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Pulses for Soil, Crop and Environmental Health

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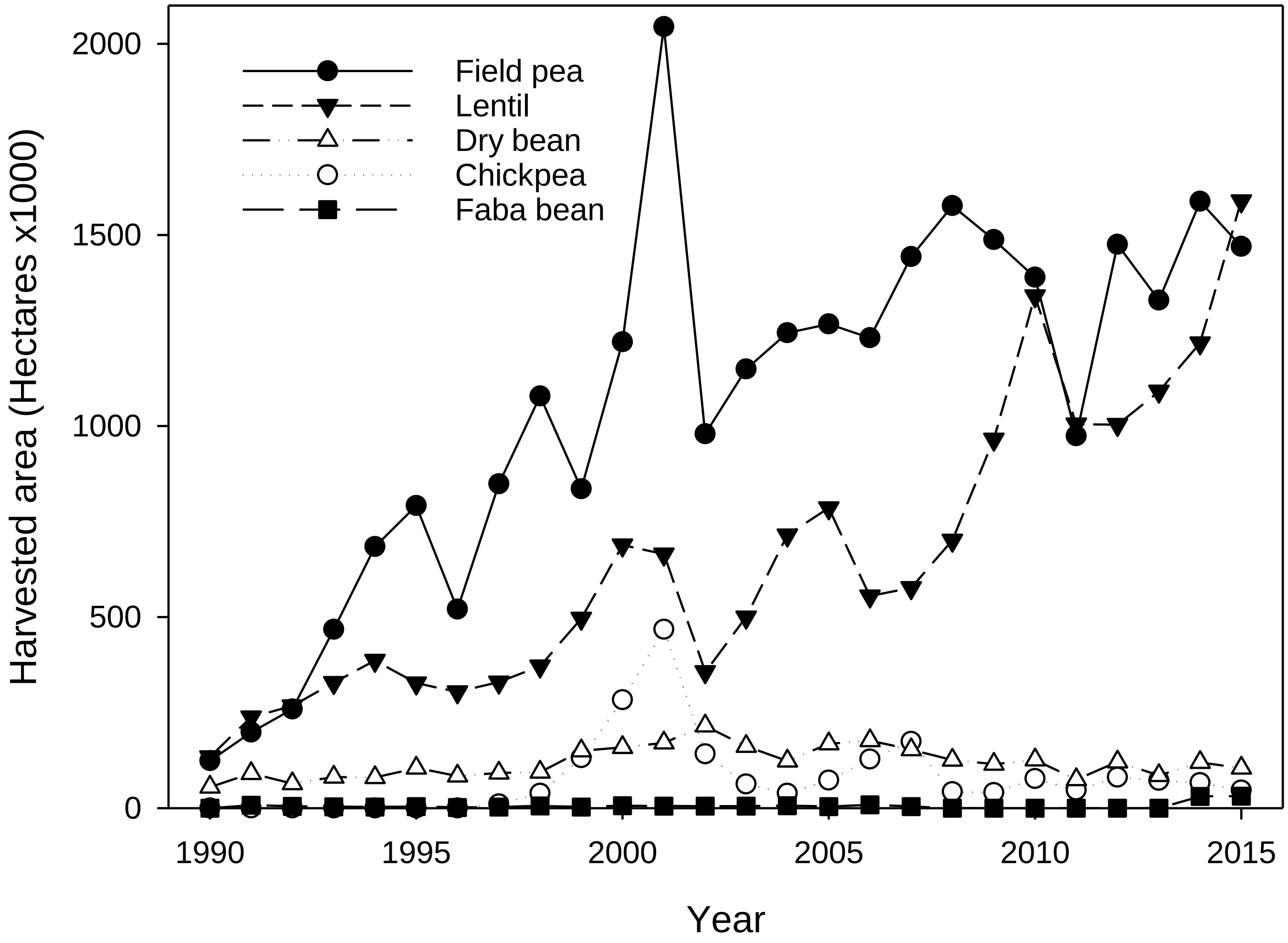
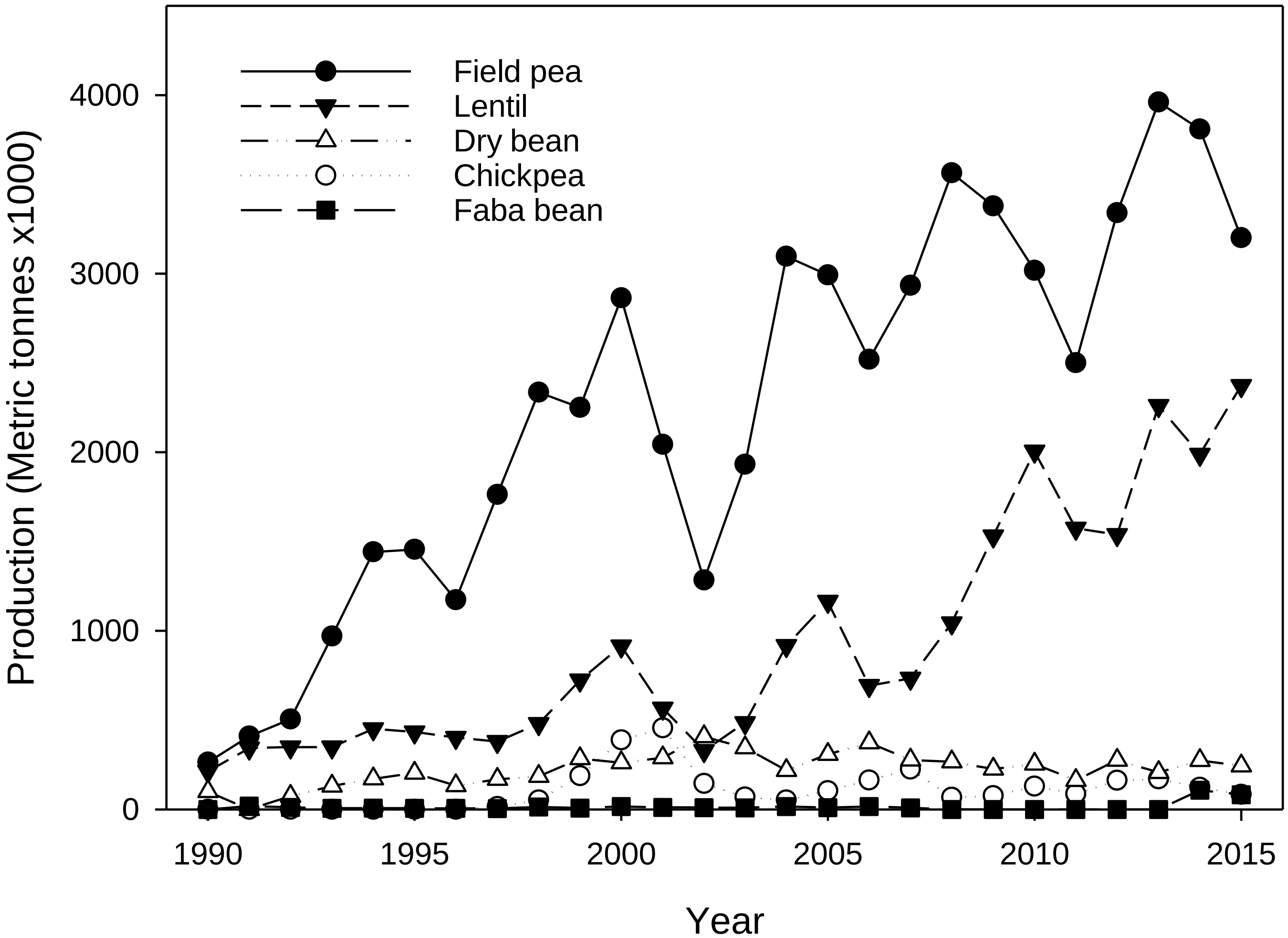
Canada

Harvested Area (hectares x1000) in Canada



Total Production (metric tonnes x1000) in Canada



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REVIEW ARTICLE

Grain legume decline and potential recovery in European agriculture: a review

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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

