Maximizing Agronomic Benefit, Minimizing Environmental Threat From Applied Nutrients:

Through Good Management It Is Possible!

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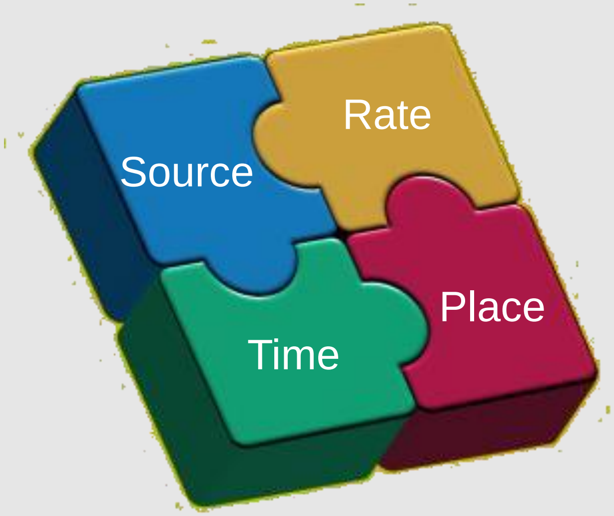
Nutrients: Use ‘Em, Don’t Lose ‘Em!

Maximizing Plant Utilization Is of Agronomic, Economic and Environmental Advantage

THE 4R SYSTEM FOR NUTRIENT STEWARDSHIP

*Right **source** at right **rate**, right **time**, right **place***



Sound Nutrient Management = Adoption, Implementation of 4 R Principles

4R concept supported by the following industry organizations initially, support is now growing around the world in counties, states, provinces, countries, agricultural industries, and environmental groups

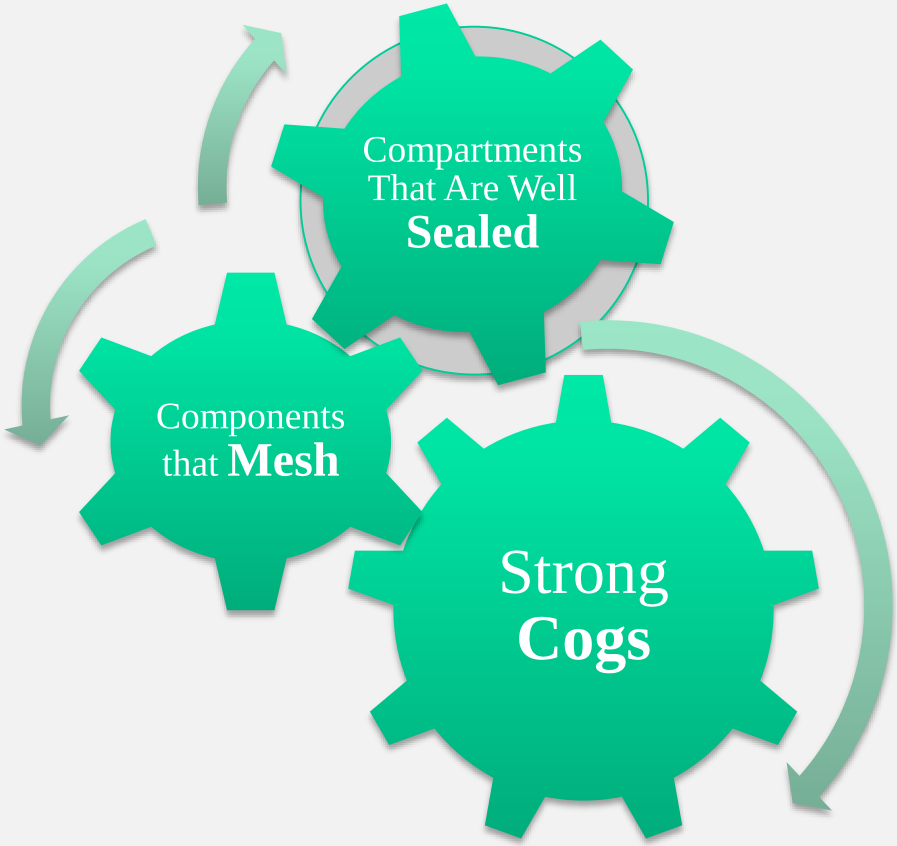
The Fertilizer Institute
Nourish, Replenish, Grow

FERTILIZER CANADA

IPNI
INTERNATIONAL PLANT NUTRITION INSTITUTE

International Fertilizer Industry Association

The Nutrient Management Gearbox

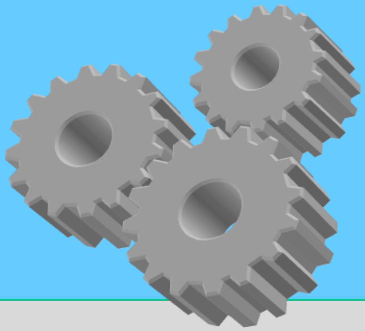


Output is Efficient Cycling of Nutrients!!

Cogs

- Cropping System: crop selection, rotation
- Soil Management: tillage, residue
- Nutrient Application: placement, rate, source, time

Mesh



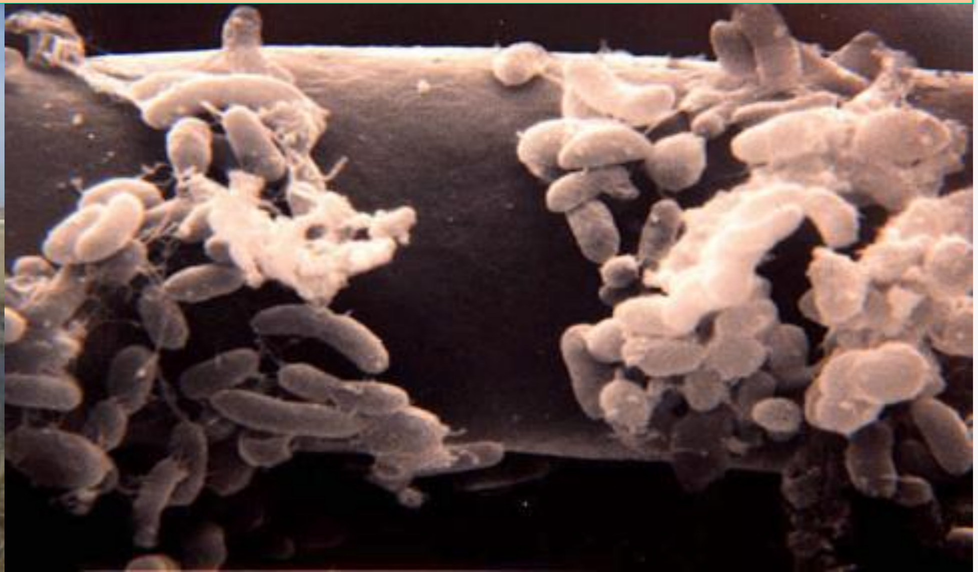
- Perennial-Annual
- Livestock-Crop
- Manure-Fertilizer






Sealing and Cycling

- Mitigating P, N losses in water through 4R
- Reducing gaseous N fluxes to air
- Promoting internal cycling, biological activity



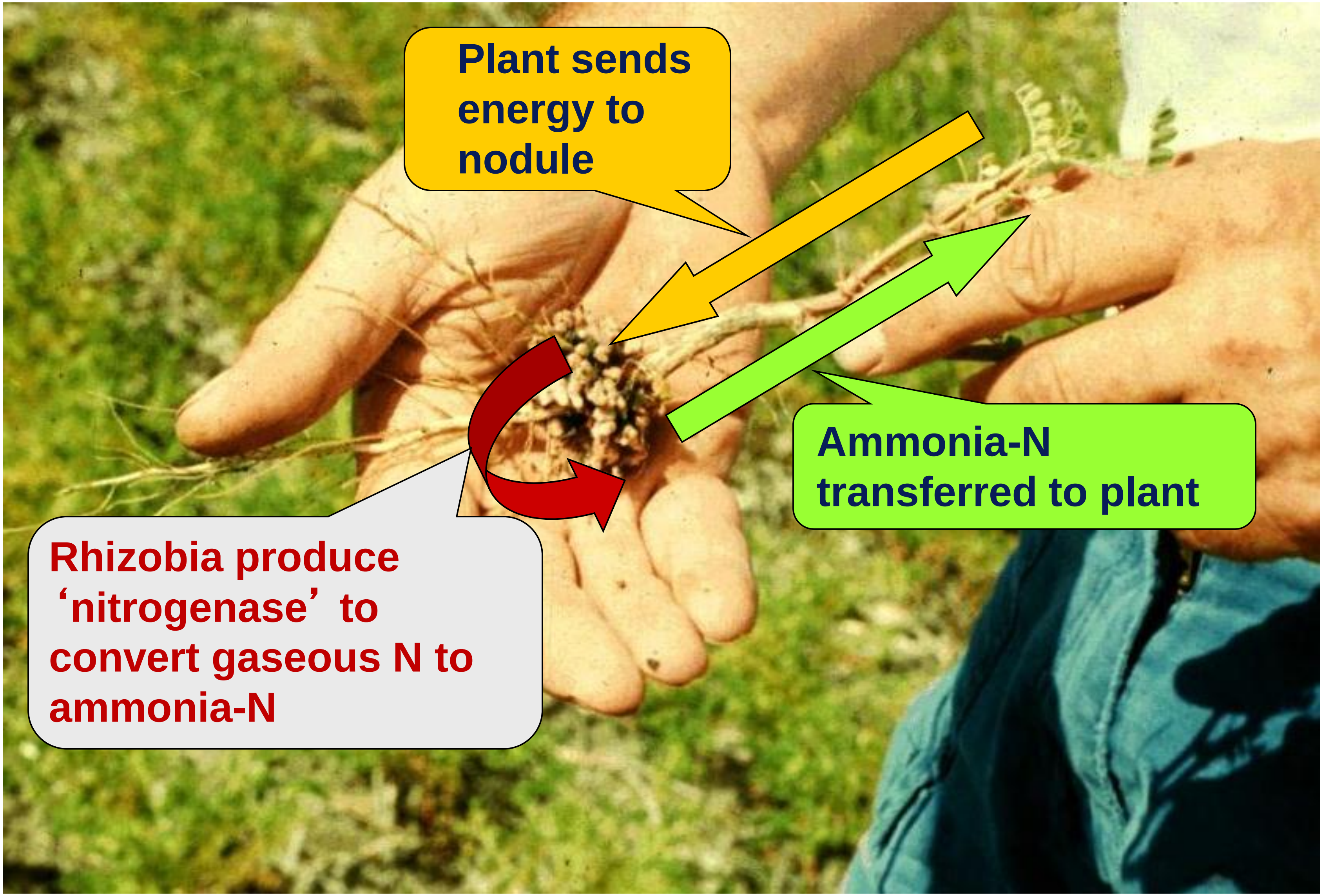
We need to manage, maintain our nutrient gearbox!

