Fertility Requirements and Contributions of Pulse Crops

Jeff Schoenau PAg
Dept of Soil Science

University of Saskatchewan
College of Agriculture and Bioresources

2016 International Year of Pulses
Pulse Crops (Grain Legumes)  
*Their Contribution to Soil Fertility:*

IT ALL STARTS HERE!

**Nodules** that form on legume roots containing superior strains of N fixing bacteria fix N for **legume crop** and contribute to N nutrition of following crop.
Nitrogen Fixation by Legumes (Courtesy Dr. F. Walley)

Nitrogen fixation is energy expensive. There is a cost to the plant.

“If it affects the plant, it affects fixation”
How Much Nitrogen is Derived From the Air and Converted Into Plant N By a Legume Crop?

• Variable: Different ways to measure give different numbers

BUT A SIGNIFICANT CONTRIBUTION!

~ 50% to 80% of N in legume comes from atmosphere via biological fixation in nodule
### Amount of N fixed in Western Canada

<table>
<thead>
<tr>
<th>Crop</th>
<th>lbs N / acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>100 - 250</td>
</tr>
<tr>
<td>Pea</td>
<td>50 - 150</td>
</tr>
<tr>
<td>Lentil</td>
<td>30 - 120</td>
</tr>
<tr>
<td>Chickpea</td>
<td>20 - 100</td>
</tr>
<tr>
<td>Dry Bean</td>
<td>5 – 70</td>
</tr>
<tr>
<td>Faba Bean</td>
<td>80 - 160</td>
</tr>
</tbody>
</table>

- Significant $ Value

- Actual amount **depends** on inoculation/nodulation, environmental conditions, soil available N and other nutrients like P.
Soil Available N

- **If available N level in soil is high** (fallow, N fertilized, residual fertilizer), **legume will use soil available N** instead of allowing fixation to occur.

If lots of N in soil, legume crop does fine. However, external input of N from atmosphere through fixation is not obtained.
Debate: Starter N or no starter N fertilizer for pulse crops?

Small amounts of starter N (< 20 lbs N / acre) for pulse crops can be beneficial:

- On highly N deficient soils (e.g. < 10 lbs NO$_3$-N in top 12”).
- Where lots of straw is incorporated that will immobilize available N.
- Where onset of N fixation is delayed by cool temperatures, wet soil.
Pea and Soybean 31 DAS
Bradwell sandy loam canola stubble with 3 lbs NO$_3$-N/acre 0-6”
SOYBEANS
INOCULATED
NO Nitrogen Added

SOYBEANS
INOCULATED
200 kg N ha⁻¹ Added
Pulse Grain, Nitrogen Yield and N Fixation at Four Sites in Saskatchewan in 2014

J. Xie PhD thesis research
Four field sites:

- Saskatoon (Dark Brown)
- Scott (Dark Brown)
- Rosthern (Black)
- Yorkton (Black)

Experimental design:

- Randomized complete block design (RCBD)
<table>
<thead>
<tr>
<th>Crop</th>
<th>Variety</th>
<th>Market class</th>
<th>Breeder</th>
<th>Herbicide resistance</th>
<th>Variety #</th>
<th>¹⁵N-study</th>
</tr>
</thead>
<tbody>
<tr>
<td>pea</td>
<td>CDC Meadow</td>
<td>yellow</td>
<td>CDC</td>
<td>group 2</td>
<td>P-1</td>
<td>✓</td>
</tr>
<tr>
<td>pea</td>
<td>CDC Amarillo</td>
<td>yellow</td>
<td>CDC</td>
<td>group 2</td>
<td>P-2</td>
<td>x</td>
</tr>
<tr>
<td>pea</td>
<td>CDC Limerick</td>
<td>green</td>
<td>CDC</td>
<td>group 2</td>
<td>P-3</td>
<td>x</td>
</tr>
<tr>
<td>lentil</td>
<td>CDC Impower</td>
<td>large green</td>
<td>CDC</td>
<td>group 2</td>
<td>L-1</td>
<td>x</td>
</tr>
<tr>
<td>lentil</td>
<td>CDC Invincible</td>
<td>small green</td>
<td>CDC</td>
<td>group 2</td>
<td>L-2</td>
<td>x</td>
</tr>
<tr>
<td>lentil</td>
<td>CDC Maxim</td>
<td>small red</td>
<td>CDC</td>
<td>group 2</td>
<td>L-3</td>
<td>✓</td>
</tr>
<tr>
<td>soybean</td>
<td>P001T34R</td>
<td>oilseed</td>
<td>Pioneer Dupont</td>
<td>group 2</td>
<td>S-1</td>
<td>x</td>
</tr>
<tr>
<td>soybean</td>
<td>TH3303R2Y</td>
<td>oilseed</td>
<td>Thunder</td>
<td>group 2</td>
<td>S-2</td>
<td>✓</td>
</tr>
<tr>
<td>soybean</td>
<td>NSC Moosomin</td>
<td>oilseed</td>
<td>Northstar Genetics</td>
<td>group 2</td>
<td>S-3</td>
<td>x</td>
</tr>
<tr>
<td>wheat</td>
<td>CDC Abound</td>
<td>hard red</td>
<td>CDC</td>
<td>group 2</td>
<td>W</td>
<td>✓</td>
</tr>
</tbody>
</table>
Pre-seeding May 2014 available nutrient content in 0-15 cm at the four sites (kg ha\(^{-1}\)).