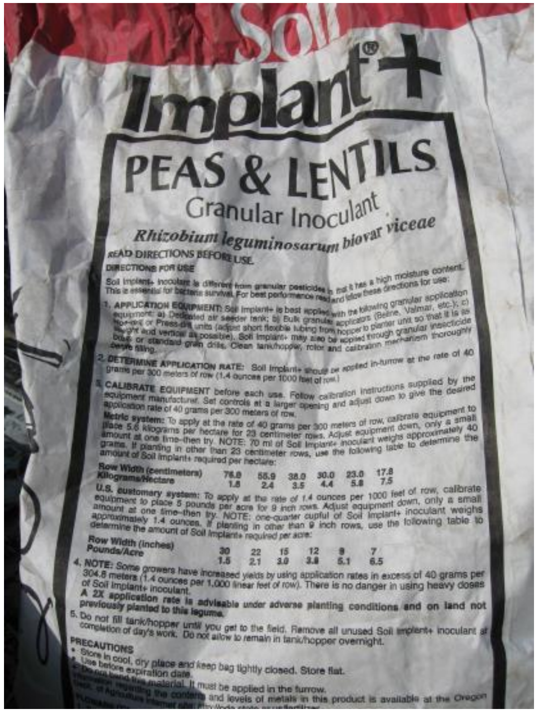
- N benefits

- Non-N benefits

1. N Benefits

N Benefits

- **Biological nitrogen fixation**



Nitrogen Fixed by Pulses in 2015

Pulse	Harvested area (ha)	Nitrogen fixed (kg N/ha)[a]	Total N fixed (x1000 kg N)
Field pea	1469800	83	121993
Lentil	1588700	72	114386
Dry bean	104400	34	3550
Chickpea	46500	33	1535
Faba bean	31200	187	5834
Total			247298

[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.

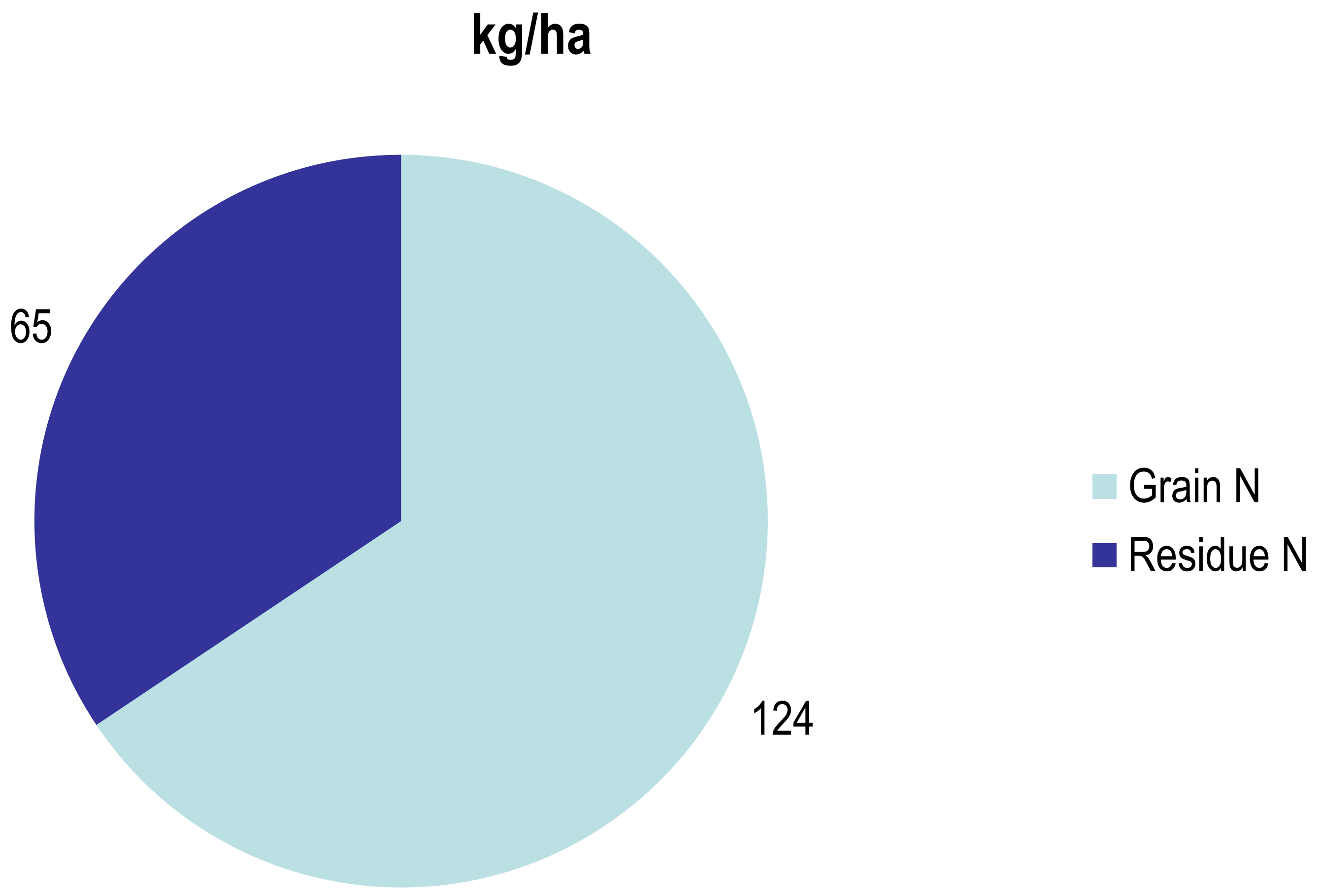
N Benefits

- 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



Lupwayi and Soon (2015) Soil Sci. Soc. Am. J.