One example each of cog, mesh, and sealing management!

- **Cog:** Cropping system: legumes in rotation
- **Mesh:** Manure-fertilizer synergies
- **Sealing:** Placement of fertilizer phosphorus

Cog: Cropping System/Rotation

Nitrogen Fixation by Legumes (Courtesy Dr. F. Walley)



Amount of N fixed in Western Canada

	lbs N / acre
Alfalfa	**100 - 250**
Fababean	**80 - 160**
Pea	**50 - 150**
Soybean	**70 - 100**
Lentil	**30 - 120**
Dry Bean	**5 – 70**

- Forage legumes fix more N than grain legumes
- N fixation has significant $ value
- Actual amount depends on inoculation/nodulation, environmental conditions, soil available N and other nutrients like P.

N Fertilizer Replacement Value of Growing a Legume:

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

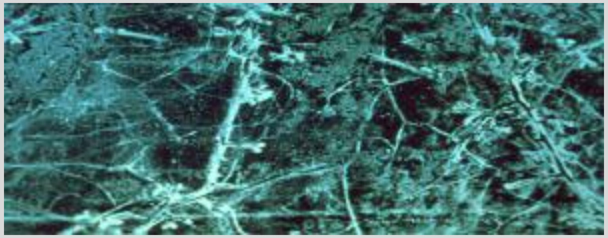
Reflects effect of N benefit and non-N benefit.

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.

Indirect Benefits

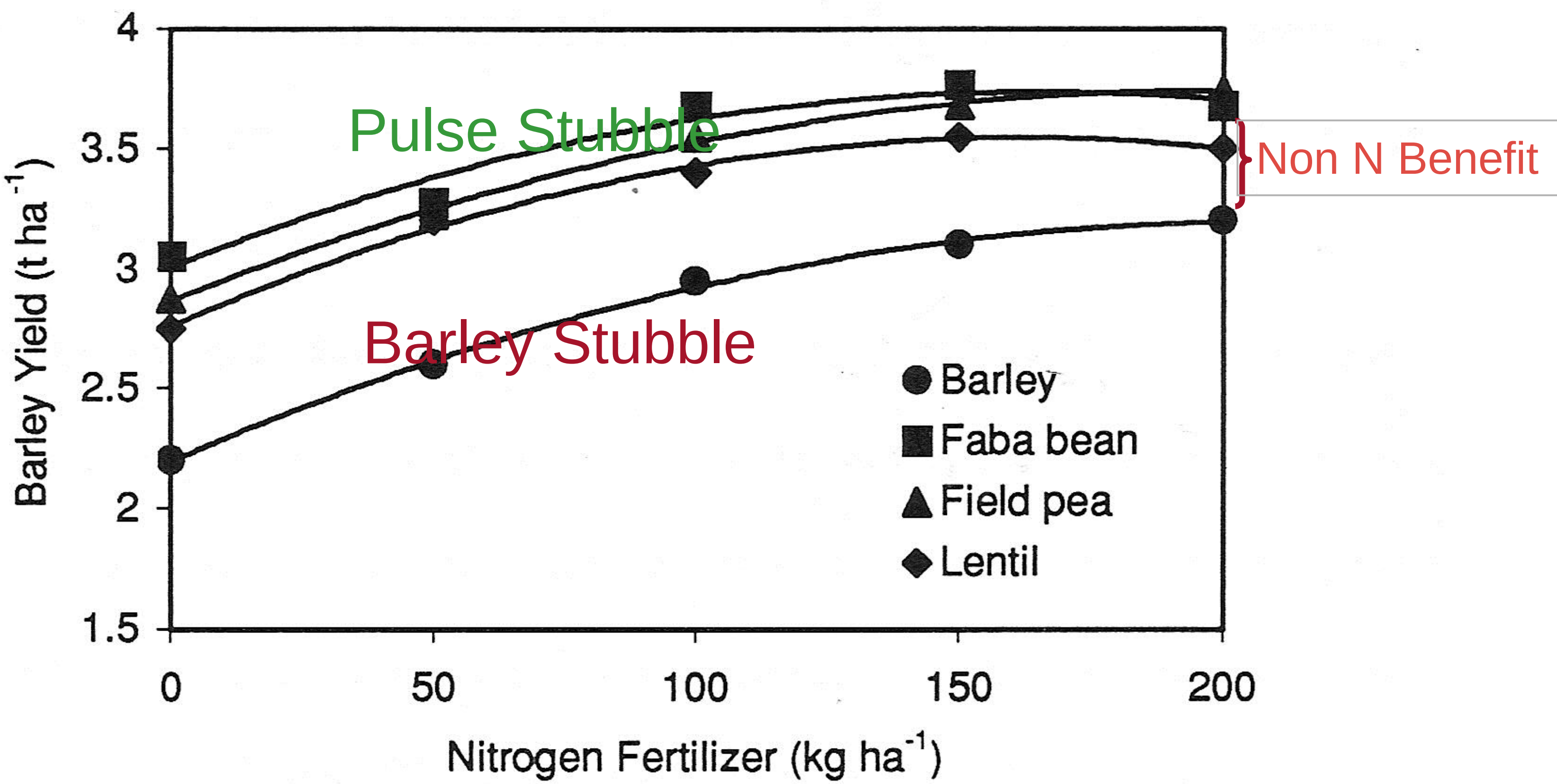
Plant growth, nutrient uptake on legume stubble is often enhanced by a greater amount than what can be explained by the nutrient in the stubble itself.



- – Better conditions for root growth
- – Stimulated biological activity

The Magic of Legumes!
Improved Soil Health

Barley Yield Response to Added N Fertilizer



From Wright 1990 at Melfort SK

Phosphorus mobilization by legumes

- Rhizosphere acidification or alkalization
- Phosphate releasing enzymes
- Morphological root traits
- Symbiotic relationship with arbuscular mycorrhizal fungi

that can also increase this beneficial symbiosis in following crops:

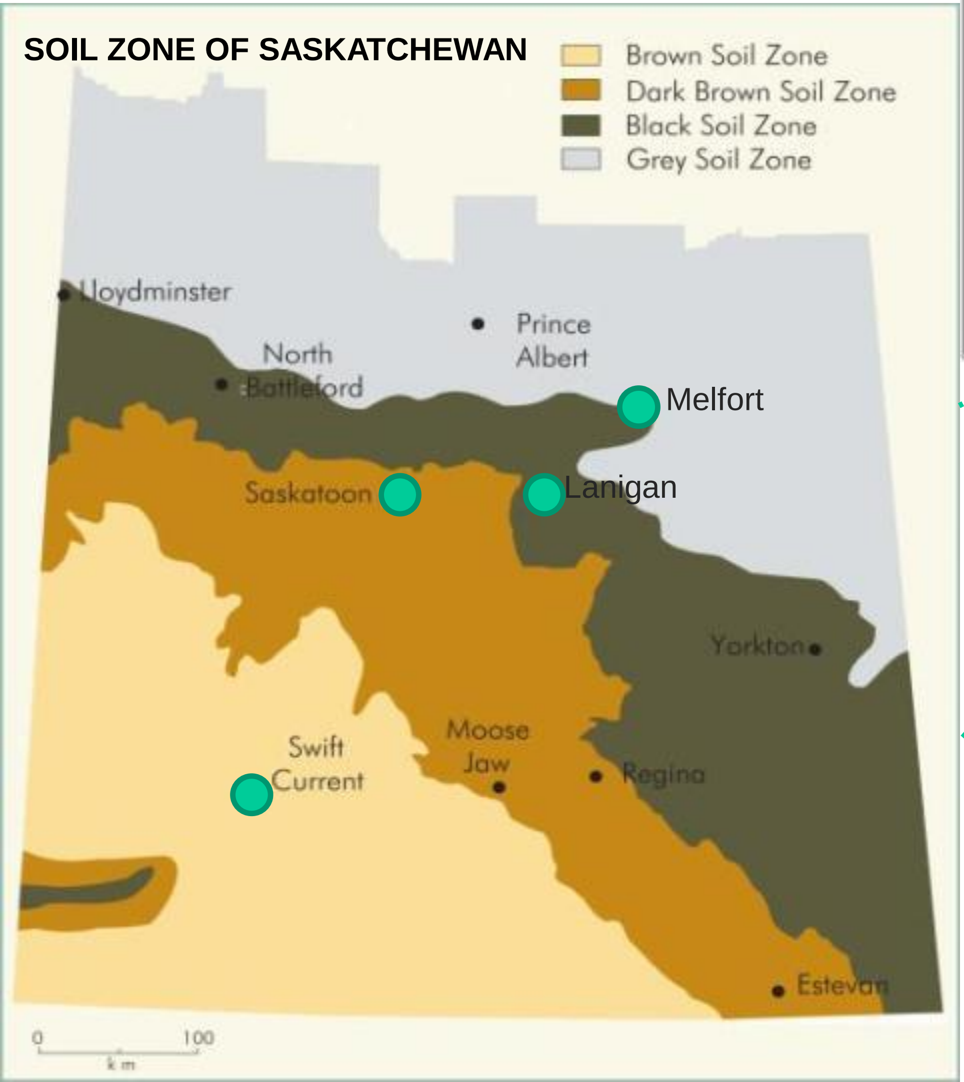
- Forage legumes have deep rooting systems, can extend into calcareous subsoils and mobilize insoluble native P reserves at depth, bring to surface for recycling.

