# To Micro or Not to Micro?

## *Update on Micronutrient Deficiencies and Responses in Prairie Soils*

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# Micronutrients

- Elements <u>required in very small amounts</u>, but <u>still essential</u>. No less important in plant nutrition than N, P, K or S. !

- Micro’s of interest for Western Canada include:

***Copper (Cu), Zinc (Zn), Boron (B) Manganese (Mn), Iron (Fe), Chlorine (Cl)***

# Micronutrients are rather “mysterious” by nature!

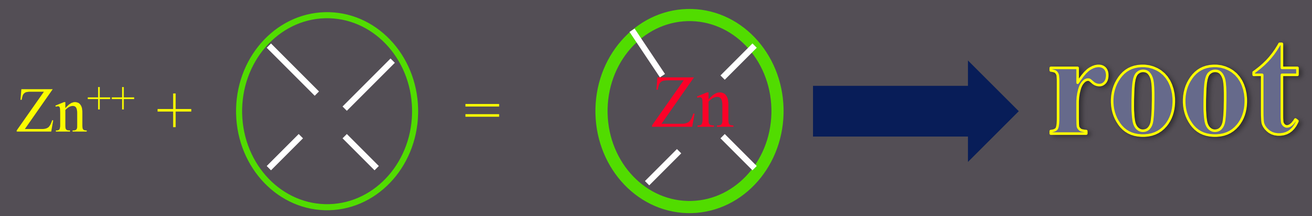

- Deficiency may appear, then disappear. Symptoms easily confused with other forms of stress.
- Unique combinations of soil, environmental and crop conditions often needed for deficiency to show up.
- Difficult to conclusively diagnose and predict responses.
- Responses often small, fleeting, variable.

# *A bit of biochemistry:*
# Plant absorption of micronutrients

- **Micro metals: copper, zinc, manganese, iron**

Absorbed by roots as **cations** (positively charged ions)

Get to roots as **chelates**: metal complexed with O.M.




*Chelates stay in solution, keeps them moving to roots.*

- **Boron** taken up as boric acid, **chlorine** as chloride anion.

  B and Cl are quite mobile in the soil.

- Uptake through roots, also foliage.

## *A bit of physiology:*
## Role of micronutrients in crop nutrition

COPPER, ZINC, MANGANESE, IRON

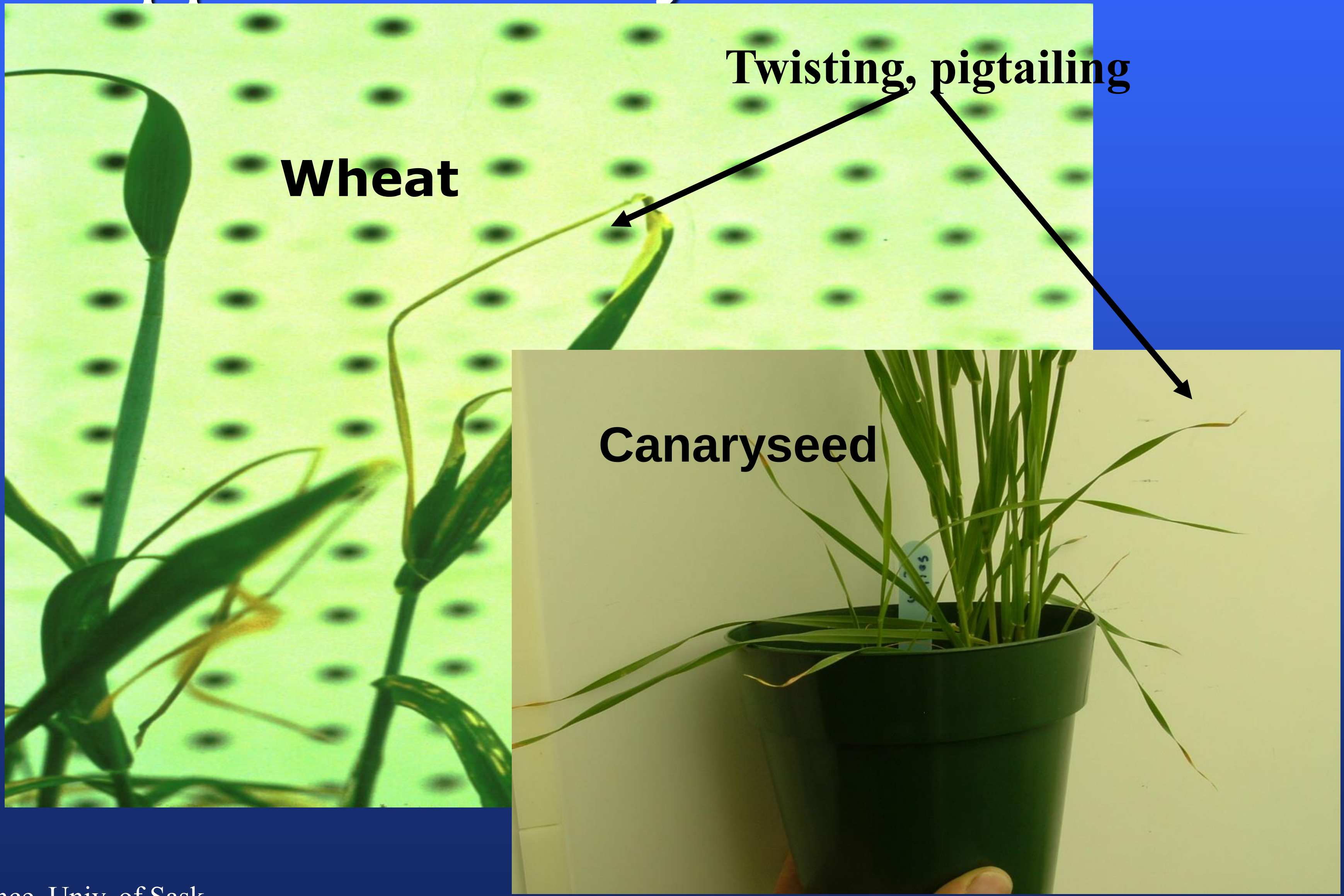
- Metals involved in photosythesis, enzymatic, hormonal functions in plant.
- Can also play roles in disease resistance.