<table>
<thead>
<tr>
<th>Site</th>
<th>Texture</th>
<th>NO(_3)-N</th>
<th>P</th>
<th>SO(_4)-S</th>
<th>K</th>
<th>pH</th>
<th>EC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saskatoon</td>
<td>Loam</td>
<td>19</td>
<td>33</td>
<td>&gt;48</td>
<td>&gt;600</td>
<td>5.9</td>
<td>0.6</td>
</tr>
<tr>
<td>Scott</td>
<td>Loam</td>
<td>25</td>
<td>26</td>
<td>9</td>
<td>&gt;545</td>
<td>6.6</td>
<td>0.1</td>
</tr>
<tr>
<td>Rosthern</td>
<td>Loam</td>
<td>6</td>
<td>28</td>
<td>5</td>
<td>322</td>
<td>6.2</td>
<td>0.1</td>
</tr>
<tr>
<td>Yorkton</td>
<td>Loam</td>
<td>8</td>
<td>47</td>
<td>5</td>
<td>463</td>
<td>7.9</td>
<td>0.1</td>
</tr>
</tbody>
</table>
Grain yield (kg/ha) of lentil, pea and soybean at the four sites.
Nitrogen yield (grain+straw) kg/ha of lentil, pea and soybean.
%ndfa: soybean > pea = lentil

% of N in plant derived from N\textsubscript{2} fixation (%ndfa)
What is Nitrogen Contribution of a Pulse to a Following Crop?

- Significant, but not typically huge if the seed is harvested and removed.

Seed contains about 70% of N in a mature pulse crop.
The amount of N removed in harvested seed is about same as N fixed from atmosphere.

N removed in harvested pulse seed obtained for “free” from fixation

In non-legume, this N has to come from soil and fertilizer
Nitrogen Benefits to Following Crop

N Fertilizer Replacement Value

How much extra fertilizer N needs to be added to bring yield of non-legume crop grown on non-legume stubble to same yield as crop grown on legume stubble.

What you are saving by growing a legume the year before versus some other non-legume.
N fertilizer replacement value

• Variable estimates!

Depends on what you are comparing to.

*For wheat*

\[
\begin{array}{ccc}
20 & \text{to} & 100\ \text{lbs N/acre} \\
\text{pea vs. canola stubble} & & \text{pea vs. wheat stubble}
\end{array}
\]
2015 wheat on 2014 lentil, pea, soy, and wheat stubble @ Saskatoon SPG land site.
Study (Jefferson et al. 2014) revealed significant N fertilizer replacement value of 2 years of alfalfa or 1 year of pea versus flax stubble to following wheat crop:

<table>
<thead>
<tr>
<th>Site</th>
<th>Alfalfa stubble (kg N/ha)</th>
<th>Pea stubble (kg N/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moist Black</td>
<td>~ 300</td>
<td>~ 180</td>
</tr>
<tr>
<td>Dark Brown</td>
<td>~ 75</td>
<td>~ 20</td>
</tr>
</tbody>
</table>
Direct N Benefit

- **Nitrogen** derived specifically from the legume crop is made available to a following crop by **microbial decomposition** of surface residues, roots, old nodules.

- Happens during growth (root exudates), after harvest, and in early spring, may show up in soil test.
Soil conditions following different crops over five years at Scott, SK (Brandt, 1996)

<table>
<thead>
<tr>
<th>Previous Crop</th>
<th>Spring Soil Moisture</th>
<th>Spring Soil Nitrate-N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fallow</td>
<td>110 mm</td>
<td>72 kg/ha</td>
</tr>
<tr>
<td>Field Pea</td>
<td>87</td>
<td>42</td>
</tr>
<tr>
<td>Lentil</td>
<td>86</td>
<td>45</td>
</tr>
<tr>
<td>Wheat</td>
<td>77</td>
<td>34</td>
</tr>
</tbody>
</table>
• Available N release also takes place during the growing season by mineralization: affected by many factors, difficult to predict.