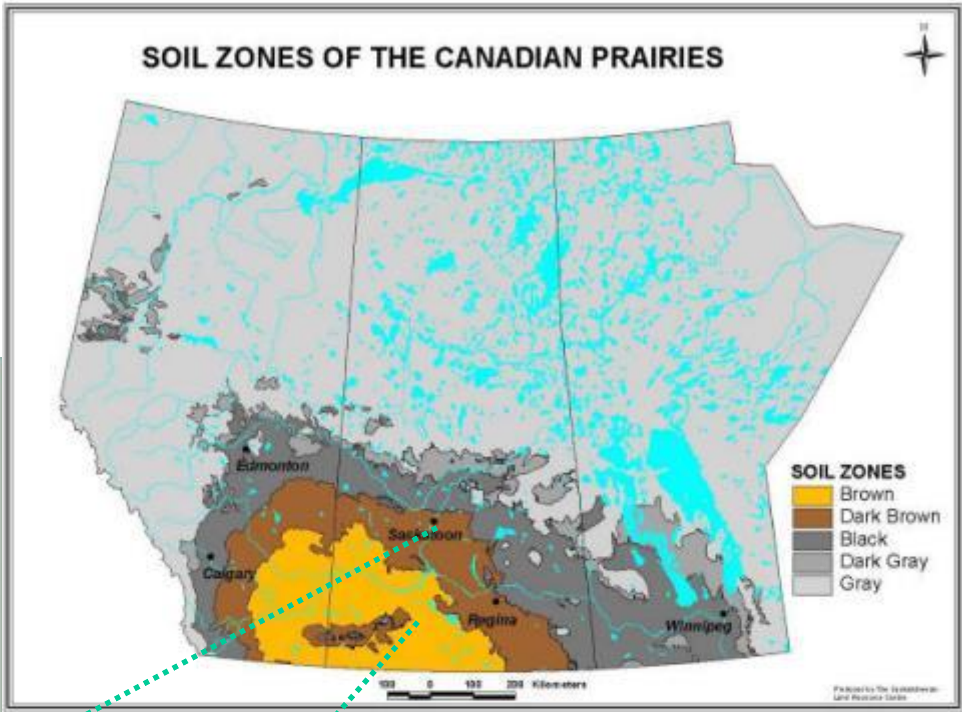
Short Rotation Forage Legumes

- Couple years of forage legume (e.g. alfalfa or clover) followed by annual crops (e.g. cereal, oilseed).
- Forage legumes fix N for themselves that also becomes available for following crop.
- Effects on P less well documented.

Study by Rehmut, Jefferson, Schoenau, 2010-2013

Experimental sites





From Canadian Plains Research Centre Mapping Division.

Crop rotation treatments:

	2010	2011	2012	2013
1	Alfalfa	Alfalfa	Wheat	Canola
2	Red Clover	Red Clover	Wheat	Canola
3	Barley1	Pea	Wheat	Canola
4	Barley2	Flax	Wheat	Canola

4 Rotations compared:

1) Alfalfa-Alfalfa-Wheat-Canola
2) Red Clover- Red Clover- Wheat-Canola
3) Barley-Pea-Wheat-Canola
4) Barley-Flax-Wheat -Canola

N Fertilizer Replacement Value calculated from 2012 wheat yield response

Sites	A-A	RC-RC	B-P
	--------	(kg N ha^{-1})	--------
Saskatoon	75	100	29
Lanigan	103	172	167
Swift Current	n.d.	n.d.	n.d.
Melfort	317	236	179

- Nitrogen fertilizer equivalent of forage legume greatest in Black soil zone site.
- Combo of direct N benefit and **non-N benefit effects**. **No large effect on soil N or crop N uptake**.
- Similar trend observed for 2013 canola but NFR values less.

P removal (kg P/ha) by crops in rotation over two years (2010+2011)

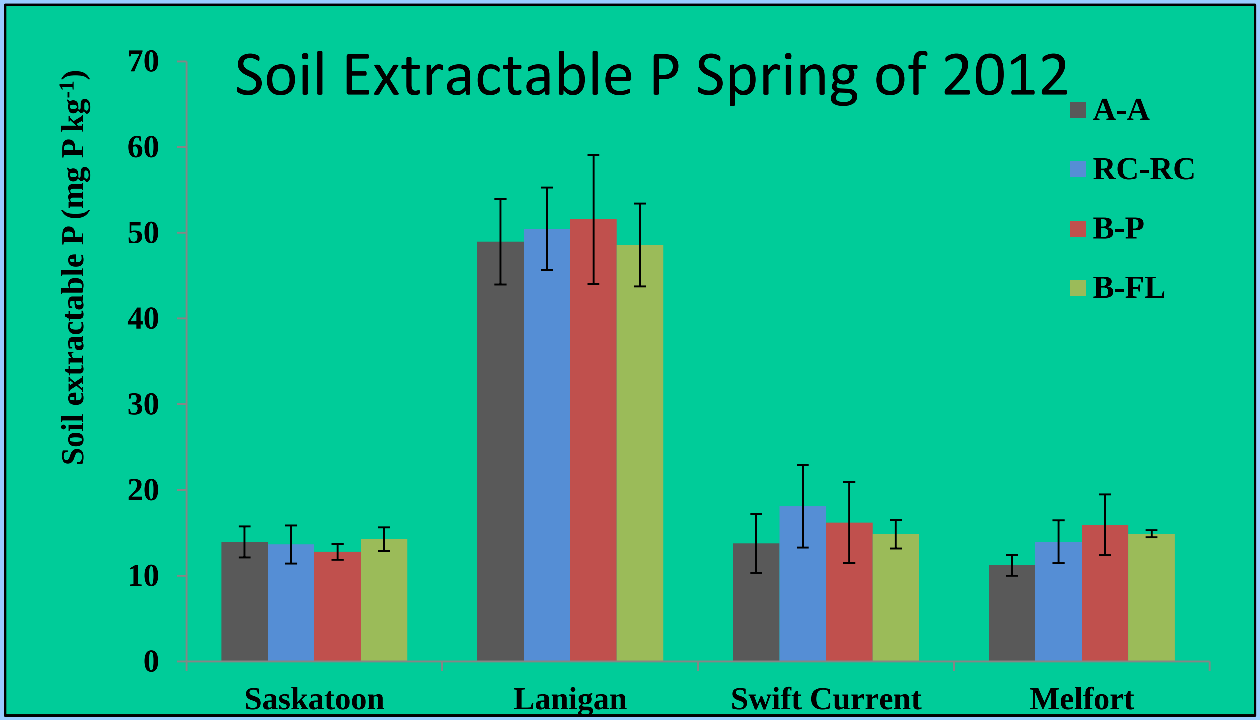
Sites	A-A†	RC-RC	B-P	B-FL
	-------------	(kg P ha^{-1})	---------------	
Saskatoon	30.2[a] §	25.0[a]	6.6[b]	9.6[b]
Lanigan	34.6[a]	25.0[b]	11.0[c]	10.5[c]
Swift Current	15.0[a]	10.3[b]	6.1[c]	5.8[c]
Melfort	19.0[a]	19.0[a]	15.8[a]	19.6[a]

† A-A is alfalfa-alfalfa; RC-RC is red clover-red clover; B-P is barley-pea; B-FL is barley-flax.