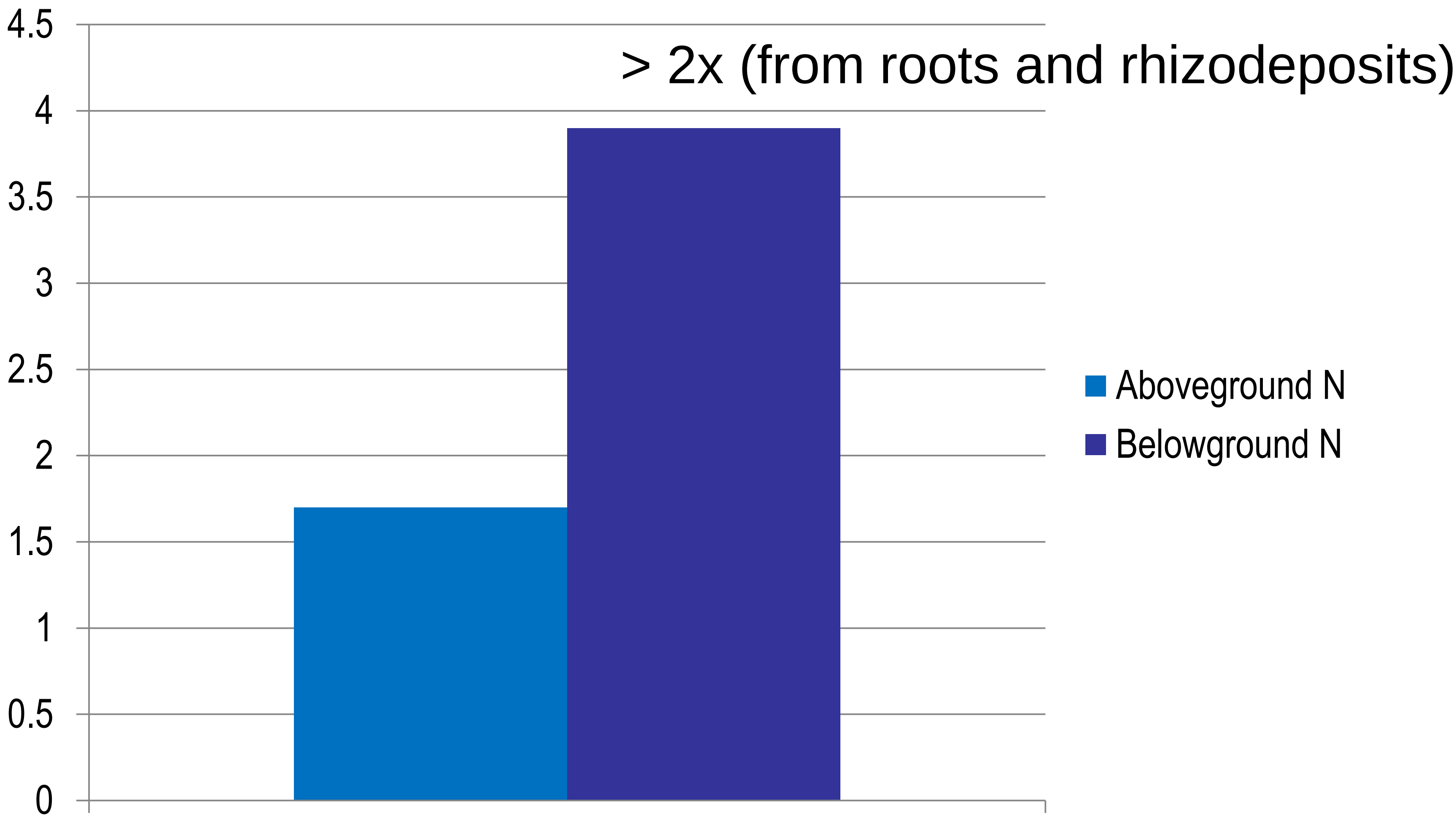
Grain N vs Residue N

- 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

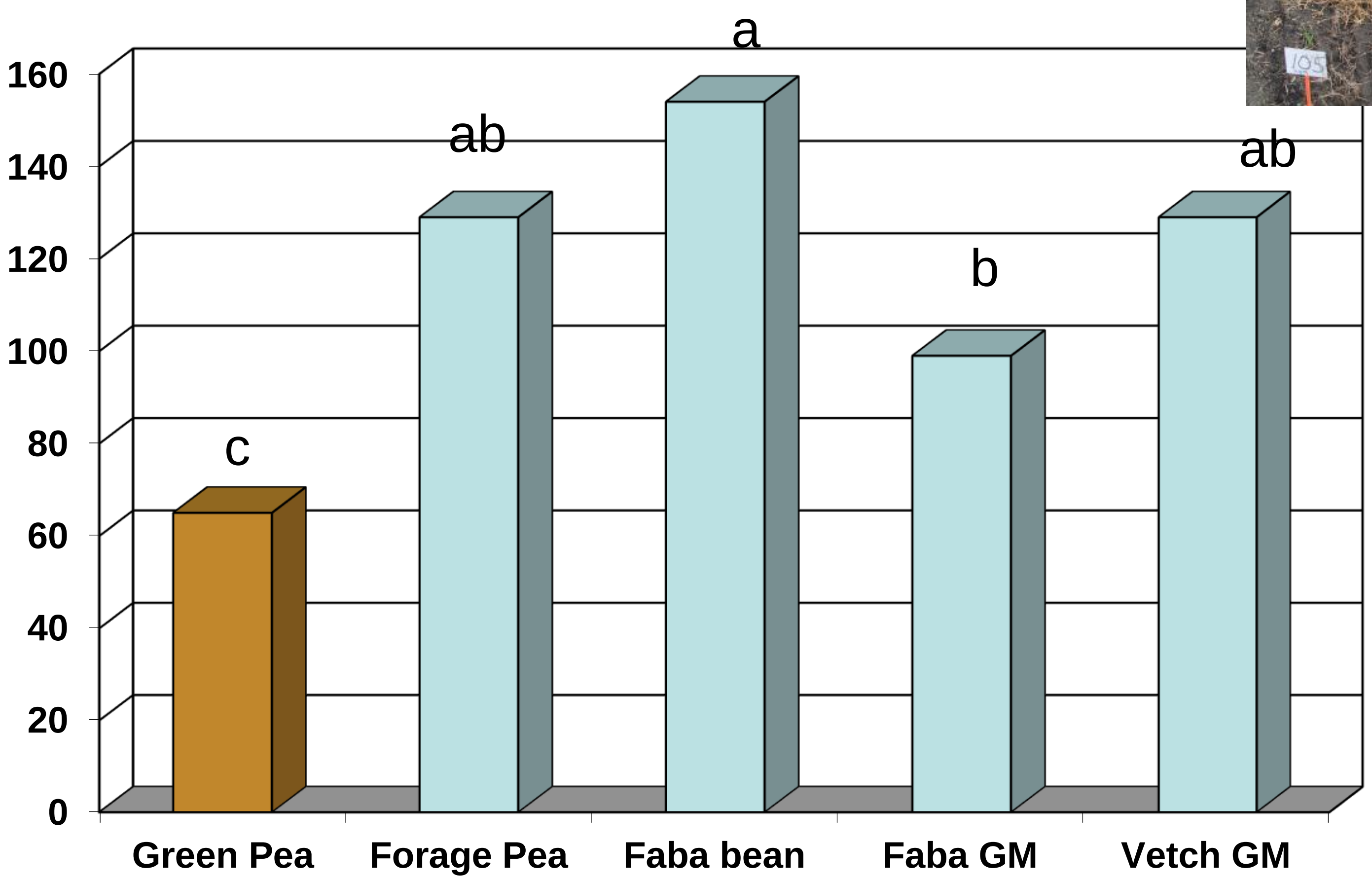


Arcand et al. (2014) Biol. Fertil. Soils

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**

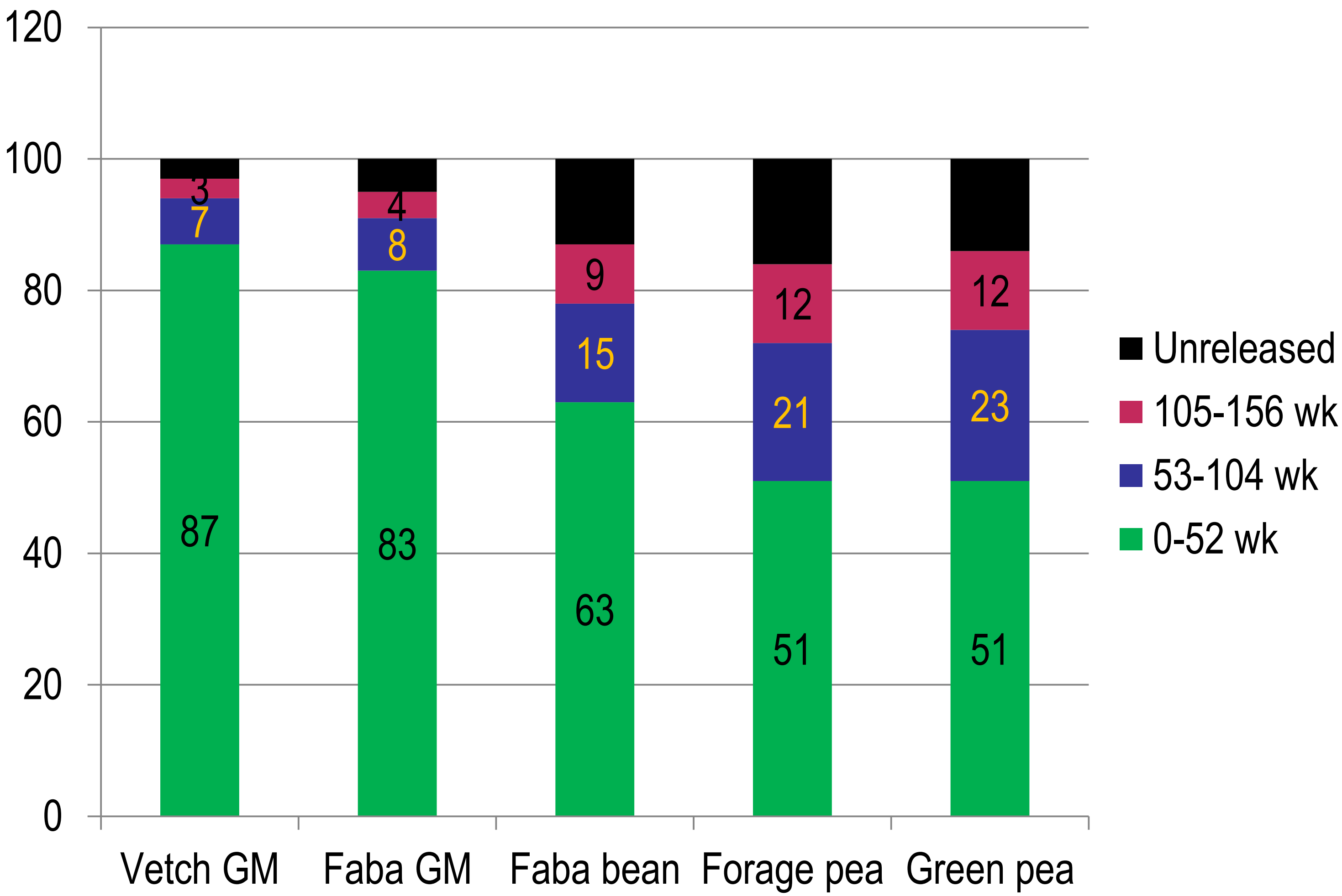
Above-Ground Residue N (kg N/ha)



