Pulses for Soil, Crop and Environmental Health

Newton Lupwayi
Agriculture & Agri-Food Canada
Lethbridge, Alberta, Canada
Harvested Area (hectares x1000) in Canada

![Graph showing harvested area (hectares x1000) in Canada from 1990 to 2015 for different crops: Field pea, Lentil, Dry bean, Chickpea, and Faba bean.]
Total Production (metric tonnes x1000) in Canada

![Graph showing total production of various crops in Canada from 1990 to 2015. The graph includes lines for Field pea, Lentil, Dry bean, Chickpea, and Faba bean. The y-axis represents production in metric tonnes x1000, and the x-axis represents years from 1990 to 2015.]
Grain legume decline and potential recovery in European agriculture: a review

Peter Zander¹ · T. S. Amjath-Babu¹ · Sara Preissel¹ · Moritz Reckling²,³ · Andrea Bues¹,⁴ · Nicole Schläfke¹ · Tom Kuhlman⁵ · Johann Bachinger² · Sandra Uthes¹ · Fred Stoddard⁶ · Donal Murphy-Bokern⁷ · Christine Watson³,⁸

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Abstract Sustainable development of agriculture is at the core of agricultural policy debates in Europe. There is a consensus that diversification of cropping would support sustainable development. However, a reduction in legume cultivation has been observed in the EU during the last decades. This decline has induced, in turn, a deficit of proteins and a reduction of ecosystem services provided by legumes. Therefore, we analysed the mechanisms that shape agricultural systems to identify leverage points for reviving European legume production. Specifically, we reviewed the factors that affect the market and non-market value of legumes and the relevant agricultural policies. We characterized the decline in
Soil, Plant and Environmental Health Benefits

- N benefits

- Non-N benefits
1. N Benefits
N Benefits

• Biological nitrogen fixation
# Nitrogen Fixed by Pulses in 2015

<table>
<thead>
<tr>
<th>Pulse</th>
<th>Harvested area (ha)</th>
<th>Nitrogen fixed (kg N/ha)(^a)</th>
<th>Total N fixed (x1000 kg N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field pea</td>
<td>1469800</td>
<td>83</td>
<td>121993</td>
</tr>
<tr>
<td>Lentil</td>
<td>1588700</td>
<td>72</td>
<td>114386</td>
</tr>
<tr>
<td>Dry bean</td>
<td>104400</td>
<td>34</td>
<td>3550</td>
</tr>
<tr>
<td>Chickpea</td>
<td>46500</td>
<td>33</td>
<td>1535</td>
</tr>
<tr>
<td>Faba bean</td>
<td>31200</td>
<td>187</td>
<td>5834</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>247298</strong></td>
</tr>
</tbody>
</table>

\(^a\) Walley et al. (2007) Agron. J.
$\$ Saved by Utilizing Fixed N in 2015

- Amount of N fixed by pulses: 250,000,000 kg (250 million kg)

- Cost of urea (March, 2015): $650/1000 kg urea
  - = $0.65/kg urea

- Cost of N = $0.65/0.46 kg N (urea has 46% N)
  - =$1.41/kg N

- Value of N fixed by pulses: $353 million

- $353 million saved by producers who grew pulses in 2015.
N Benefits

• Biological nitrogen fixation

• N cycling: benefit to subsequent crops
N Benefits to Succeeding Crops?

- Most of the 250 million kg of fixed N – exported off the farm with the legume grain.
Grain N vs. Residue N at Harvest: Field Pea

Grain N vs Residue N

• These estimates:
  – Do not include root N contributions
  – Quantify N released only to the first crop grown after a pulse crop
Grain N vs Residue N

• These estimates:
  – Do not include root N
Aboveground vs Belowground Pea N (g/pot) Recovered by Wheat

> 2x (from roots and rhizodeposits)

Arcand et al. (2014) Biol. Fertil. Soils
Grain N vs Residue N

• These estimates:-
  – Do not include root N
  – Quantify N released only to the first crop grown after a pulse crop
Above-Ground Residue N (kg N/ha)

Green pea – least residue N

GM residues released >80% of their N in the first 52 wks.
-Faba bean residues released >60%.
-Pea residues released ~50.