  Example: Copper deficiency may aggravate ergot infections.

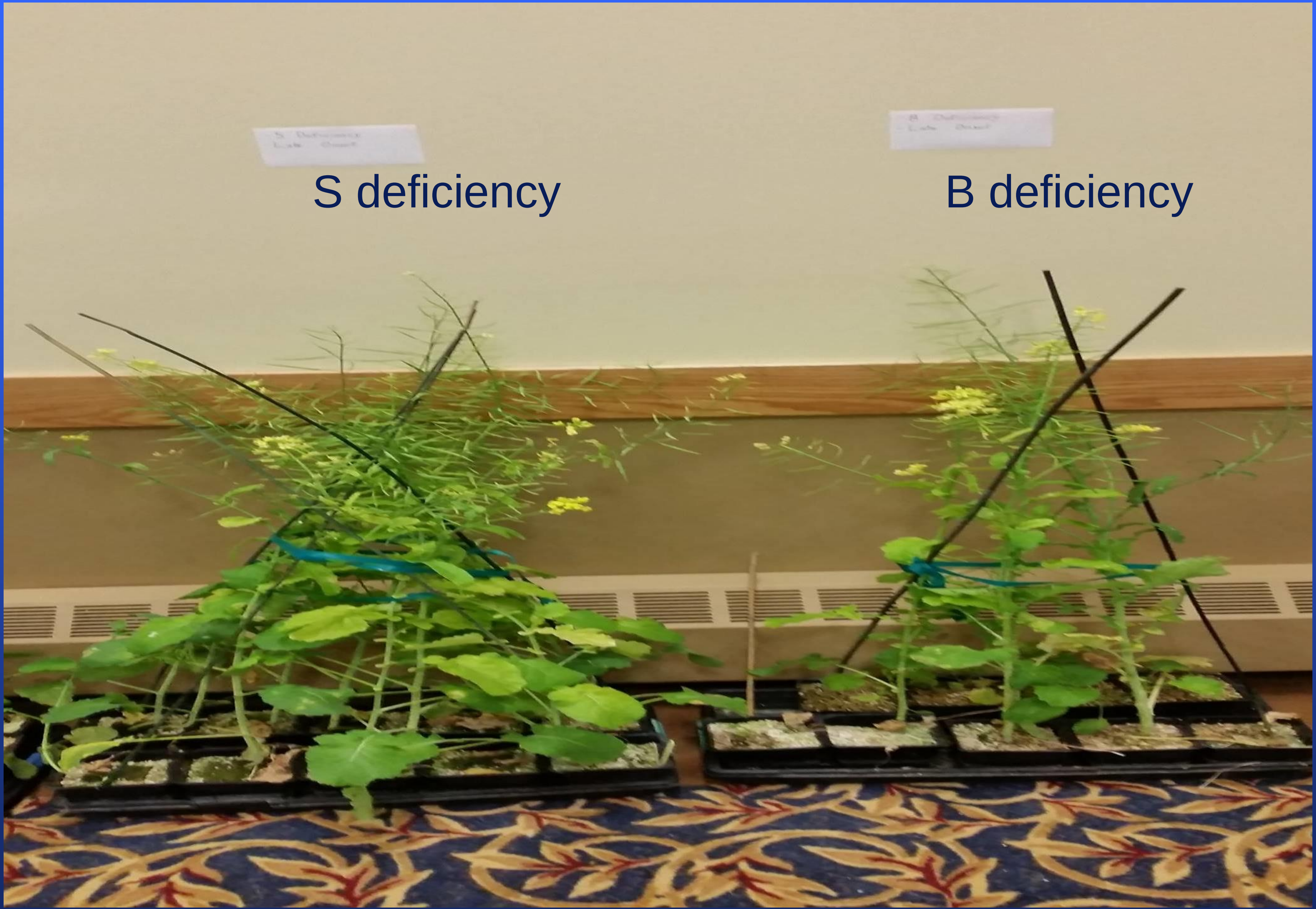
BORON:  Cell wall extension, division at growing points, especially affects reproduction ie pollination.

CHLORIDE: Charge balancing, osmotic relationships, cell turgor, resistance to root and leaf diseases

# Copper deficiency in cereals




Zn deficient wheat

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# Diagnosing Micronutrient Deficiencies

- Using visual inspection alone is risky, inconclusive.
- Soil and tissue testing are useful tools.
  - Micronutrient tests receive fair amount of criticism, debate

*But, as an attempt to measure biologically significant fraction, no better or worse than a lot of macro tests.*

- Must recognize that micronutrient availability can vary greatly across farm fields.

- Deficiencies tend to occur in patches, localized areas within a field: eroded knolls, sand, gravel lens.
- Sampling strategy must account for this.

