point in time available P	Hedley extraction procedure (Hedley et al. 1982)
NLFA/PLFA	Soil	Size, nature & physiological state of soil microbial community	Extracting, purifying and analyzing PLFA from soil (Clapperton and Lacey, unpublished)
Biodiversity	Soil	Qualification of AMF population	Polymerase Chain Reaction; Gel Electrophoresis
Inoculum Potential	Soil/Root	AMF potential at beginning of growing season	Infectivity Assay (Brundett 1999)
Root Colonization	Root	Percent of root colonized by AMF	Staining (Vierheilig et al. 1998); Gridline Intersect Method (Giovannetti and Mosse 1980)
Plant N & P	Plant	Nutrient uptake from soil	Digestion of tissue on auto analyzer (Thomas et al. 1967)

Four soil samples per plot were taken at emergence, five leaf, flag leaf, anthesis, and physiological maturity. The samples were bulked into one composite sample and put through 2 mm sieves before analysis (Table 2). Two plants were taken at four locations per plot and ground before N and P analysis. Soil samples and root samples were also

[1] Durum following durum was grown in 15 x 24 m plots

taken at intermediate stages for analysis of phospholipids/neutral lipid fatty acids (PLFA/NLFA), biodiversity, and mycorrhizal root colonization. This sampling scheme will be repeated in 2005.

Results and Discussion

Soil N and P was not significantly different between the treatments, as determined by NH_4/NO_3 and nitrate and phosphate flux measurements (data not shown). The most evident results from the 2004 season were the effect of the treatments on mycorrhizal colonization (Figure 1). Colonization after the pulse crops was high, especially lentil which exhibited the highest colonization between the five leaf and flag leaf stages of development. Using canola as a precrop resulted in no colonization for the first 2 sampling times, with a maximum colonization reaching only 6% between anthesis and maturity. Since canola is a non-mycorrhizal crop, it was expected that AMF development would be delayed in the subsequent durum crop, but the treatment effect did not taper off at the end of the growing season.

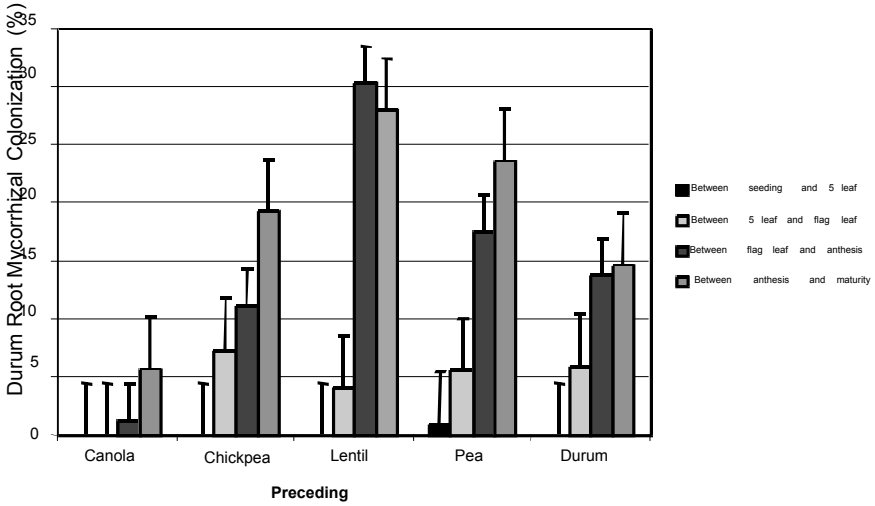

Figure 1. Effect of previous crop on mycorrhizal colonization of durum wheat roots. Error bars are standard errors of the means (3 replicates).

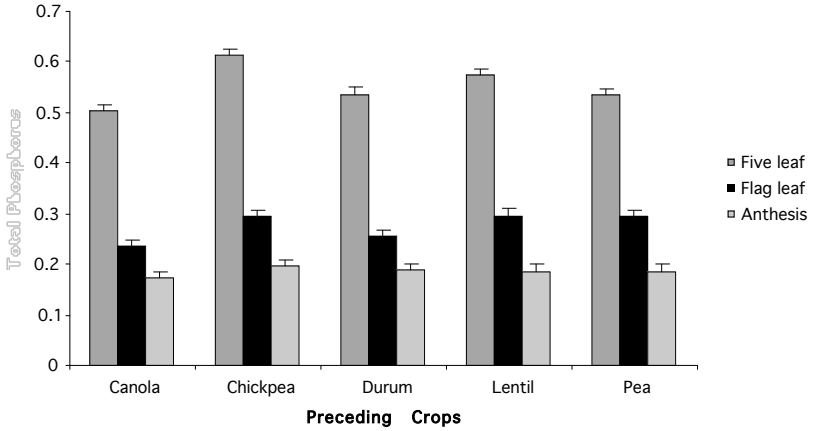

Figure 2. Effect of previous crop on P concentration of durum wheat. Error bars are standard errors of the means (3 replicates).

The lower colonization levels were also related to lower concentrations of total P in the plants (Figure 2). Durum P uptake was higher after chickpea and lentil and lower after canola and durum. Canola is lower than all others but an interaction (*P=0.02*) showed that differences are greatest at the flag leaf stage and before maturity. The crop preceding durum had no significant difference on plant N uptake (data not shown).

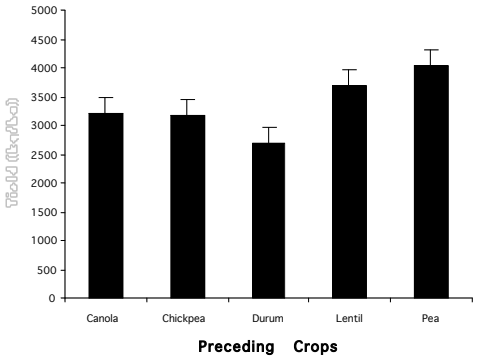

Figure 3. Effect of previous crop on grain yield of durum. Error bars are standard errors of the means (3 replicates).

Previous crop was significant (*P=0.06*) after lentil and pea, while the other treatments resulted in lower yields (Figure 3). The 2004 season was unusually wet and cool and the lower durum yields may be partially explained by the large incidence of tan spot resulting from the durum monoculture.

Conclusions

Increased durum yield following a pulse crop is a result of both the nitrogen and non-N benefits, including AMF symbiosis. The preliminary results of this study indicate that the increased plant P uptake cannot be explained by changes in the soil N and P pools, and are related to increased AMF colonization. The biodiversity of the AMF population and the changes in microbial community structure over the growing season must still be evaluated. The possibility that including pulse crops in a durum-based rotation have a positive influence on the soil microbial populations must still be looked into, as well as repeated sampling and analysis in 2005.

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