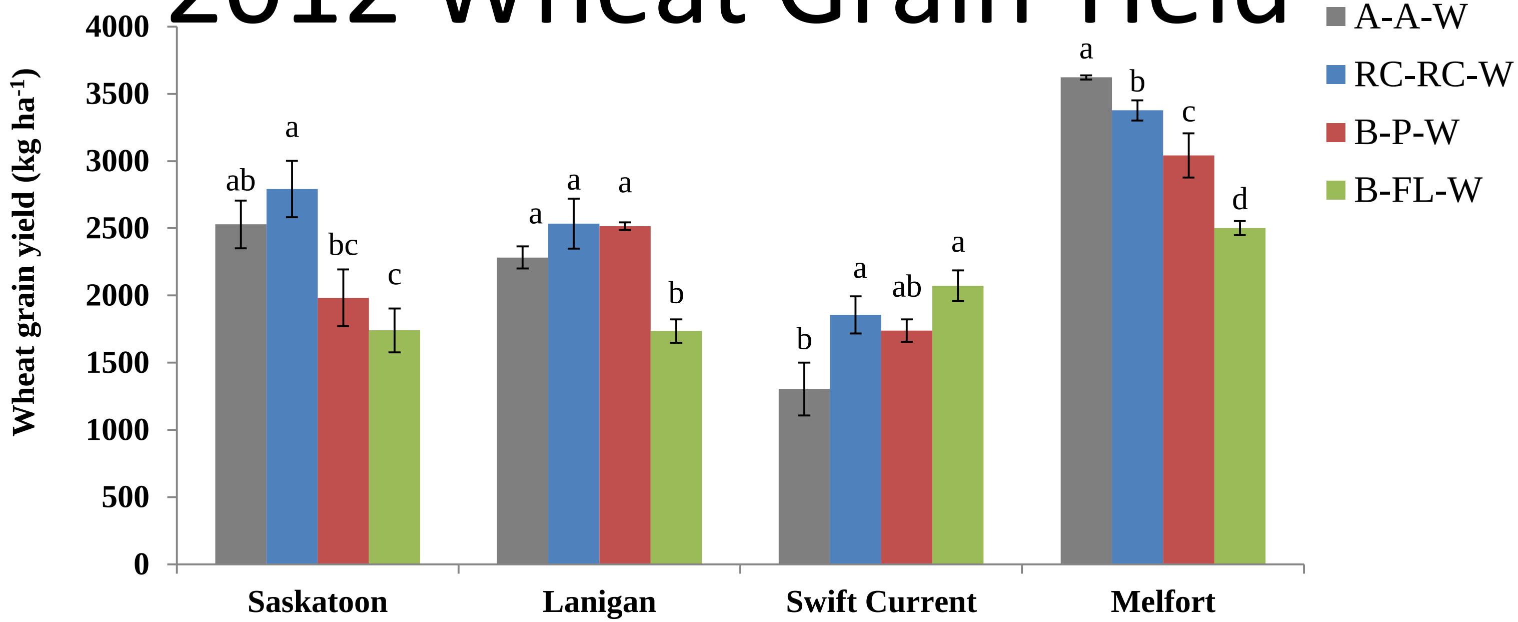
Impacts on Phosphorus Fertility

- Two years of alfalfa and red clover took up greater amounts of P from the soil relative to barley-pea and barley-flax, especially in the second year.

But no significant reduction in soil available P

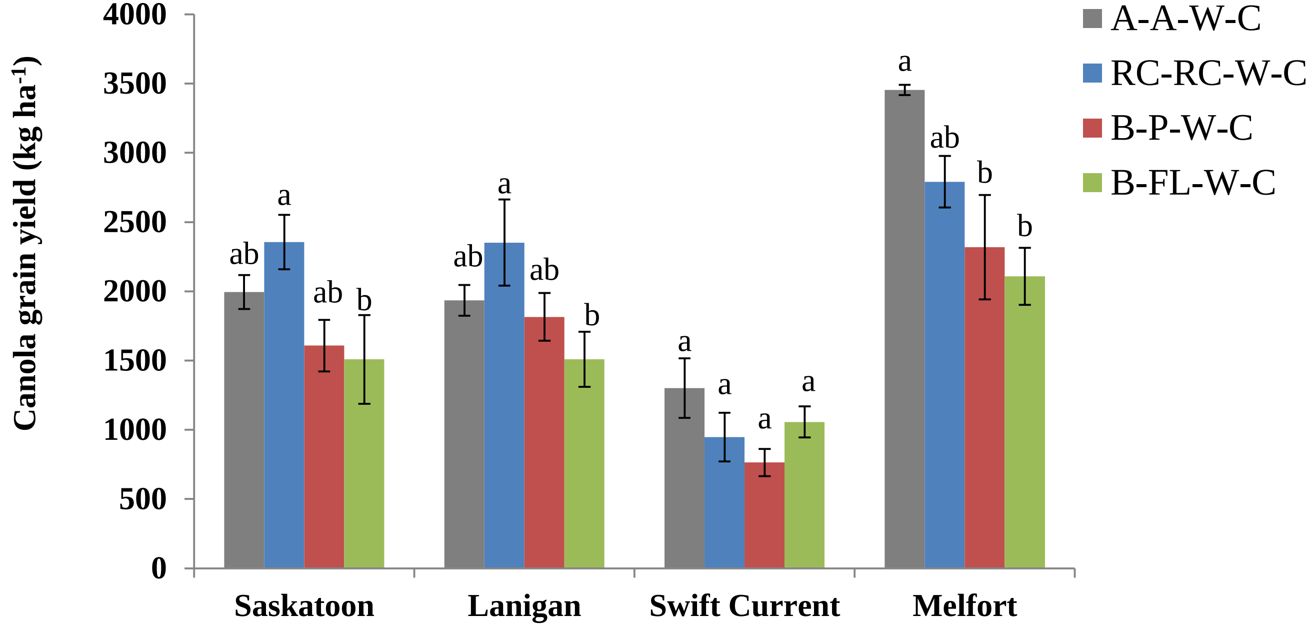


2012 Wheat Grain Yield

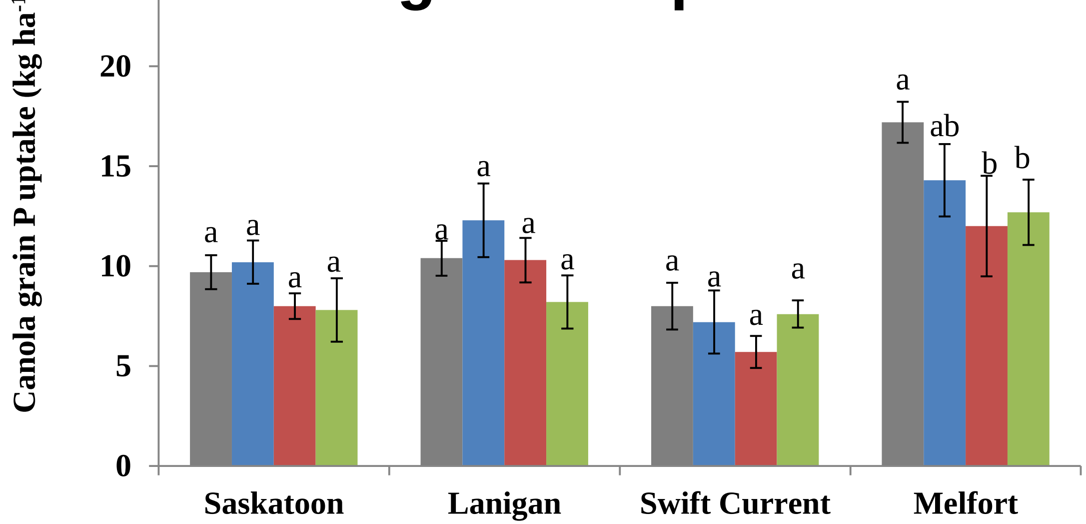


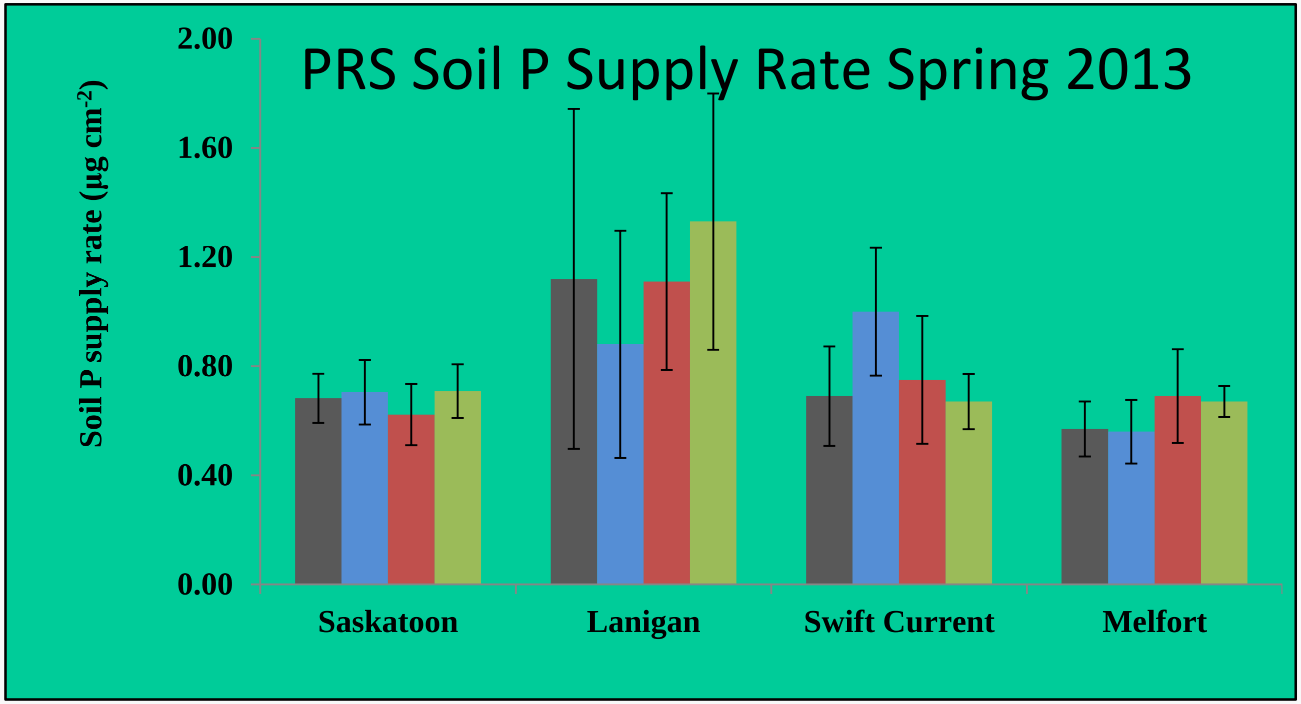
- Wheat on legume stubble, especially alfalfa and red clover, yielded significantly higher at three of four sites.
- At Swift Current, alfalfa dried out soil profile.