**Know Where to Look!**

# Soil Conditions Contributing to Micronutrient Deficiencies

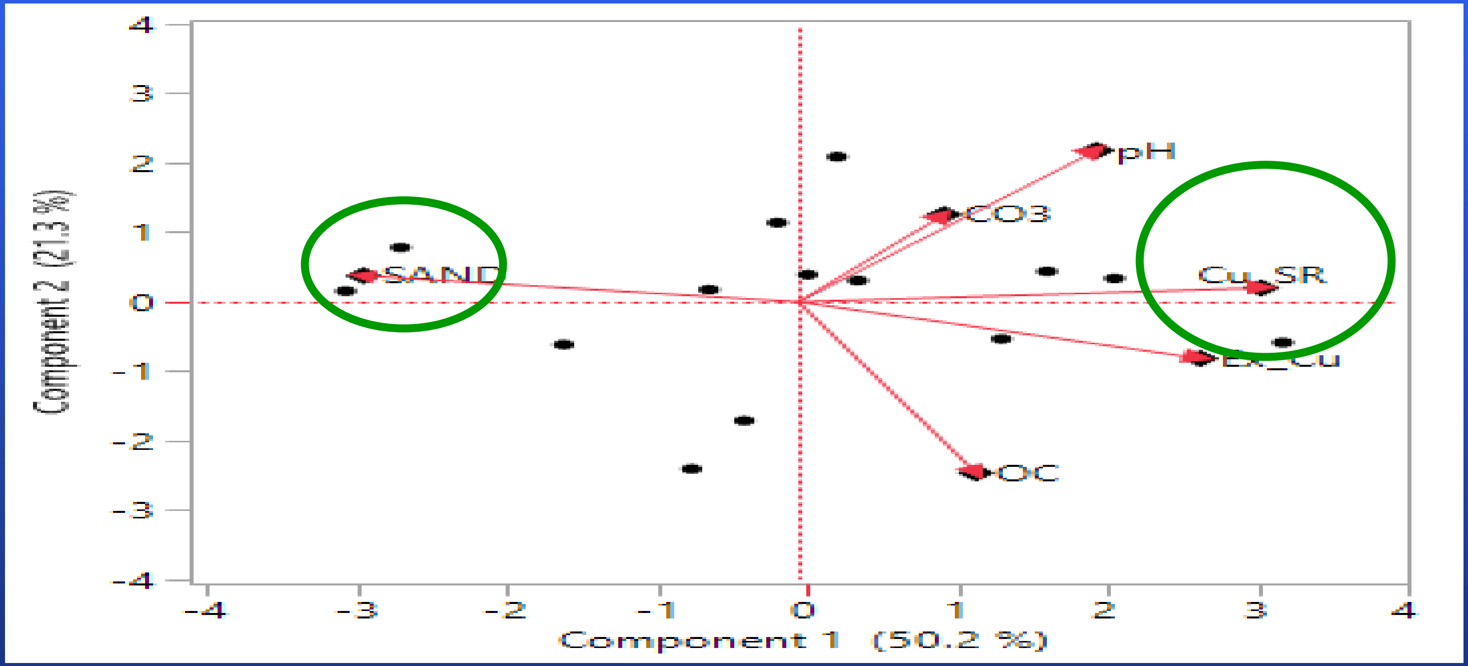
- **Sandy:**
  - low content of minerals capable of releasing micronutrients by weathering.

- **Calcareous (high lime content), high pH:**
  - will fix micros like Cu and Zn into insoluble forms.
- **Very low or very high O.M. content.**
  - low O.M. can contribute to low B availability. Peat soils can suffer from deficiency in Cu, Zn and Mn.
- **Nutrient imbalances.**
  - high soil P can interfere with Zn and Cu uptake.
  - addition of Cu and Zn can reduce plant growth on P deficient soils

Sandy gray, peaty soils have greatest frequency of micronutrient deficiencies

# *"Available" Copper in 14 Brown and Dark Brown SK soils (Rahman 2015)*

Ex_Cu = DTPA Extractable Cu; Cu_SR= PRS$^{TM}$ probe Supply rate of Cu




Lower sand content equates with higher available soil copper

- Generalizations about where and when a micronutrient deficiency will occur can be dangerous.
- Soil and tissue testing are tools that can add some resolution.  Some debates about critical levels.
- When responses are isolated and not clear cut, difficult to establish recommendation criteria.

- **A combo of soil and tissue testing, plus some test strips most conclusive.**

# Responses to Micronutrient Fertilization

## COPPER

Of the micronutrients, **Cu** is the element **most likely** to arise as a **limitation** in SK.

Cereals, especially wheat, are crops most susceptible.

**Empty Heads (Cu-deficiency)**

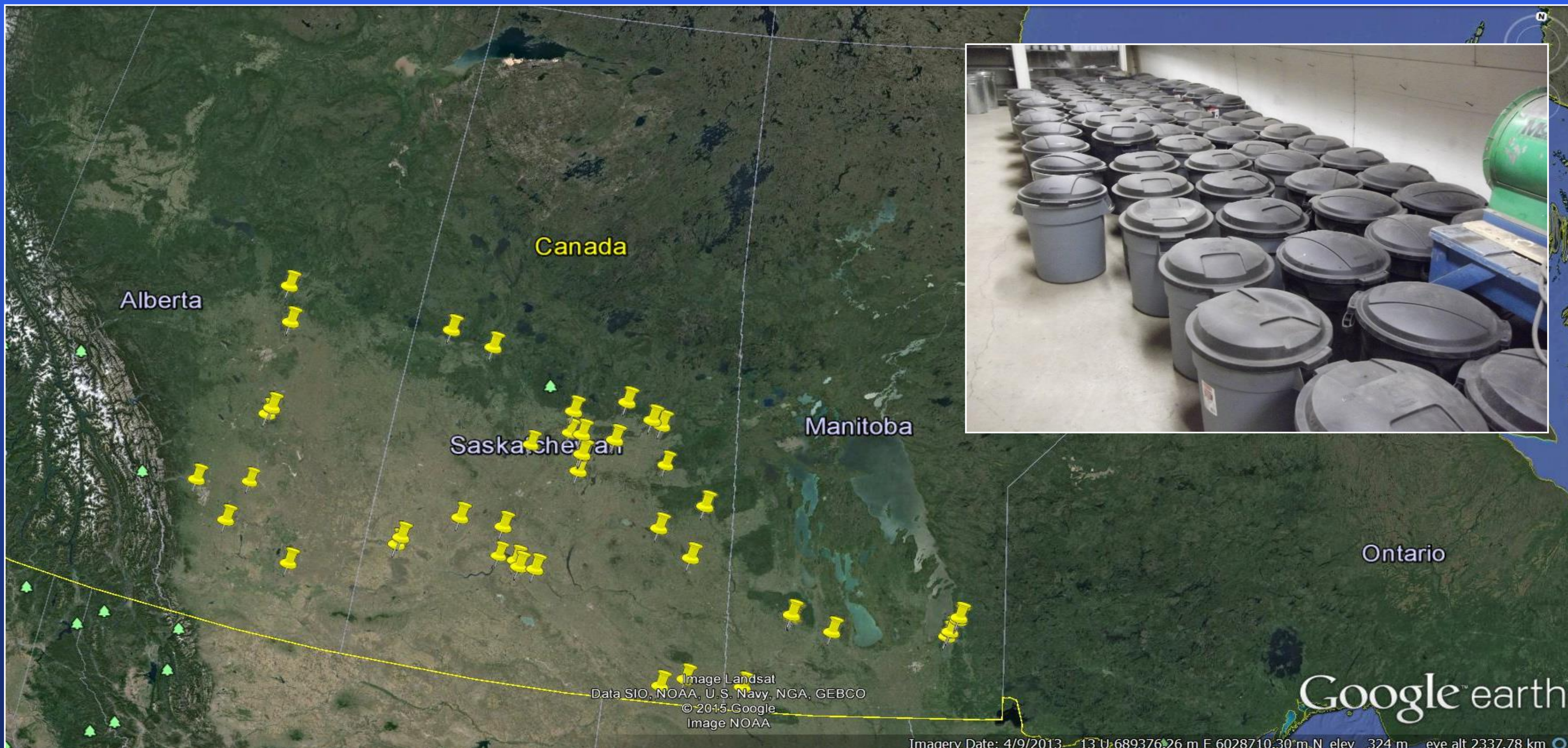
# Response of HRS Wheat (var. Barrie) to Copper Fertilization in a Gray Luvisol near Porcupine Plain, SK. (Malhi et al., 2003)

