Cropping sequence effects on N fixation and C and N inputs of pea, lentil, and chickpea

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SPG Contributions	Project Status	Duration/Timeline of Project (Year to Year)	Co-funders	Total Project Cost
$254,956.10	Completed	June 2011 – May 2014	Saskatchewan Ministry of Agriculture – Agriculture Development Fund (ADF) (amount unknown)	$254,956.10

Project Description

To quantify nitrogen (N) fixation of pea, lentil, and chickpea grown in sequence with oilseeds, pulses, and cereals by determining N fixation and pulse residue N inputs (roots, rhizodeposits and above ground); to determine carbon (C) and N inputs of pea, lentil, and chickpea as they are affected by cropping sequence; to examine the influence of previous crop (oilseed, cereal, or pulse) on soil inputs of pea, lentil, and chickpea; to investigate differences in microbial community structure between the pea, lentil and chickpea and as affected by cropping sequence; to quantify biological N fixation in different pulses in rotations of different diversity in the field.

The accurate assessment of below-ground cycling of N and C in lentil, chickpea and pea, in combination with a more complete evaluation of microbial community structure under these pulses and as affected by rotation sequence will provide important information on optimizing pulses in rotations for Saskatchewan farmers.

It is the goal with this project to collect more data on N and C rhizodeposition from a variety of pulse crops simultaneously, using consistent methodologies. The more accurate assessment of belowground N will improve estimations of the N credit from N2 fixation from different pulse crops.

Preceding crops in a rotation sequence will affect microbial populations affecting processes like biological N2 fixation, residue decomposition and rhizodeposition in crops further in the rotation sequence.

Greenhouse and field studies were conducted to measure and compare amounts of carbon and nitrogen added by different pulse crops (chickpea, pea and lentil) in different rotation sequences with wheat and brassica crops (canola or mustard) through aboveground residues (leaves, pods and stems) and belowground residues (roots and rhizodeposits).

Continuously cropped rotations (P-P-P, L-L- L, CP-CP-CP: where P=pea, L=lentil and CP=chickpea) were evaluated for inherent differences among the different pulse crop species. A second experiement examined the influence of the immediately preceding crop (P-W-P vs P-M-P and P-W-CP vs P-M-CP; where W=wheat and M=mustard). Additional rotations included L-W-L and CP-W-CP that along with the P-W-P rotation evaluate rhizodeposition in alternating pulse crop-wheat crop rotations.

Rotation sequences were examined for their influence on biological N2 fixation, aboveground nitrogen and carbon contributions, and belowground nitrogen and carbon contributions in the pulse crop grown as the third crop in the sequence. Large intact soil cores were extracted from an existing field study after the first two years of the rotation sequence were complete. The pulse crops were labeled directly with 15N and 13C to enable researchers to track and quantify N and C originating from the plant into the soil through the sloughing off of root hairs, nodules and root exudation. Microbial populations were examined for changes to the structure of the microbial community (for example, shifts in proportions of bacteria and fungi among other changes) resulting from the different rotation sequences.

Outcome

In the side-by-side comparison of chickpea, pea and lentil in the greenhouse experiments, chickpea produced the most biomass, had the highest percentage %Ndfa (derived from atmosphere – a measure of biological N2 fixation) and fixed the most N. However, in the field, chickpea grown in continuous rotation was the lowest producing, had the lowest %Ndfa and the lowest amount of N from fixation. Other rotations with chickpea as the third crop in rotation were all lower than any of the rotations with pea as the third year crop. Plants in the greenhouse are well watered and maintained under near optimal conditions, whereas in the field the natural water deficits particularly common to the Brown soil zone are assumed to limit productivity and BNF. The greenhouse study shows the potential for chickpea to thrive in productivity and BNF in well-watered conditions.

Cropping sequence had a large effect on productivity and BNF. Not surprisingly, each of the pulse crops performed least well when grown in a continuous rotation compared to diverse rotations. Growing lentil and chickpea after canola or mustard in rotation negatively affected BNF and productivity in both pulse crops compared to when the pulses were grown after immediately after wheat. At least in the Brown soil zone, it is recommended that the pulse crops not be grown immediately after a brassica crop.

Year 1 crops in the 3-yr rotations also influenced productivity and BNF. Chickpea and lentil grown repeatedly in a sequence (i.e., CP-W-CP and L-W-L) were up to 40 % more productive and fixed more N (up to 3.5 x) than chickpea and lentil in rotations where pea was the first crop in the rotation (P-W-CP, P-W-L). Cropping sequence did not affect the proportion of C and N originating from above-ground and below-ground residues but had a large affect on the quality of the rhizodeposits, which in turn affected the microbial community and decomposition of these compounds and their stability in different soil pools.

While continuously cropping pulse crops is not recommended (nor practiced by farmers) increasing diversity beyond growing a pulse crop every second year did not necessarily improve N fixation and productivity. In the Brown soil zone growing a pulse crop alternately with wheat should maximize the benefit of the pulse crop. It is notable that rhizodeposit-C and N from each of the pulse crops was >10 times higher when the crops were grown in diverse rotations compared to continuous rotations.

Results from this research will bolster claims on the environmental sustainability of pulse crops through an improved accounting of pulse derived C and N input to soils.

In particular, by quantifying belowground (root and rhizodeposit) N derived from N fixation, producers will have a better understanding of the net N credit of various pulse crops (pea, lentil, chickpea). In addition, by comparing N2 fixation and C input from these pulses grown in sequence with cereals and oilseeds, inferences regarding the most efficient crop combinations to maximize N fixation and C storage may be drawn. Economic benefits may be derived from more efficient utilization of N2 fixation, thus reducing the N fertilizer requirements for subsequent crops, and positioning the Saskatchewan Pulse industry to take advantage of a future Cbased economy.

This project provides further evidence of the large underground contribution to N budgets from pulse crops. Pea is identified as the "best" pulse crop in terms of amounts of rhizodeposited N per gram of roots produced. When estimating the contribution of N from belowground residues an estimate of approximately 2X the N supplied in the above ground residue provides a conservative estimation.

Research Objective

OBJECTIVE 1
To quantify nitrogen (N) fixation of pea, lentil, and chickpea grown in sequence with oilseeds, pulses, and cereals by determining N fixation and pulse residue N inputs (roots, rhizodeposits and above ground).

OBJECTIVE 4
To investigate differences in microbial community structure between the pea, lentil and chickpea and as affected by cropping sequence.

OBJECTIVE 2
To determine carbon (C) and N inputs of pea, lentil, and chickpea as they are affected by cropping sequence.

OBJECTIVE 5
To quantify biological N fixation in different pulses in rotations of different diversity in the field.

OBJECTIVE 3
To examine the influence of previous crop (oilseed, cereal, or pulse) on soil inputs of pea, lentil, and chickpea.