Residues of grain legumes, especially forage pea and faba bean, released more N during the 2\textsuperscript{nd} and 3\textsuperscript{rd} years than GM residues.
N Benefits to Succeeding Crops

• So substantial amounts of the N in aboveground and belowground crop residues can be released to subsequent crops (not just the first crop) in rotation – N cycling.
N Benefits

• Biological nitrogen fixation

• N cycling: benefit to subsequent crops

• Greenhouse gas emissions
Greenhouse Gases: CO$_2$

- Increased microbial activity during residue decomposition increases CO$_2$ emissions.

- But the non-renewable energy used in the manufacture, transportation, and application of N fertilizer used in cereals results in much more CO$_2$ emissions than use of legume N.
Greenhouse Gases: N$_2$O

- Mineralization of legume N results in N$_2$O emissions.
- But N fertilizer – greater N$_2$O emissions than biologically fixed N.
Greenhouse Gas Emissions Life Cycle (100 Yr) Assessment, Saskatchewan (kg CO₂ eq.)

MacWilliam et al. (2014) Agric. Syst.
N Benefits

• Biological nitrogen fixation

• N cycling: benefit to subsequent crops

• Greenhouse gas emissions

• Aboveground and belowground biodiversity
Aboveground and Belowground Biodiversity

• Pulses enable spatial and temporal diversification of agro-ecosystems.

• The aboveground diversity:
  – supports beneficial insects like pollinator bees
  – increases belowground diversity (soil organisms):
    • Biological soil health
Soil Microbial Biomass - Crop Residue Effects

Soil Microbial Diversity - Crop Residue Effects

Shannon's diversity index ($H'$)

Treatment

- Control
- Fert.
- Wheat
- Barley
- Canola
- Peas
- Clover

Aboveground and Belowground Biodiversity

- Crop rotation meta-analysis: 15.1% greater microbial richness and 3.4% greater Shannon index of diversity.
  
  Venter et al. (2016) Pedobiol.

- “By increasing the quantity, quality and chemical diversity of residues, high-diversity rotations can sustain soil biological communities, with positive effects on soil OM and fertility” – Biological soil health.
  

  - Nitrogen fixation
  - Nutrient cycling
  - Biological disease/pest control
  - Degradation of agro-chemicals
  - Etc.

  - All have economic and environmental benefits.
Summary of N Benefits

• Legumes usually grown without N fertilizer.
• N benefit to non-legume crops grown in rotation with pulse crops – less N fertilizer applied.

• Agronomic/Economic benefits:-
  - Healthy (well-nourished) soils/crops
  - Less $$ spent on N inputs

• Environmental benefits:
  - Less N fertilizer pollutes surface and ground water
  - Less greenhouse gas emissions
Non-N Benefits
Non-N Benefits

• Residual soil water
Residual Soil Water (mm/100 cm, 2006 - Rainfed)

Residual Soil Water

- Pulse crops leave more unused water in the soil profile than oilseed crops or wheat.

- Pulse crops extract water mostly in top 60 cm soil.
  - Pulse crops – shallower rooting depth – than wheat or canola.
Root Mass (kg/ha) at Different Soil Depths - Rainfed

Non-N Benefits

• Residual soil water

• Biological disease and pest control
Disease and Pest Control

• In rotations, legumes break cereal disease/pest cycles, especially for some soil-borne root diseases.

• Sporulation of wheat common root rot pathogen *Bipolaris sorokiana* (telemorph: *Cochliobolus sativus* on crop crowns:–

  – Cereals > Pulses = Oilseeds (# of conidia/g crown tissue)


• Wheat common root rot incidence (0-4 scale) :

  – Pea-Wheat rotation: 0.99
Total Weeds (plants/sq. m) in Year 2 Wheat

Weeds

Barley Grass (plants/sq. m) in Year 3 Wheat

Brome Grass (plants/sq. m) in Year 3 Wheat

Benefits of Biological Pest Control

• Agronomic/Economic:-
  – Healthy soils/crops – less disease/pests
  – Less $$$ spent on purchase and use of pesticides

  • European survey: 20-25% reduction in agro-chemical costs, and savings of up to €31 per hectare (von Richthofen et al. (2006)).

• Environmental:-
  – Less pesticides polluting crops, land and water
  – Less greenhouse gases produced in the manufacture, transportation and use of pesticides
Non-N Benefits

• Residual soil water

• Biological disease and pest control

• P nutrition

• Soil structure (tilth)
Summary: Soil, Crop and Environmental Health

- Relative to nonlegume crops, pulses produce healthy soils that produce healthy crops (nutrition and crop protection) in an environmentally healthy manner.

- Human and livestock health? Whole new topics.
Acknowledgements