| | |
|---|---|
| Control | 1566 kg/ha (a) |
| 2 kg Cu/ha Soil incorp at seeding | 1591 kg/ha (a) |
| 0.25 kg Cu/ha Foliar at flagleaf | 2555 kg/ha (b) |

**Flaten et al., 2003 also found foliar application most effective for correction of Cu deficiency in year of application.**

Dr. R. Hangs glasshouse research with Cu, Zn and B in **wheat-pea-canola** rotation

# Soil Collection (47 soils from SK, MB, AB)

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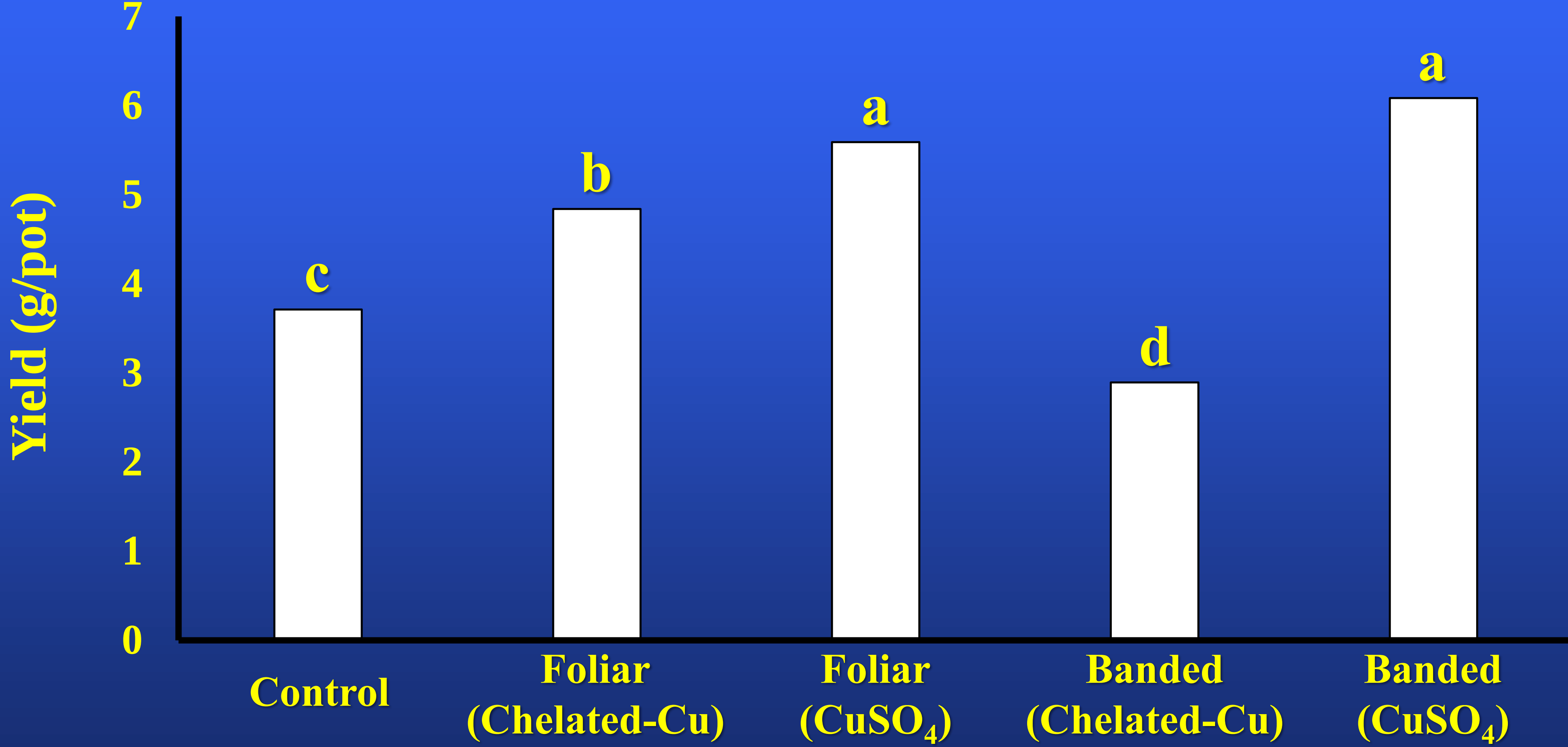
# *Wheat Grain Yield Yr 1 2015*