Green pea – least residue N

Lupwayi and Soon (2015) Soil Sci. Soc. Am. J.

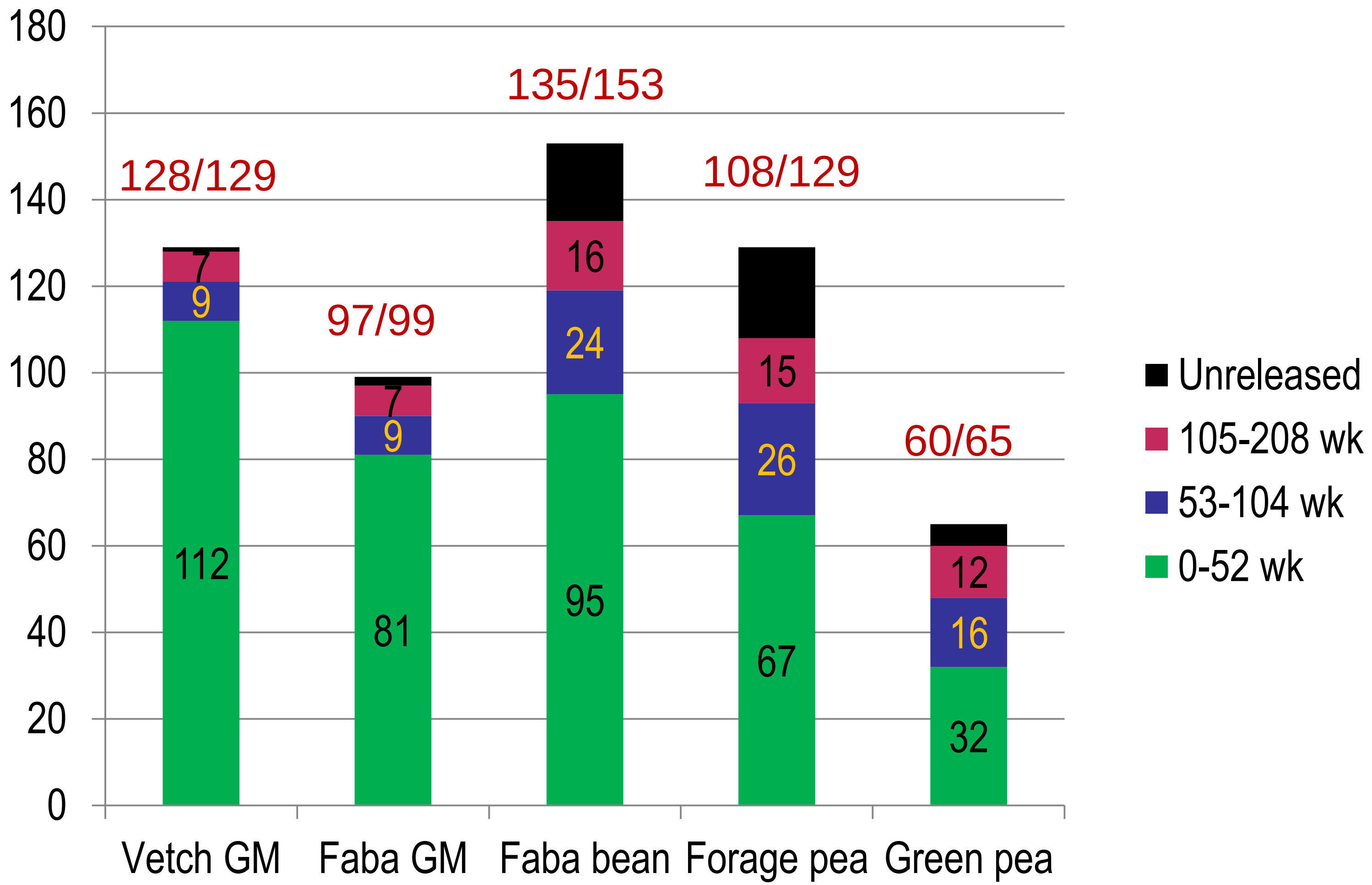
N Released (% of Initial) in 3 Consecutive Crops



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

Lupwayi and Soon (2015) Soil Sci. Soc. Am. J.

N Released (kg N/ha) in 3 Consecutive Crops



Residues of grain legumes, especially forage pea and faba bean, released more N during the 2^{nd} and 3^{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**