Example: N credit of 20 lbs N/acre for every 40 bu/ac of pea yield (Beckie et al. 1997)
1 lb N /ac for every bu/ac of pea yield (McKenzie, 2008)

Pea credit greater than lentil credit (Adderley et al. 2005)
Note: Nitrogen in above-ground after harvest pulse residue makes little contribution to N supply to following crop. < 10% of N in above ground pulse residue is made available to crop in following year. Controlled environment study (Xie et al 2014) showed only 4% of pea residue N and 3% of soybean residue N recovered by wheat. *Below ground effects are what counts!*
• Below ground N (roots and rhizodeposits) found to comprise 34% of N in lentil (Arcand et al. 2014)

• Arcand et al. 2014 report for peas, higher below ground contribution to following wheat crop (13% of N) compared to above ground (9%).
Crop nitrogen uptake on pulse stubble is often enhanced by a greater amount than what can be contributed by the pulse residue itself.

- Better conditions for root growth
- Stimulated biological activity

The Magic of Pulses!

Non-N benefit of pulses contributes to higher yield potential.

*Therefore put same or more fertilizer on crop grown on pulse stubble*
What About Phosphorus?

- Legumes can often mobilize and access P already present in the soil better than many other crops can.

- Legume roots can acidify root zone and solubilize calcium phosphates common in prairie soils.

- Explains why pulses are sometimes not highly responsive to P fertilization. Good scavengers
Pulse crops have different tolerances to seed-placed fertilizer P

With ~ 15% seed bed utilization (e.g. 1” spread opener, 9” spacing), max safe rates according to provincial guidelines:

- Pea: 15 lbs P$_2$O$_5$/ac
- Lentil, Chickpea: 20 lbs P$_2$O$_5$/ac
- Faba bean: 40 lbs P$_2$O$_5$/ac
- Soybean (limited SK research): 20 lbs P$_2$O$_5$/ac

Note: Crop removal as P$_2$O$_5$ about 30 for pea and soy, 20 for lentil
2014 Soybean Yield at Central Butte SK as Influenced by P Fertilizer Application Method for 20 lb P$_2$O$_5$/acre applied as 11-52-0 (Weiseth 2015)
Above ground (grain + straw) P uptake (kg P/ha).

Note: Multiply by 2.3 to get kg P$_2$O$_5$/ha.
What are effects of legumes on P nutrition of following crops?

• **P uptake** by non-legume **generally increased** following legume versus non-legume (pulse: Sulewski et al; forage Rehmut et al. 2014).

**Possible Reasons**

– Increased soil P availability
– Increased colonization of roots by beneficial AM fungi
– Improved root growth and crop demand
Available **Phosphorus** Supply Rate At Indian Head SK Plots

Soil P Supply Rate

Short Term (5yr) No-Till

Long Term (25yr) No-Till

Pea Stubble LSD (0.05) = 0.15
Wheat Stubble LSD (0.05) = 0.07
Error bars = ± Std. dev.

Available Phosphorus Supply Rate At Indian Head SK Plots

Soil P Supply Rate

Short Term (5yr) No-Till

Long Term (25yr) No-Till

Pea Stubble LSD (0.05) = 0.15
Wheat Stubble LSD (0.05) = 0.07
Error bars = ± Std. dev.
Important benefit of pulse can be enabling greater access to soil P and other nutrients by the following crops:

Better rooting environment, root health, beneficial biological associations (AM fungi).

A benefit that is rather difficult to directly measure!
K uptake (kg K/ha) in grain and straw in 2014

Note: Multiply K by 1.2 to get kg K₂O/ha
Sulfur uptake (kg S/ha) in grain and straw in 2014
Peas not highly responsive to S fertilization
Summary

• Legumes reduce our reliance on mineral fertilizers: N fixation, scavenging of P and other nutrients

*Benefits the legume and crops that follow, largely through below-ground contribution*

• For pea and soybean, max safe rates of seed-placed P are less than crop removal.

• Short season soybeans are good yielders and N fixers, have high P (and K) demand.
Thanks for opportunity to participate!

Thanks to Xing Jie, Tom Warkentin, CDC Pulse Crew

Funders: Sask Pulse Growers, ADF, WGRF