## *(12 mineral soils; n = 48)*




**Bars with the same letters are not significantly different (P >0.05) using LSD.*

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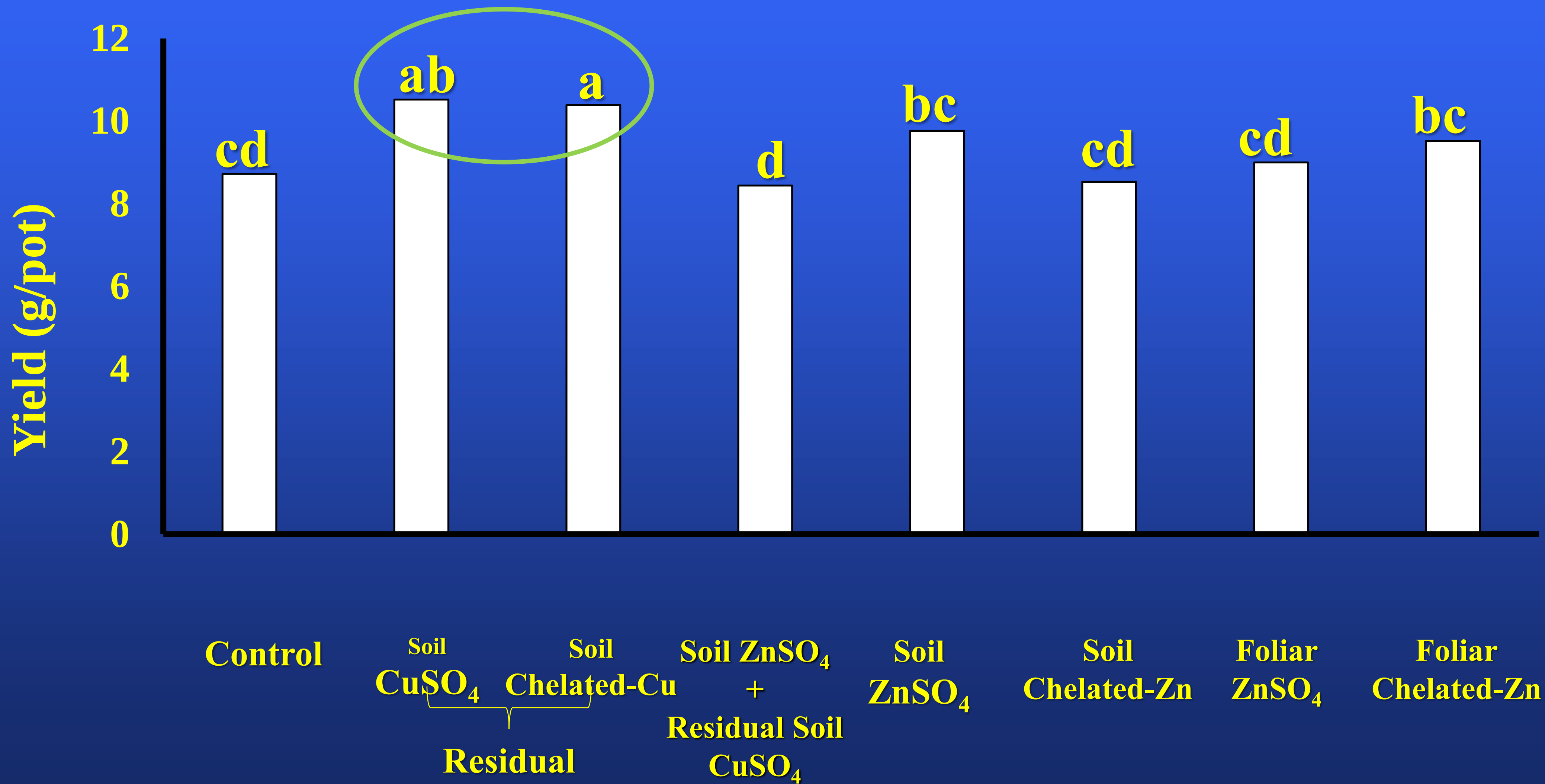
# *Pea Grain Yield Yr 2 2016*

## *(12 mineral soils; n = 48)*




*Bars with the same letters are not significantly different (P >0.05) using LSD.*

- Pea yield responded positively and significantly to Cu fertilizer **applied the year before** to wheat.
  – Fungicidal or nutritional effect?

- Trend to pea yield positively responding to soil and foliar Zn application, but not statistically significant @ $p<0.05$.

# ZINC

- No significant yield responses of dryland crops to zinc sulfate addition in 23 field trials in SK in 80's (Singh et al. 1987).
- Significant responses of cereals to zinc application on eroded knoll soils under growth chamber conditions (Cowell and Schoenau 1993; Greer et al. 2002).
- Corn has high Zn requirement, response in low testing soils.
- High rates of P application to soils that are marginal or deficient in Zn can induce severe Zn deficiency.

Lentils grown in glasshouse on 10 southern SK soils showed variable response to zinc (Maqsood et al., 2016 J. Plant Nutr. 39).