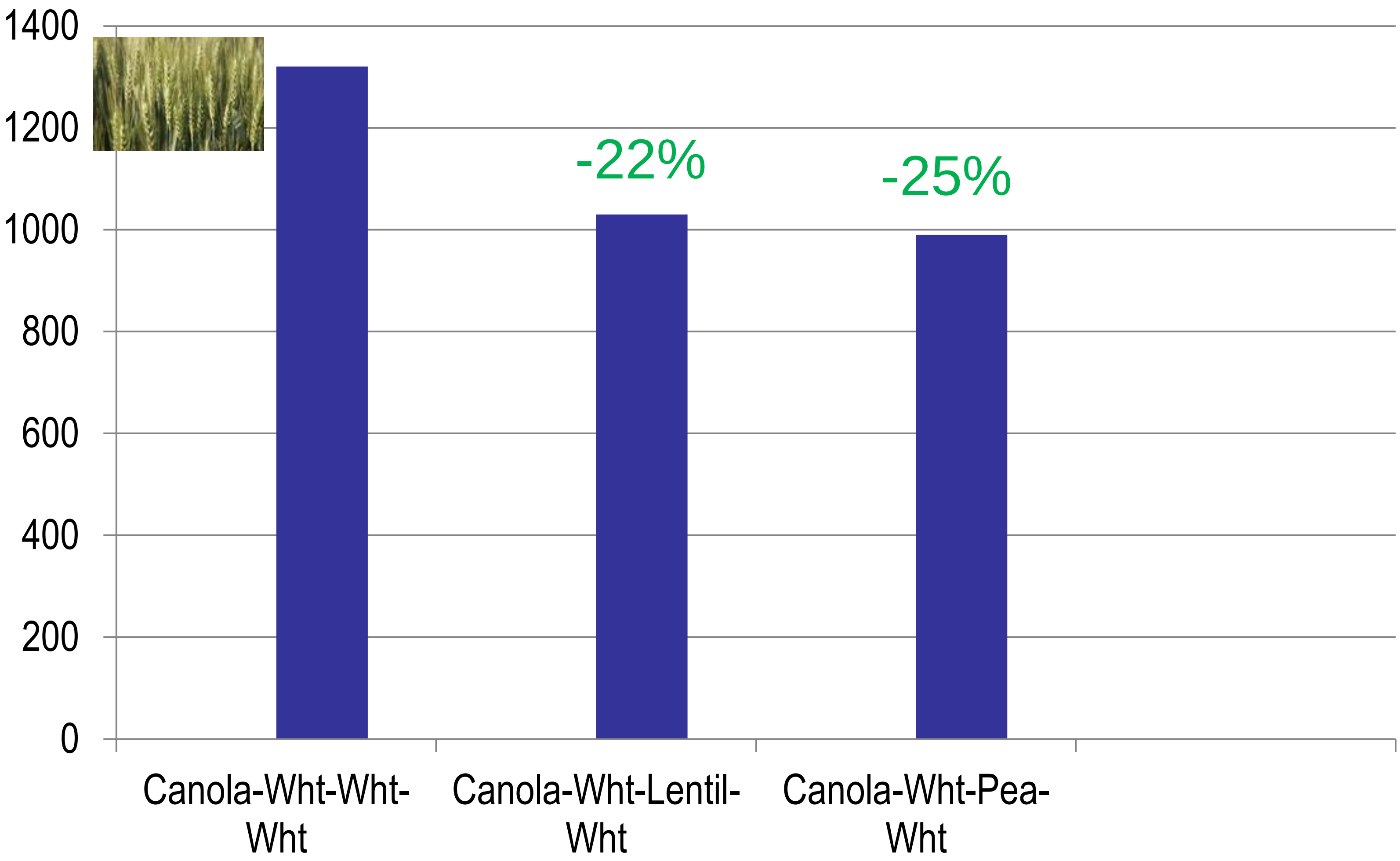
Greenhouse Gases: CO_2

- 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_2O

- Mineralization of legume N results in N_2O emissions.
- But N fertilizer – greater N_2O emissions than biologically fixed N.

Greenhouse Gas Emissions Life Cycle (100 Yr) Assessment, Saskatchewan (kg CO_2 eq.)



MacWilliam et al. (2014) Agric. Syst.

N Benefits

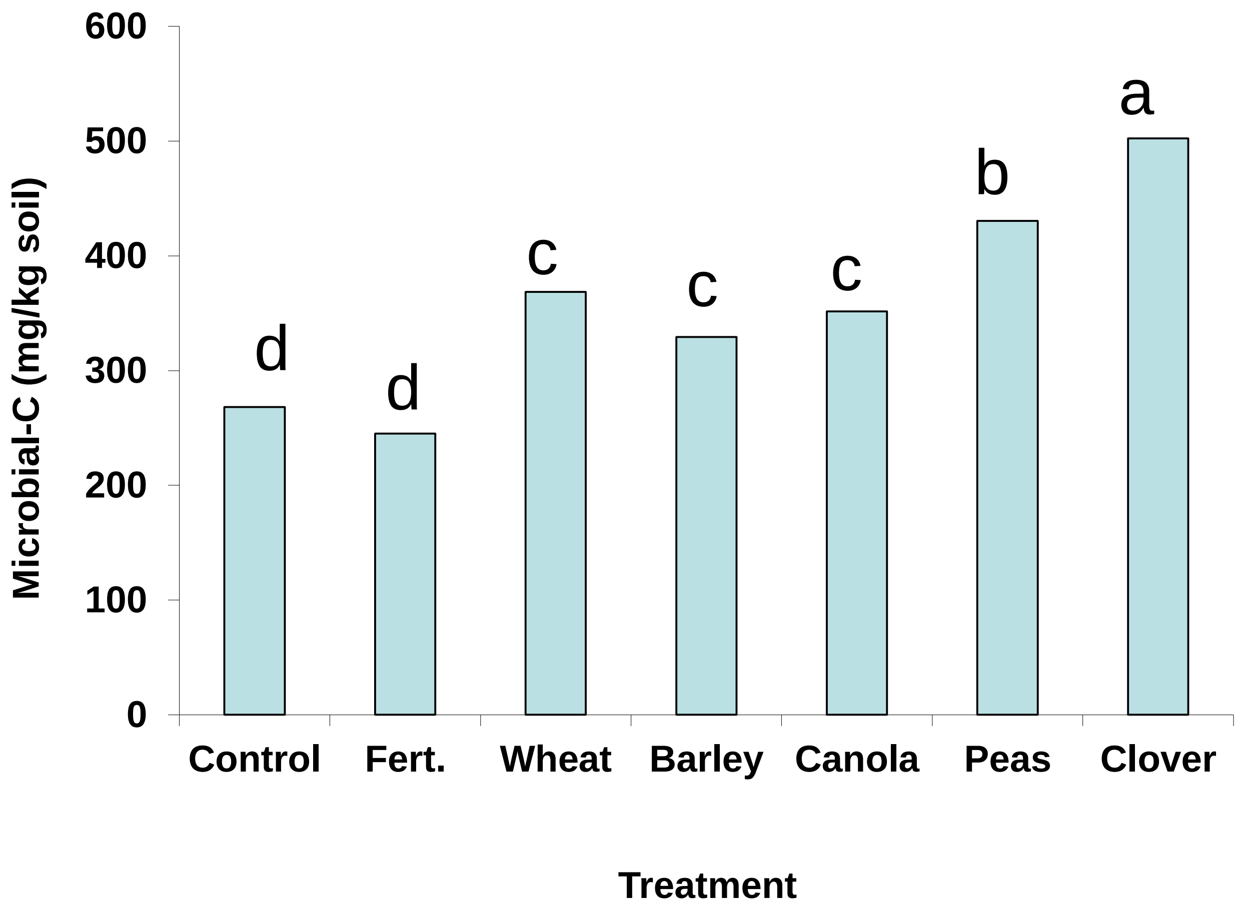
- Biological nitrogen fixation
- N cycling: benefit to subsequent crops
- Greenhouse gas emissions
- **Aboveground and belowground biodiversity**

Aboveground and Belowground Biodiversity

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

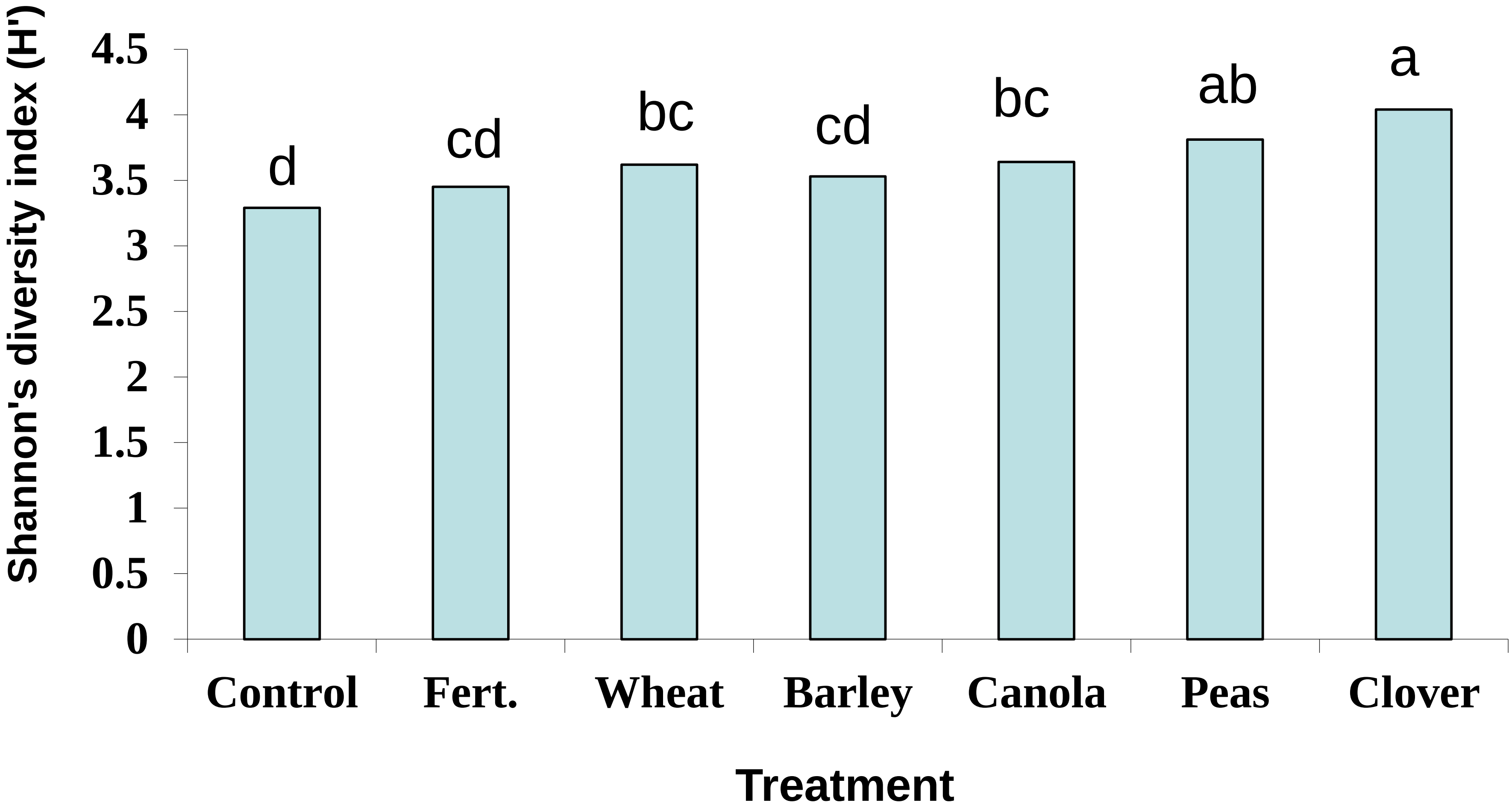
- The aboveground diversity:-
  - supports beneficial insects like pollinator bees
  - increases belowground diversity (soil organisms):-
    - Biological soil health