2013 Canola grain yield



2013 Canola grain P uptake and removal





- Maintenance of soil available P levels, despite greater crop removal of P, reflects <u>ability of legume to mobilize soil P</u>.

Crop P balance over a four-year rotational cycle

Site	Treatment	Fertilizer P applied	P removed in biomass	P balance‡
		---------------------- (kg P ha^{-1})	----------------------	
Saskatoon	A-A-W-C†	6.6	49.4[a §]	**-42.8[b]**
	RC-RC-W-C	6.6	43.2[a]	**-36.6[b]**
	B-P-W-C	6.6	22.1[b]	**-15.5[a]**
	B-FL-W-C	6.6	24.7[b]	**-18.1[a]**
Lanigan	A-A-W-C	6.6	54.5[a]	**-47.9[d]**
	RC-RC-W-C	6.6	48.3[b]	**-41.7[c]**
	B-P-W-C	6.6	22.9[c]	**-16.4[b]**
	B-FL-W-C	6.6	17.0[d]	**-10.4[a]**
Swift Current	A-A-W-C	6.6	27.5[a]	**-21.0[b]**
	RC-RC-W-C	6.6	24.4[ab]	**-17.9[ab]**
	B-P-W-C	6.6	17.4[b]	**-10.9[a]**
	B-FL-W-C	6.6	18.0[b]	**-11.5[a]**
Melfort	A-A-W-C	6.6	52.3[a]	**-45.7[b]**
	RC-RC-W-C	6.6	48.7[ab]	**-42.2[ab]**
	B-P-W-C	6.6	43.5[b]	**-37.0[a]**
	B-FL-W-C	6.6	42.4[b]	**-35.8[a]**

Over long-term, forage legumes can deplete soil P through greater P removal in harvest.

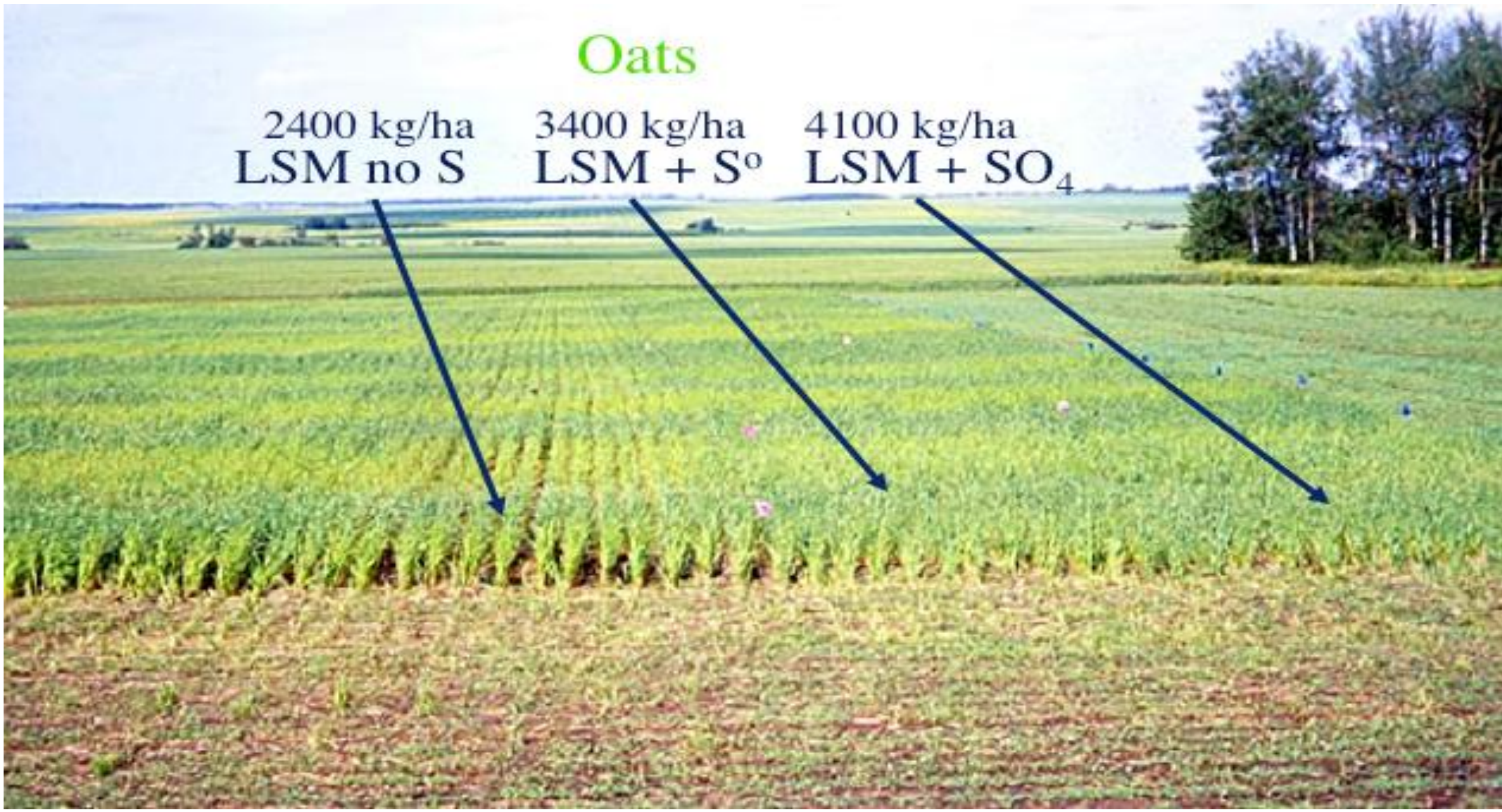
Summary of Findings

Forage legumes in rotation for a short time generate significant fertility benefits, reduce fertilizer requirement:

Greater removal of P and other nutrients over longer term means depletion will eventually need to be addressed with fertilizer P and/or manure

Mesh: Manure – Fertilizer Synergies

Effect of Liquid Swine Manure and Urea Applied Without and With Supplemental Sulfur Fertilizer on S Deficient Gray Soil (Schoenau, King and Malhi, 2014)



Liquid Swine Manure:

Readily plant available nutrients, especially N, but may be low in S: Often high Available N: Available S ratio.

- A field trial near Melfort, Saskatchewan on a Dark Gray Chernozem in place since 1999 offers unique ability to examine **long-term effects** of application of **liquid swine manure**.
- Band - injected liquid swine manure **since 1999** in **Canola-Cereal** (barley or oat) crop rotation

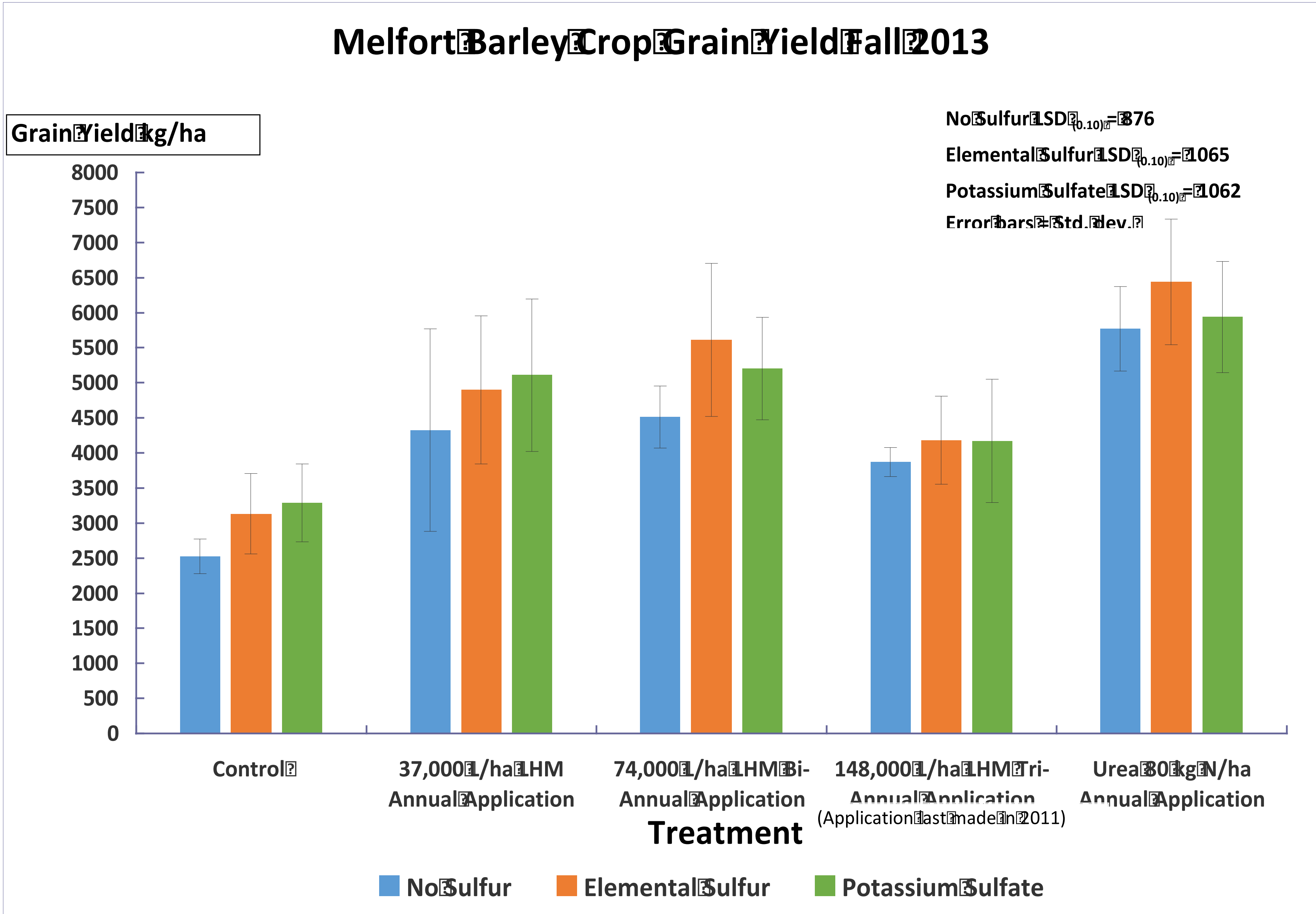
LSM Applications

1) Control (no manure or fertilizer)
2) 37,000 $l \cdot ha^{-1}$ every year (1X annually)
3) 74,000 $l \cdot ha^{-1}$ every 2nd year (2X every 2nd)
4) 111,000 $l \cdot ha^{-1}$ every 3rd year (3X every 3rd)
5) Urea at 80 kg N / ha every year