- A few positive responses on Brown SCZ soils from south-west, south-central SK

- Higher OM soils (Dk Brown, Black) further north and east: no response


**Figure 1.** Small green lentil grown at 3 Zn rates on Ardill Brown Chernozem Soil

# Lentil Response to Zn Fertilization in Field

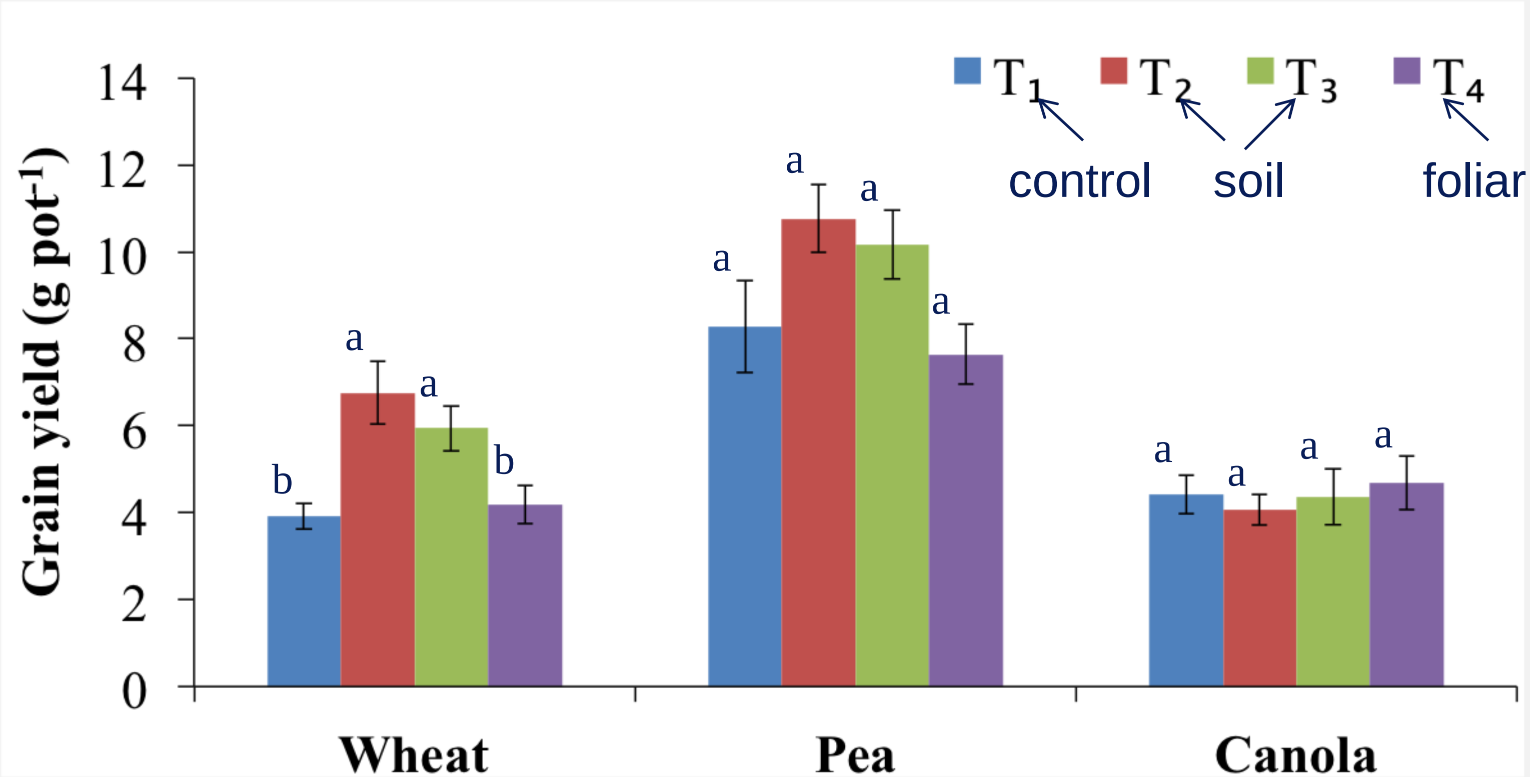
## Anderson, 2015

| Site | Yield† | Zn Rate (kg ha⁻¹) 0 | 2.5 | 5 | SEM‡ | P values Rate (R) | Cultivar (C) | R*C Interaction |
|---|---|---|---|---|---|---|---|---|
| Central Butte<br>DTPA Zn:0.5 mg/kg | Grain | 2919 | 2880 | 2913 | 359 | 0.9944 | 0.5542 | 0.9250 |
| | Straw | 2597 | 2502 | 2508 | 194 | 0.9285 | 0.1982 | 0.5882 |
| Saskatoon<br>DTPA Zn: 1.9 mg/kg | Grain | 4104 | 4355 | 4172 | 183 | 0.6089 | 0.8774 | 0.7352 |
| | Straw | 3743 | 3946 | 3872 | 168 | 0.6907 | 0.6904 | 0.7619 |

Some trends for positive response of pea to Zn fertilization in glasshouse (Rahman, 2015),
but only significant for one organic soil (Hangs, 2016).

# 2015 Glasshouse Study (N. Rahman)

**SCEPTRE** Soil O.V (Sceptre, SK)
DTPA Cu=1.6; ***Zn=0.7***; B=1.7 mg kg$^{-1}$




**Response to Cu** **Response to Zn** **Response to B**

## Zn fortification of pea grain from Zn fertilization of Sceptre Association soil.

| Treatment | Grain Zn concentration |
| --- | --- |
| | *mg Zn per kg* |
| Control | 16.7b |
| Soil Zn sulfate | 19.0ab |
| Soil Zn chelate | 23.0a |
| Foliar Zn chelate | 20.4ab |
| *p*-values | 0.023 |