Soil Microbial Biomass - Crop Residue Effects



Lupwayi et al. (2004) Can. J. Soil Sci.

Soil Microbial Diversity - Crop Residue Effects



Lupwayi et al. (2004) Can. J. Soil Sci.

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.

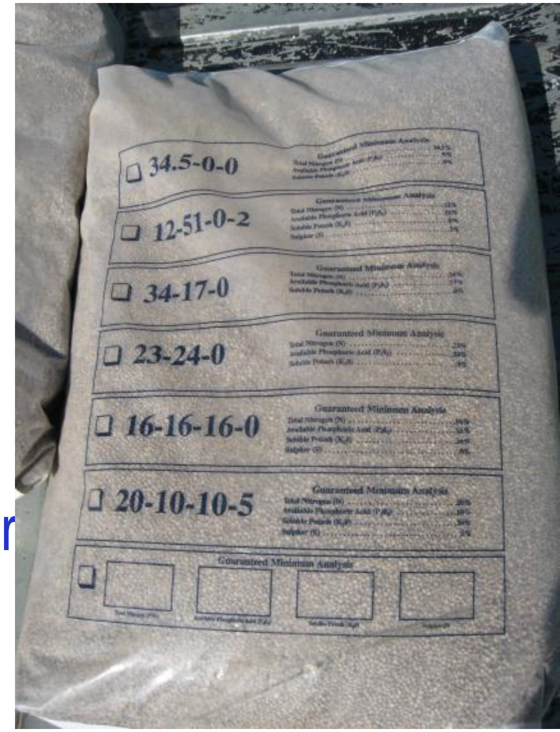
Tiemann et al. (2015) Ecol. Letters

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

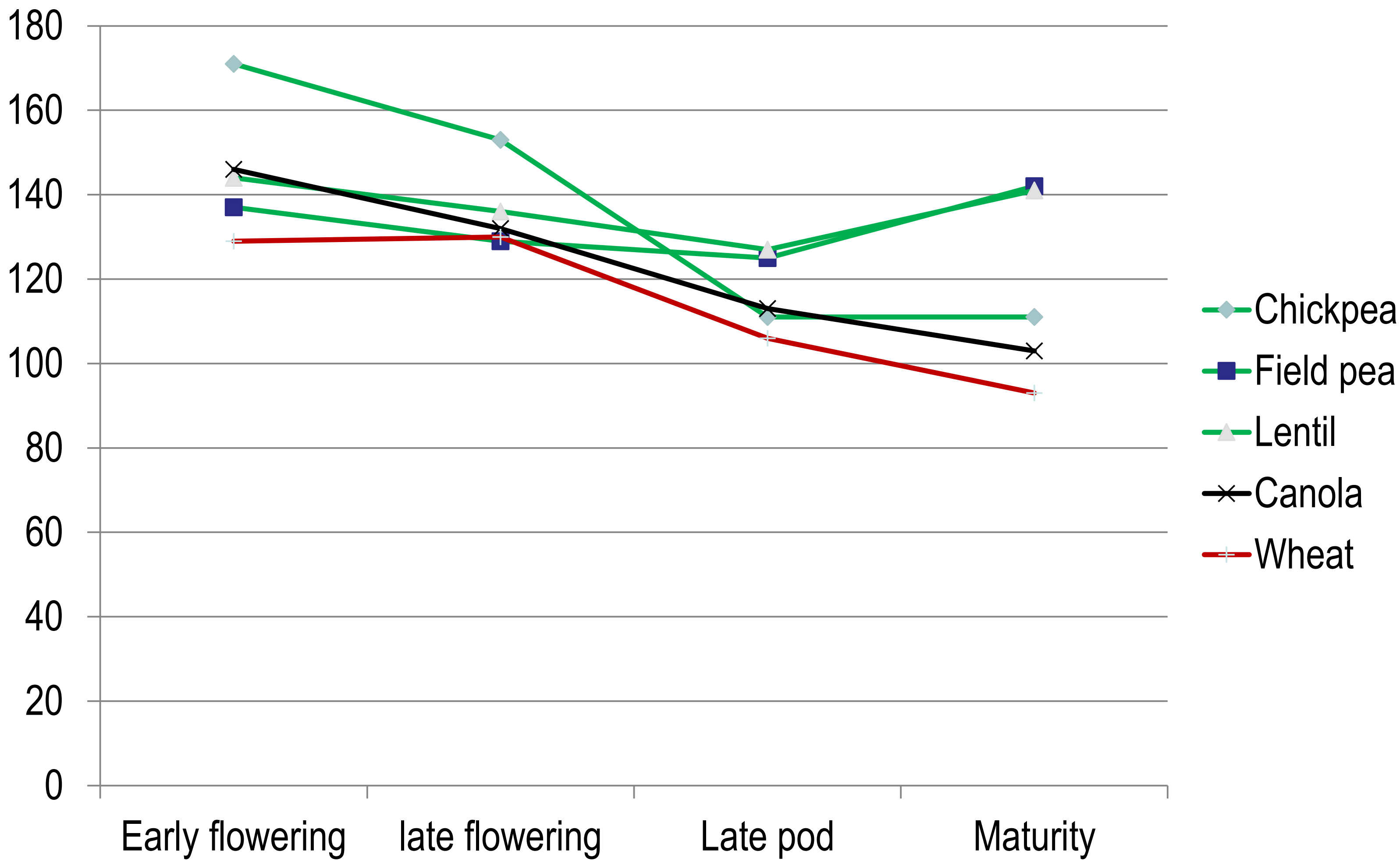


Non-N Benefits

Non-N Benefits

- Residual soil water

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



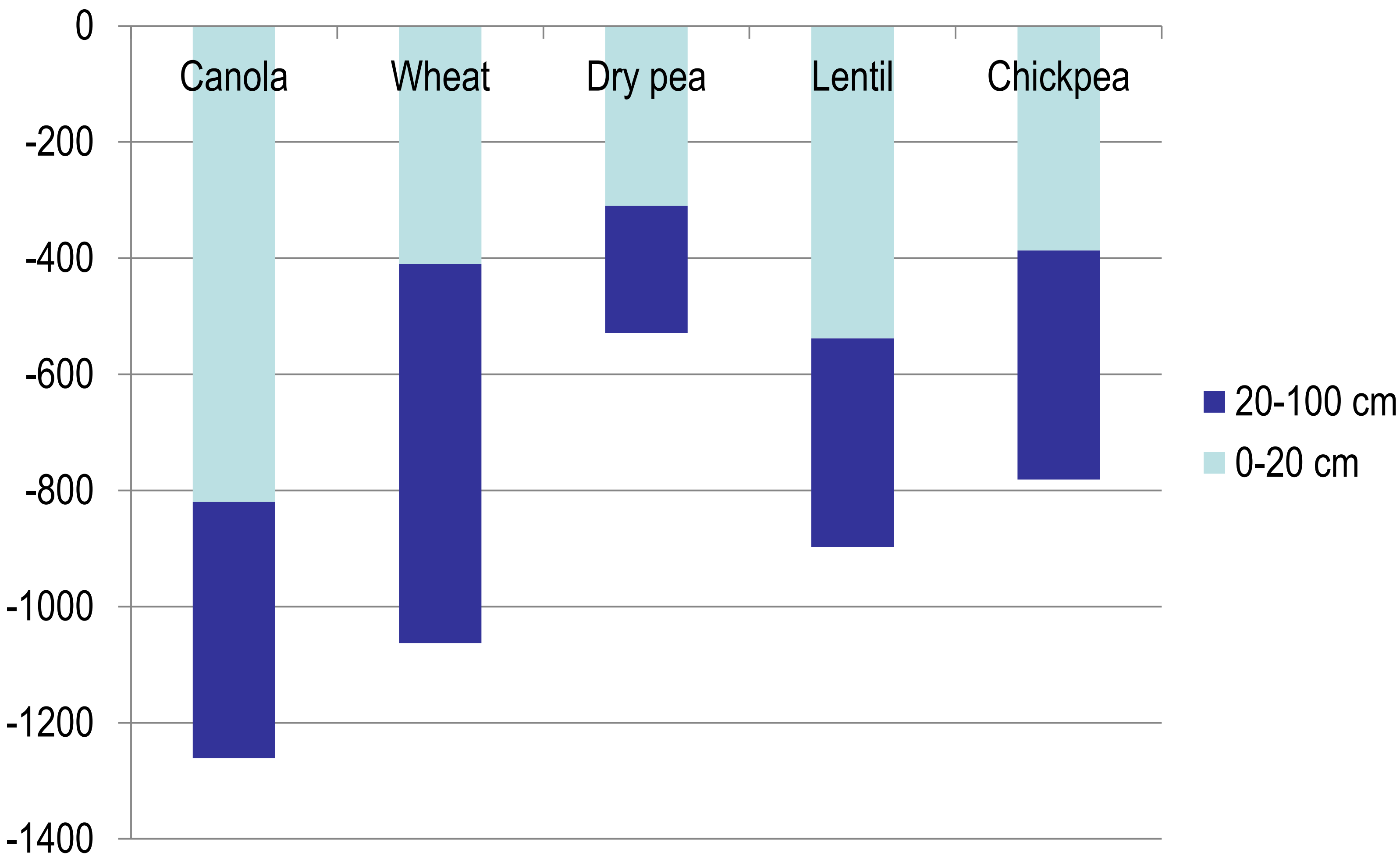
Gan et al. (2009) Agric. Water Manage.