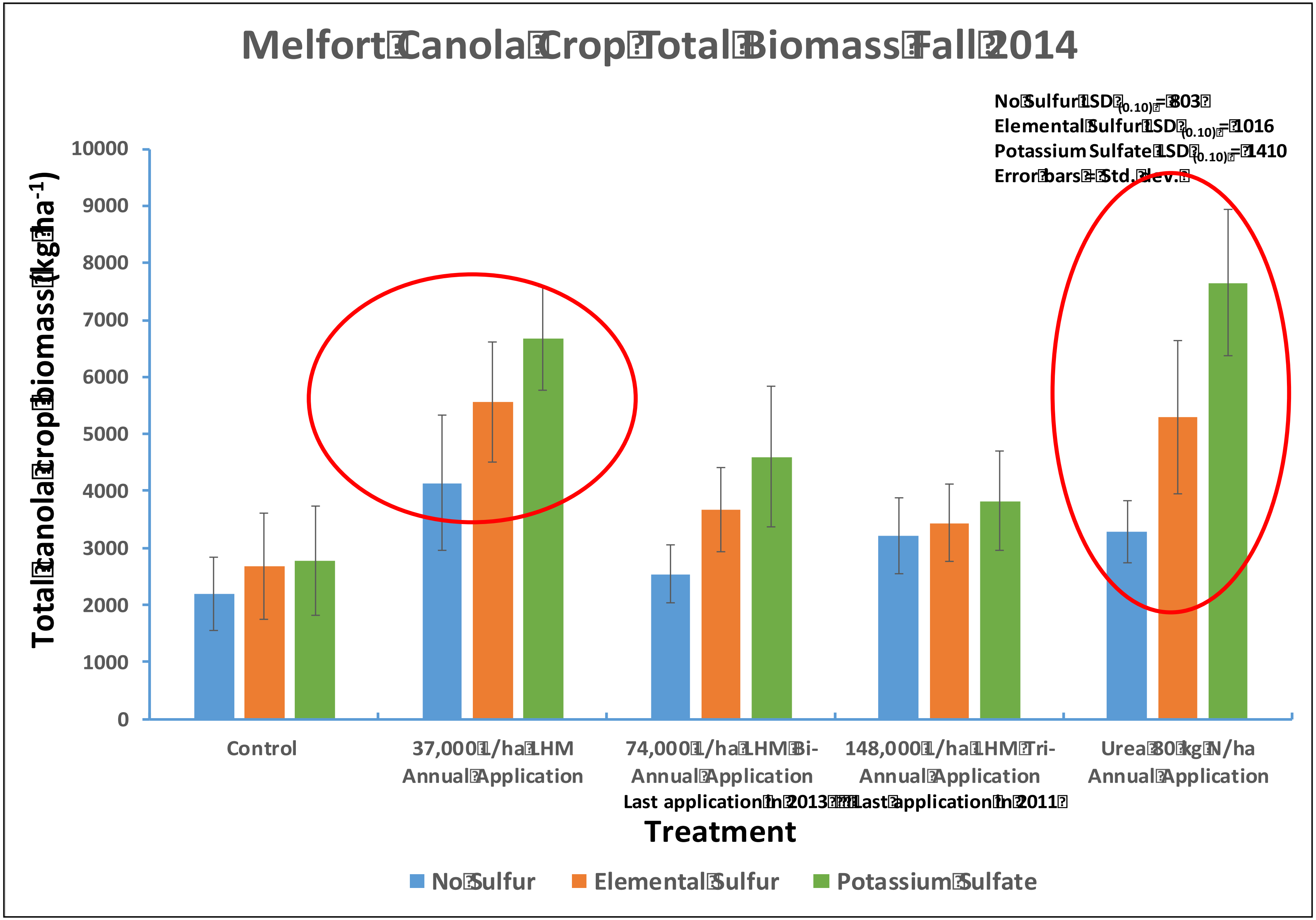
Soil is **prone to sulfur deficiency**, **LSM low in available S**

- so sub-plots of no supplemental S fertilizer versus S fertilizer

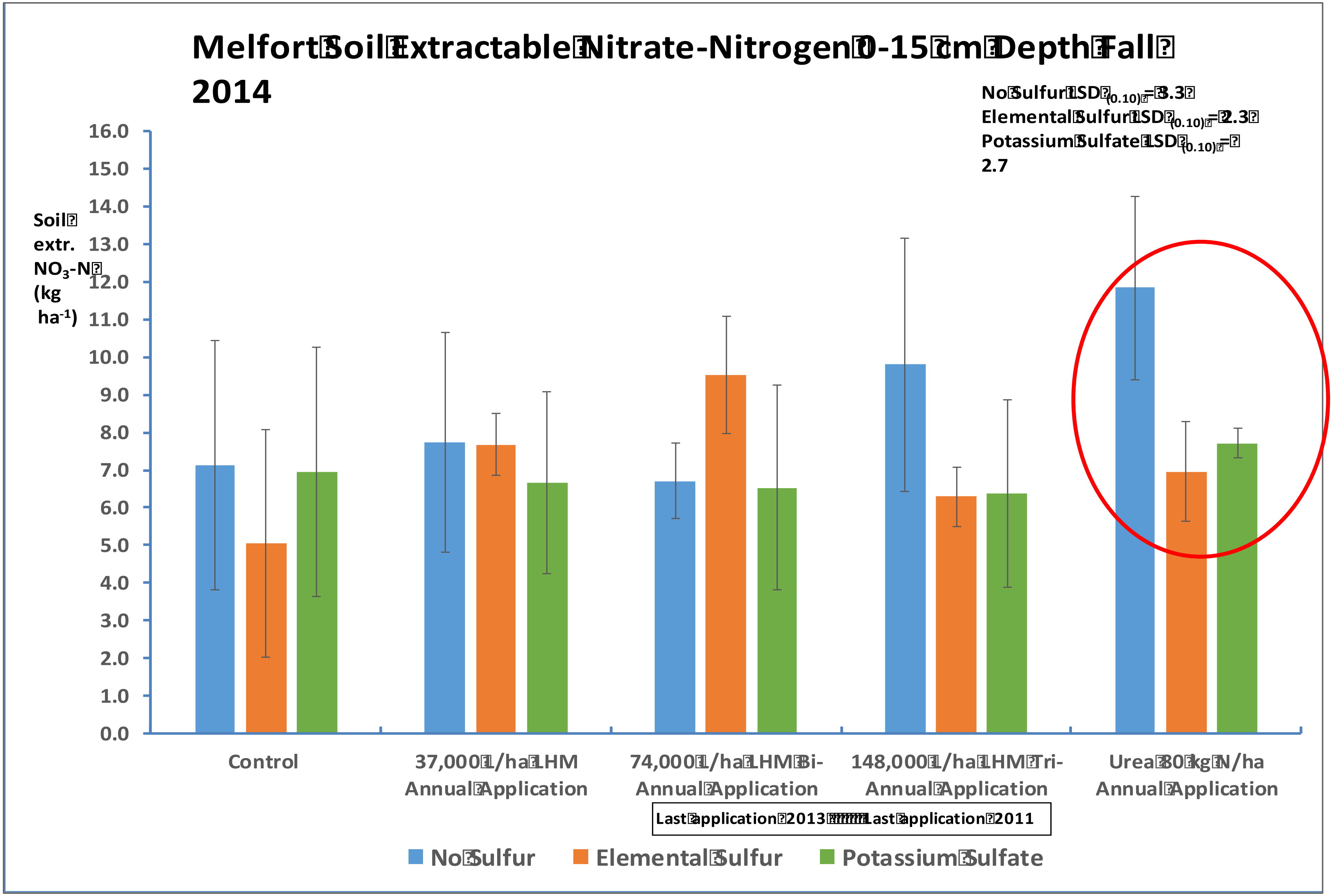
  S fertilizer: broadcast elemental S or potassium sulfate @ 40 kg S·ha^{-1} every third year



Melfort Barley Crop Grain Yield Fall 2013
Grain Yield kg/ha
No Sulfur LSD (0.10) = 876
Elemental Sulfur LSD (0.10) = 1065
Potassium Sulfate LSD (0.10) = 1062
Error bars = Std. dev.
8000
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Control
37,000 L/ha LHM Annual Application
74,000 L/ha LHM Bi-Annual Application
148,000 L/ha LHM Tri-Annual Application
(Application last made in 2011)
Urea 80 kg N/ha Annual Application
Treatment
No Sulfur
Elemental Sulfur
Potassium Sulfate