# BORON

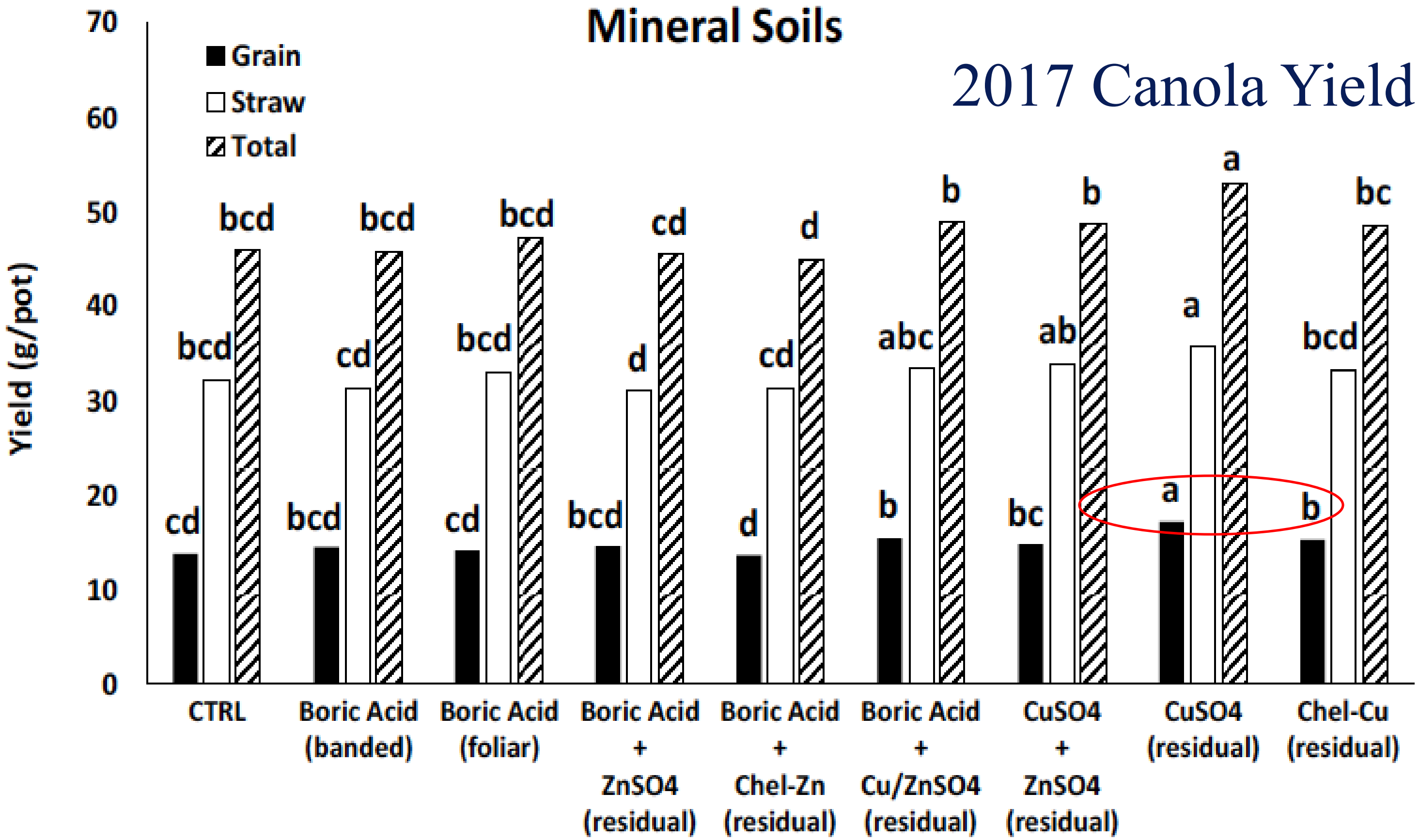
**Canola, alfalfa** are crops most susceptible to deficiency.

**Large yield responses** to B fertilization in W. Canada reported in literature are **quite rare**.

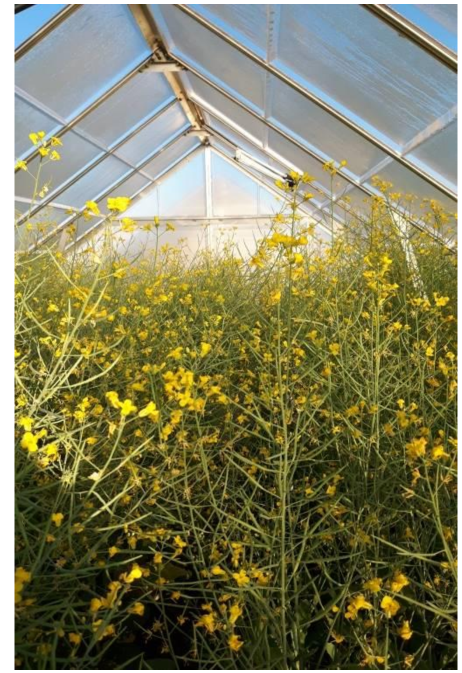
Even on soils with very low extractable B content, some studies report no significant yield response of canola to B application (Karamanos et al. 2002; Malhi et al., 2003).

In glasshouse, only two of twelve mineral soils responded positively to B fertilization (Hangs and Schoenau, 2018)