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



Gan et al. (2009) Agric. Ecosys. Environ.

Non-N Benefits

- Residual soil water

- **Biological disease and pest control**

Disease and Pest Control

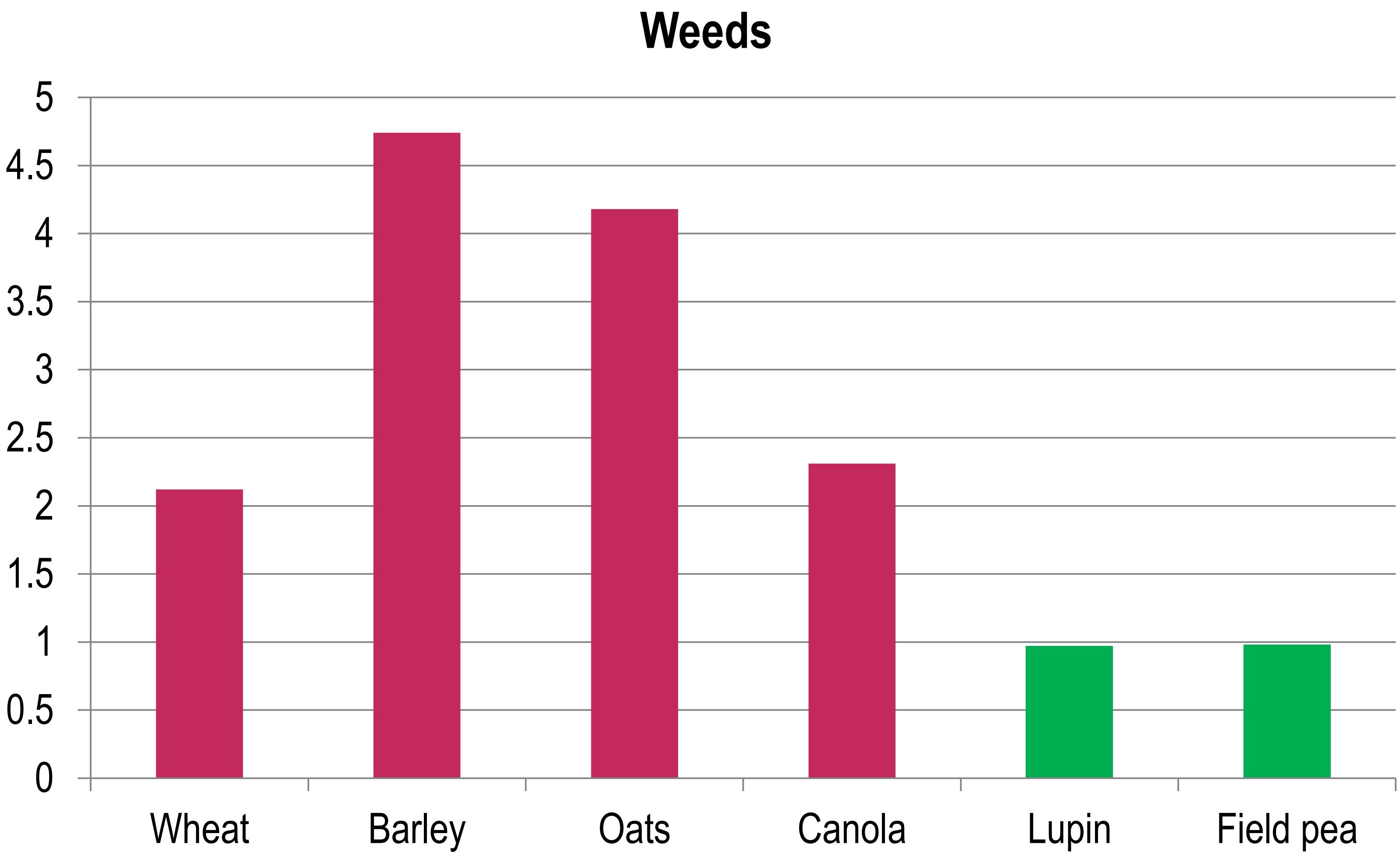
- In rotations, legumes break cereal disease/pest cycles, especially for some soil-borne root diseases.

- Sporulation of wheat common root rot pathogen *Bipolaris sorokiana* (telemorph: *Cochliobolus sativus* on crop crowns:-
  - Cereals > Pulses = Oilseeds (# of conidia/g crown tissue)

Duczek et al. (1996) Can. J. Plant Sci.