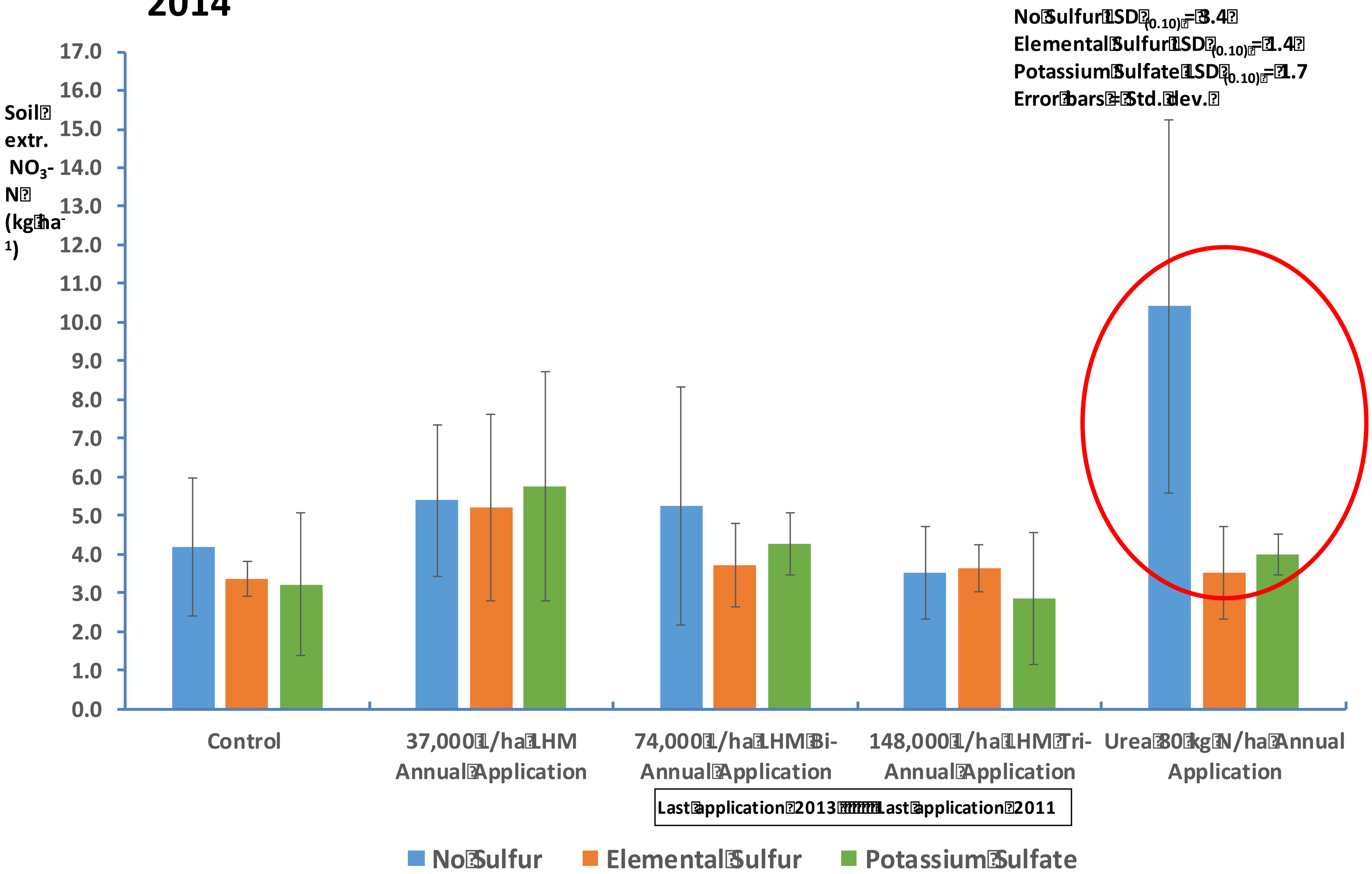


Melfort Canola Crop Total Biomass Fall 2014
No Sulfur LSD $_{(0.10)}$ = 803
Elemental Sulfur LSD $_{(0.10)}$ = 1016
Potassium Sulfate LSD $_{(0.10)}$ = 1410
Error bars = Std. dev.
Total canola crop biomass (kg ha^{-1})
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Control
37,000 L/ha LHM Annual Application
74,000 L/ha LHM Bi-Annual Application
Last application in 2013
148,000 L/ha LHM Tri-Annual Application
Last application in 2011
Urea 80 kg N/ha Annual Application
Treatment
No Sulfur
Elemental Sulfur
Potassium Sulfate



Melfort Soil Extractable Nitrate-Nitrogen 0-15 cm Depth Fall 2014
No Sulfur LSD $_{(0.10)}$ = 3.3
Elemental Sulfur LSD $_{(0.10)}$ = 2.3
Potassium Sulfate LSD $_{(0.10)}$ = 2.7
Soil extr. NO_3-N (kg ha^{-1})
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Control
37,000 L/ha LHM Annual Application
74,000 L/ha LHM Bi-Annual Application
148,000 L/ha LHM Tri-Annual Application
Urea 30 kg N/ha Annual Application
Last application 2013 Last application 2011
No Sulfur
Elemental Sulfur
Potassium Sulfate

Melfort Soil Extractable Nitrate-Nitrogen 90-120 cm Depth Fall 2014



Summary of Findings

Best crop yield, utilization of manure N, lowest residual nitrate when supplemental S fertilizer added to ensure appropriate N:S balance for canola.

Very evident for urea and also sometimes for LSM.

Sealing: The Importance of Phosphorus Fertilizer **Placement**

A Field Study of the Effect of Fertilizer P (11-52-0) Application Method on Soybean
(Blake Weiseth MSc U of S 2015)

Treatments

C 1) No P fertilizer

SP 2) Seed placed P at 20 kg P_2O_5 ha^{-1}

DB 3) Banded P below seed at 20 kg P_2O_5 ha^{-1}

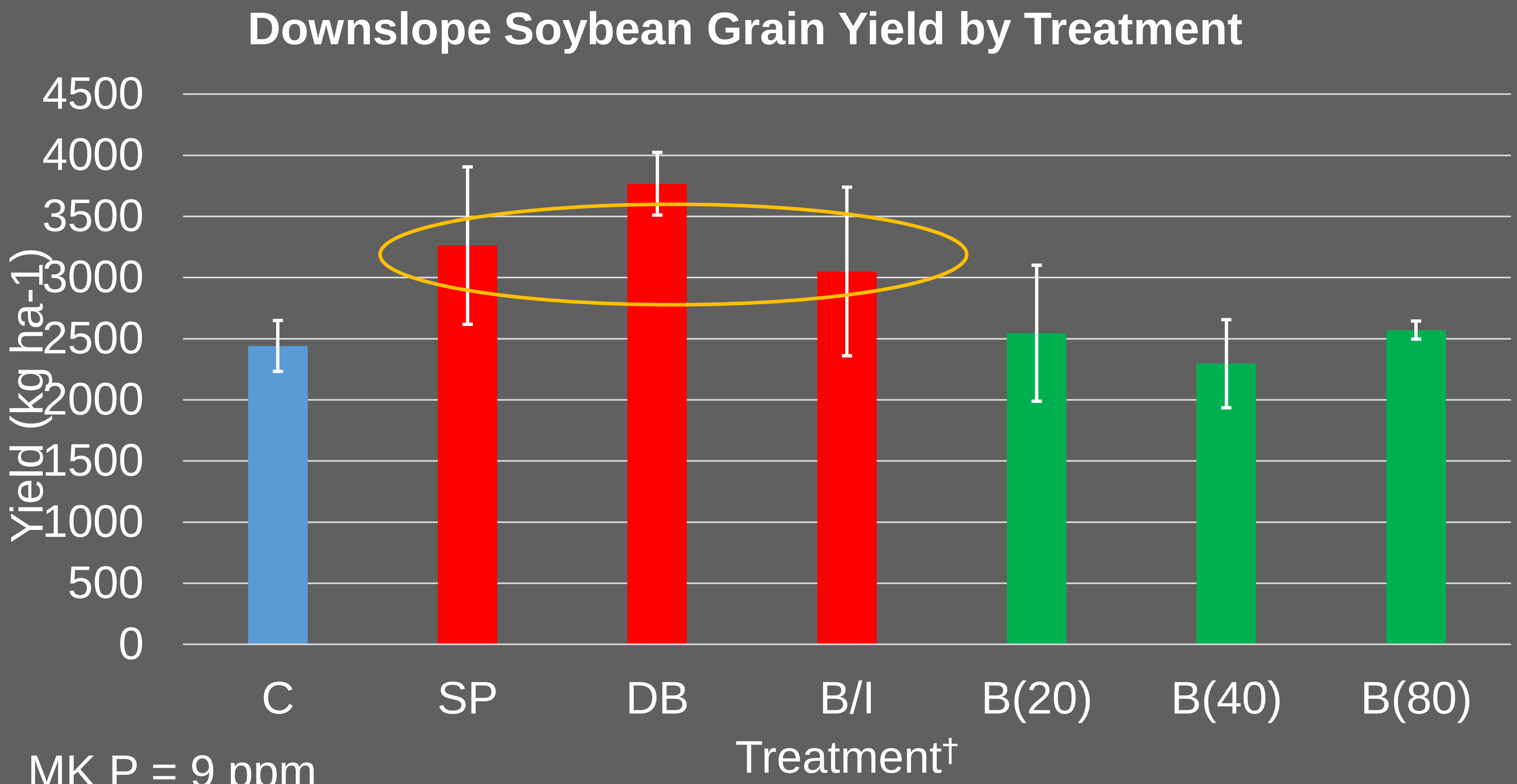
B/I 4) Broadcast P at 20 kg P_2O_5 ha^{-1} with incorporation;

B(20) 5) Broadcast P at 20 kg P_2O_5 ha^{-1} without incorporation;

B(40) 6) Broadcast P at 40 kg P_2O_5 ha^{-1} without incorporation;

B(80) And 7) Broadcast P at 80 kg P_2O_5 ha^{-1} without incorporation.