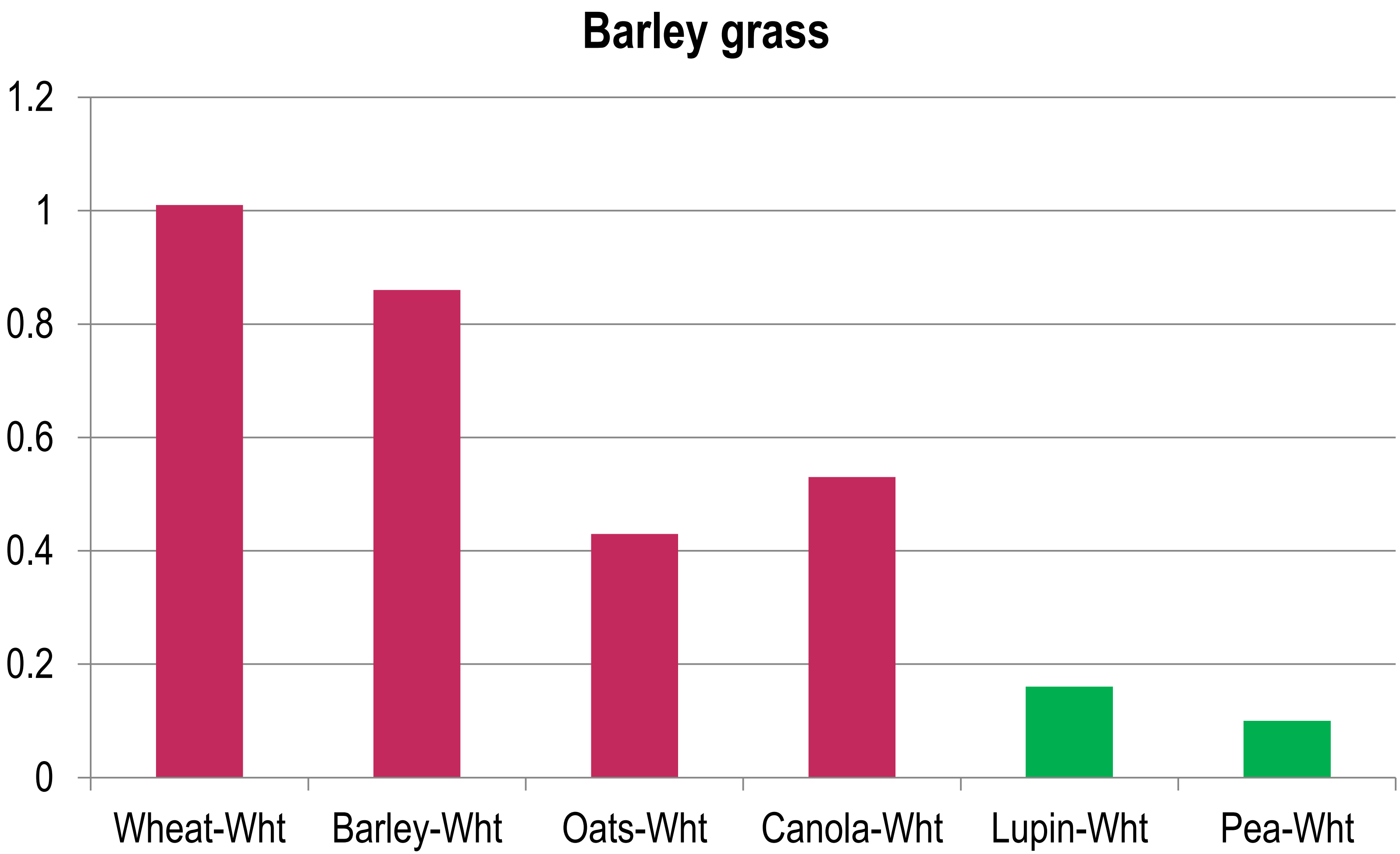
- Wheat common root rot incidence (0-4 scale) :
  - Pea-Wheat rotation: 0.99
  - Wheat-Wheat rotation: 3.19. **Stevenson & van Kessel (1996) Soil Sci. Soc. Am. J.**

Total Weeds (plants/sq. m) in Year 2 Wheat



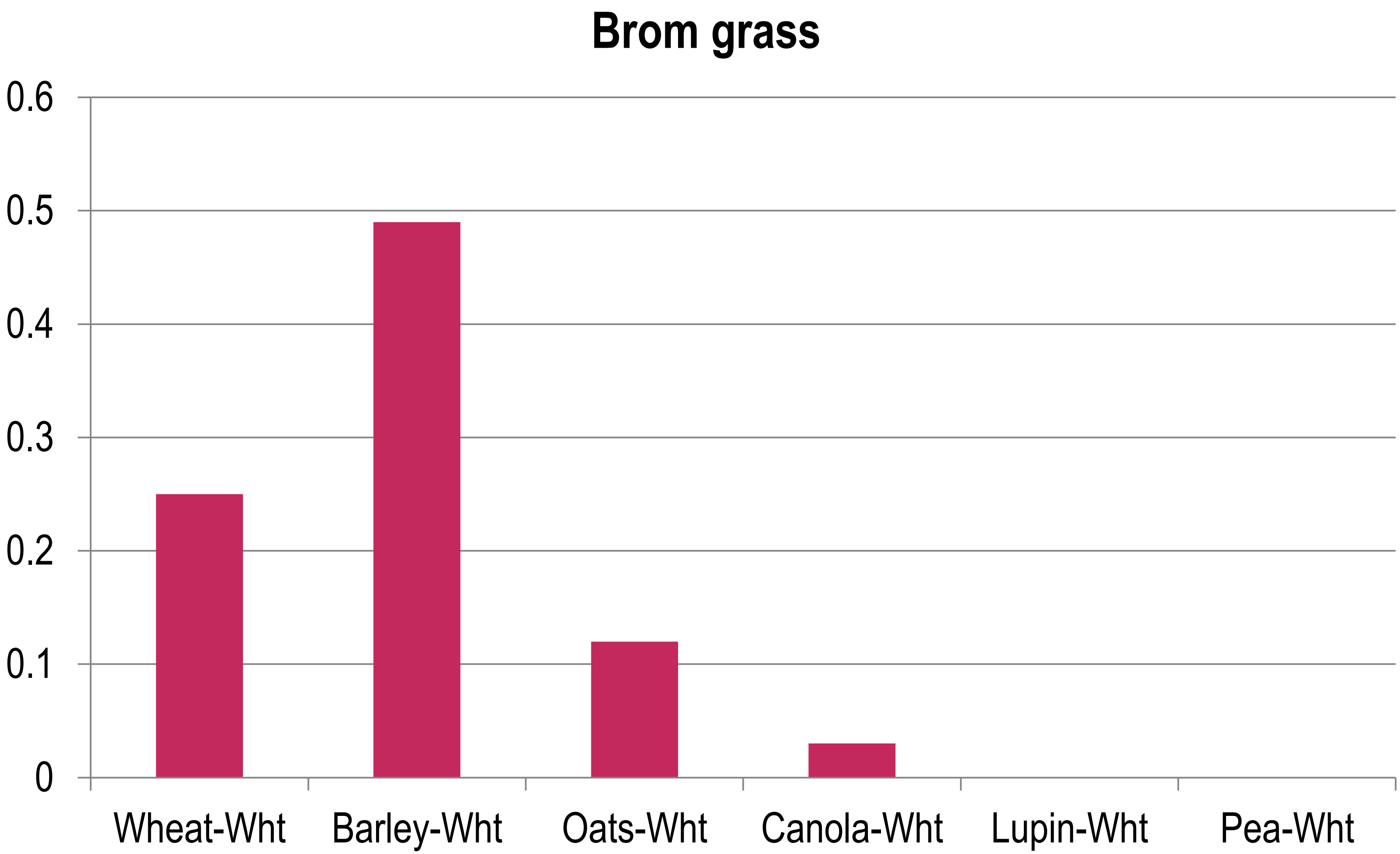
Malik et al. (2015) Crop Pasture Sci.

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



Malik et al. (2015) Crop Pasture Sci.

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



Malik et al. (2015) Crop Pasture Sci.

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