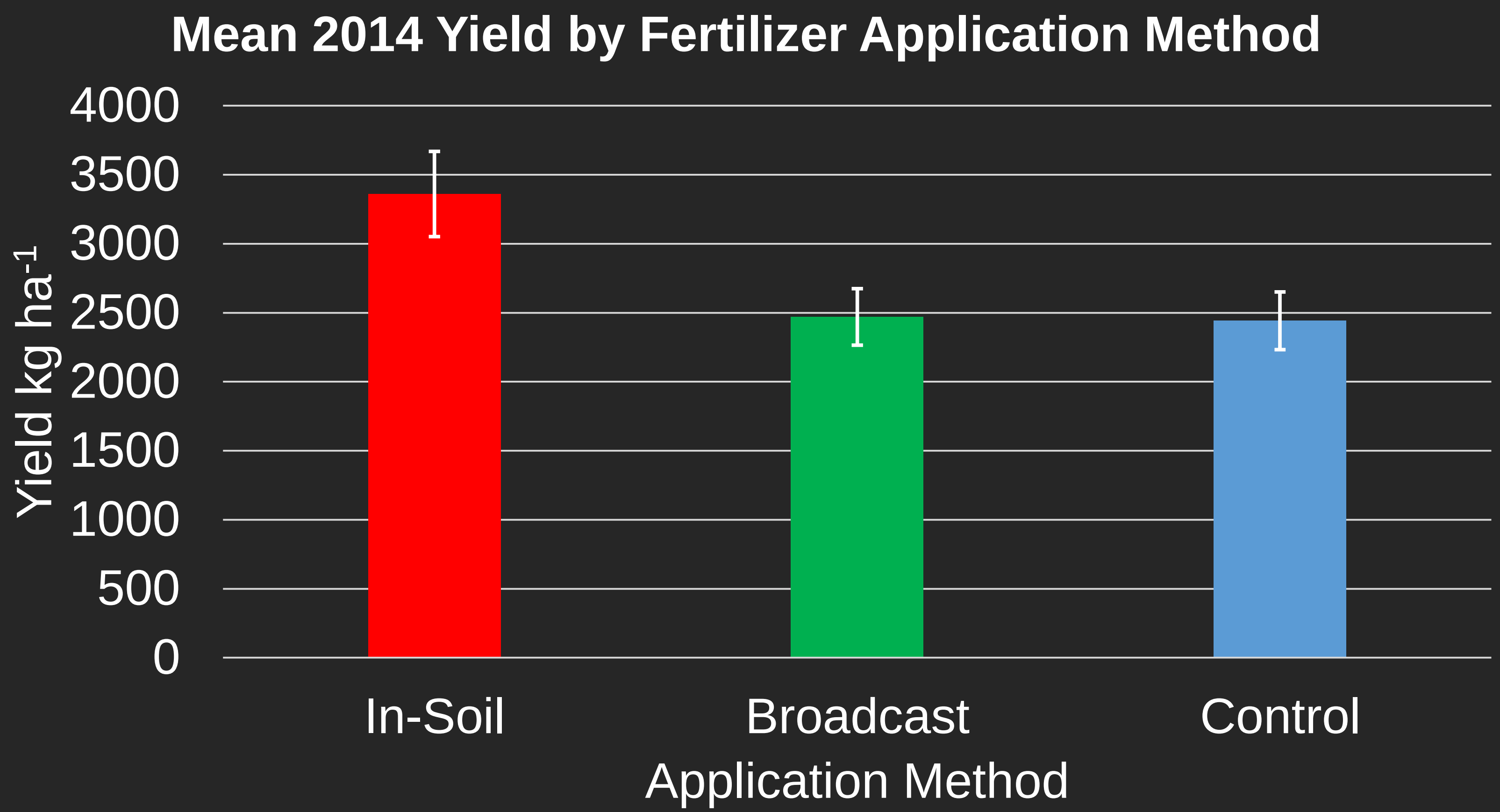
Results



MK P = 9 ppm

†A description the of the treatments is as follows: C: Control (no P); SP: Seed-placed (20 kg P_2O_5 ha^{-1}); DB: Deep band (20 kg P_2O_5 ha^{-1}); B/I: Broadcast with incorporation (20 kg P_2O_5 ha^{-1}); B(20): Broadcast (20 kg P_2O_5 ha^{-1}); B(40): Broadcast (40 kg P_2O_5 ha^{-1}); and B(80): Broadcast (80 kg P_2O_5 ha^{-1}).

Results



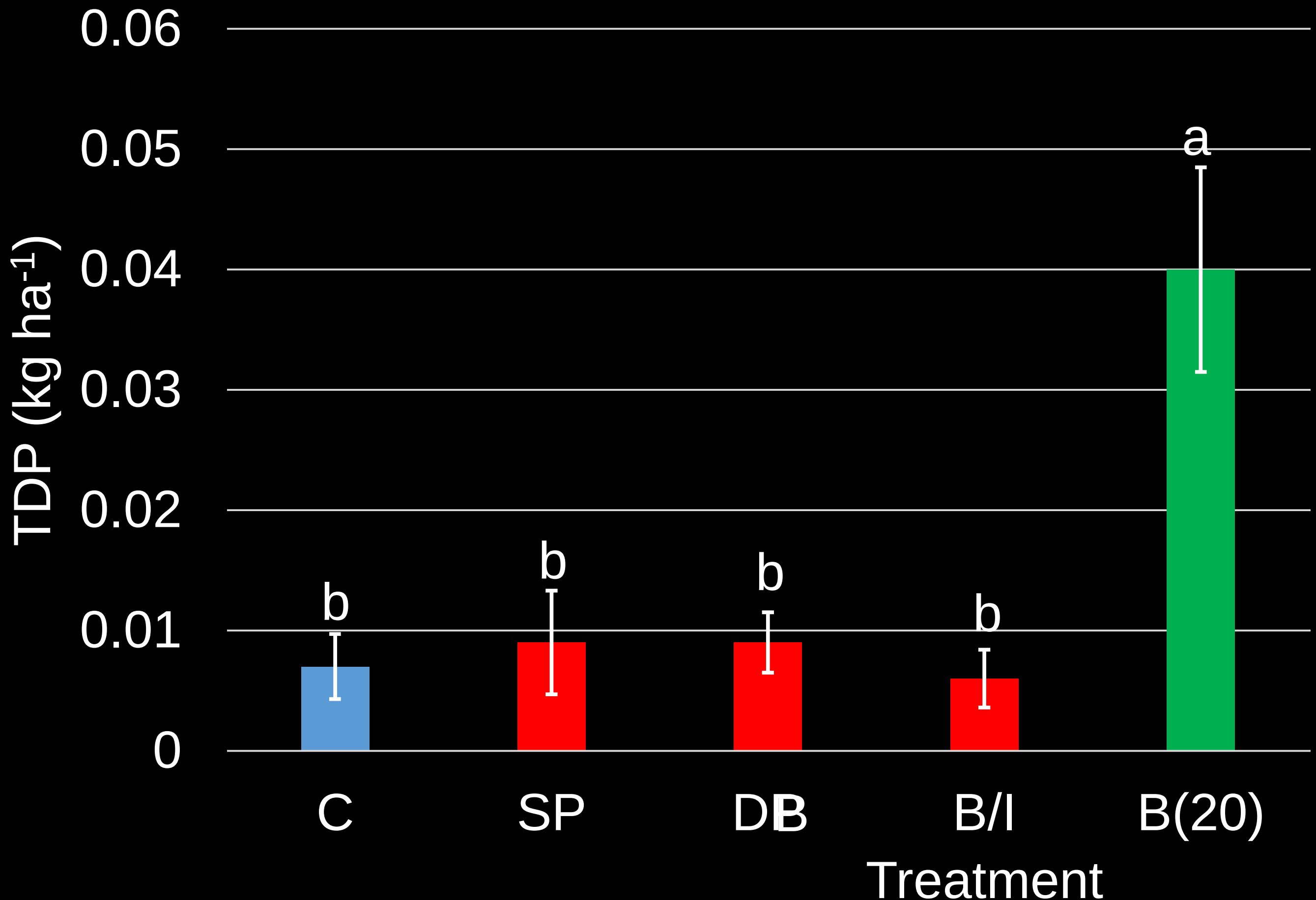
In-soil P placement superior to broadcast in increasing crop P fertilizer recovery and crop yield.

What about P movement off-site in run-off?

Thin Section Slab Collection

(Dept. of Soil Science, University of Saskatchewan)

Mean Total Dissolved P Export in Snowmelt by Treatment



In-soil placement prevents P fertilizer loss in run-off water

p=0.03

Summary

In-soil placement enhances effectiveness of P fertilizer and limits movement off-site in run-off.

The Future

- Rate: *More robust variable rate prescriptions*
- Source: *New enhanced efficiency products, novel combinations of organic/inorganic, nanofertilizers*
- Timing, Placement *More pre-plant and post-plant to spread workload, more interest in broadcasting, strategic tillage. Operational versus Biological Efficiency*
- *4R Certification of Farms on the Prairies*

Will Keep The Nutrient Management Gearbox Churning and Turning!

Thank you for your attention!