# Response of canola to added boron on 12 SK mineral soils in 2017 glass house study




2017 Canola Yield

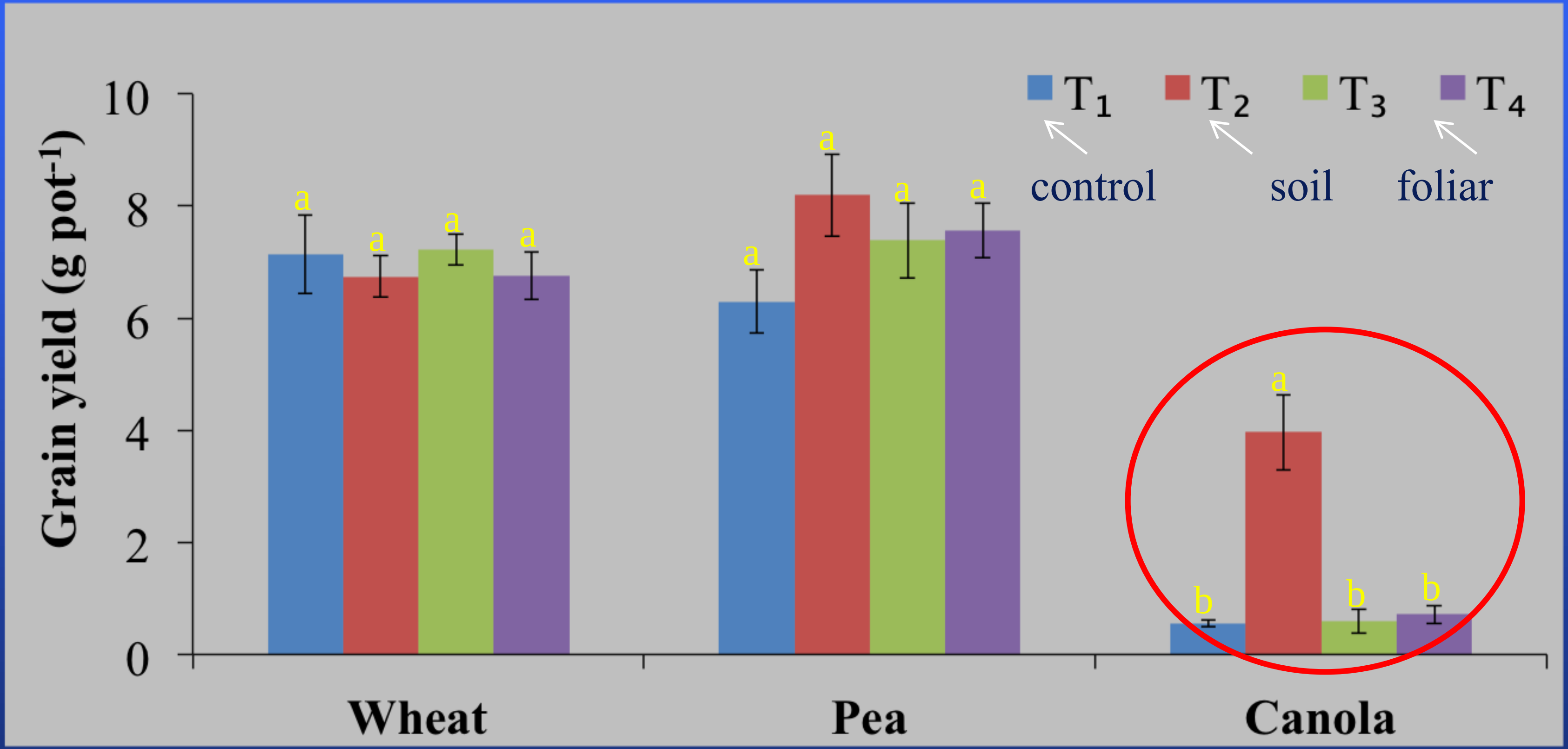


| Effect | P-value |
|---|---|
| Soil | <.0001 |
| Fert Cu | 0.0013 |
| Fert Zn | 0.1262 |
| Fert B | 0.1942 |

- **On 2 of the 12 mineral soils, canola responded significantly to B fertilization (sandy, low OM, low avail B)**
- **Residual Cu from 2015 produced a canola yield increase in 2017**

**WHITEFOX O.DGC** (Nipawin, SK) Rahman 2016

Cu=1.3; Zn=1.8; ***B=0.5*** mg $kg^{-1}$




**Response to Cu** **Response to Zn** **Response to B**

# MANGANESE

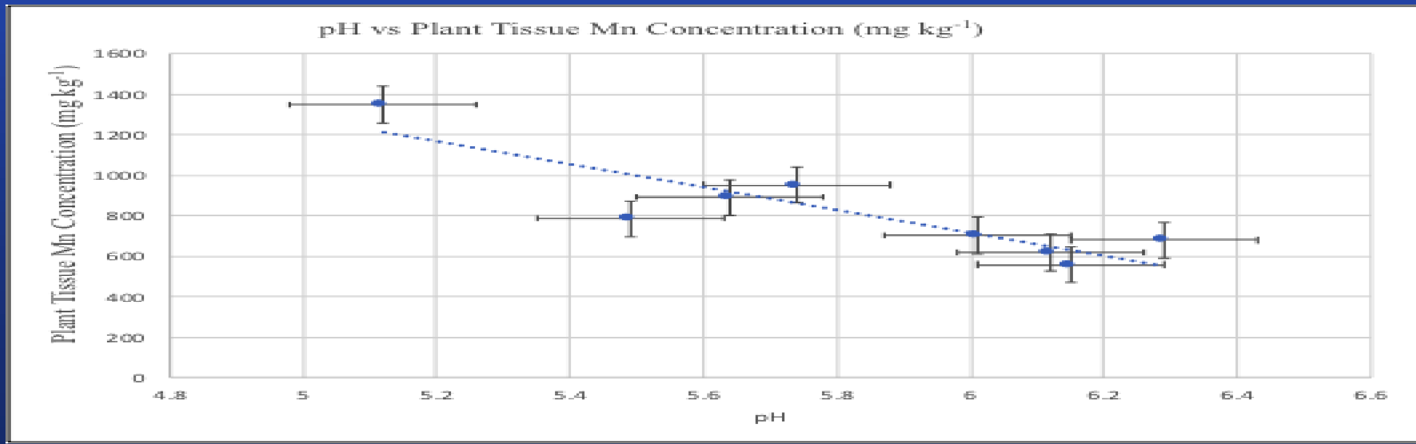
Cereals, especially oats, grown on peaty soils at northern agricultural fringe could respond to manganese.

Deficiencies of Mn rare in mineral soils.

But **Mn toxicity suspected** in a few very sandy, acidic, Gray soils in east-central SK

# K. Lamb PLSC 492.3 2018 Project on Mn Toxicity in Canola

| | pH | Canola D.M. Yield (g) |
|---|---|---|
| **Control** | 5.5 | 0.74± 0.15 |
| **Limed** | 6.1 | 1.49± 0.28 |

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# IRON

Iron (Fe) deficiencies produce rather marked symptoms: interveinal chlorosis: iron deficiency chlorosis "IDC"


Source: Fe deficiency chorosis in soybean. North Dakota State University Crop and Pest Report 6/23/11 Kandel and Goos http://www.ag.ndsu.edu/cpr/plant-science/iron-deficiency-chlorosis-in-soybean-6-23-11

- High pH, poor drainage, nitrates, carbonates, salts, aggravates Fe deficiency
- Soybeans rather inefficient users of Fe. Some varieties more sensitive to Fe deficiency than others: note IDC rating for variety.

## Response of Soybean to Iron (Hangs and Schoenau, 2017)

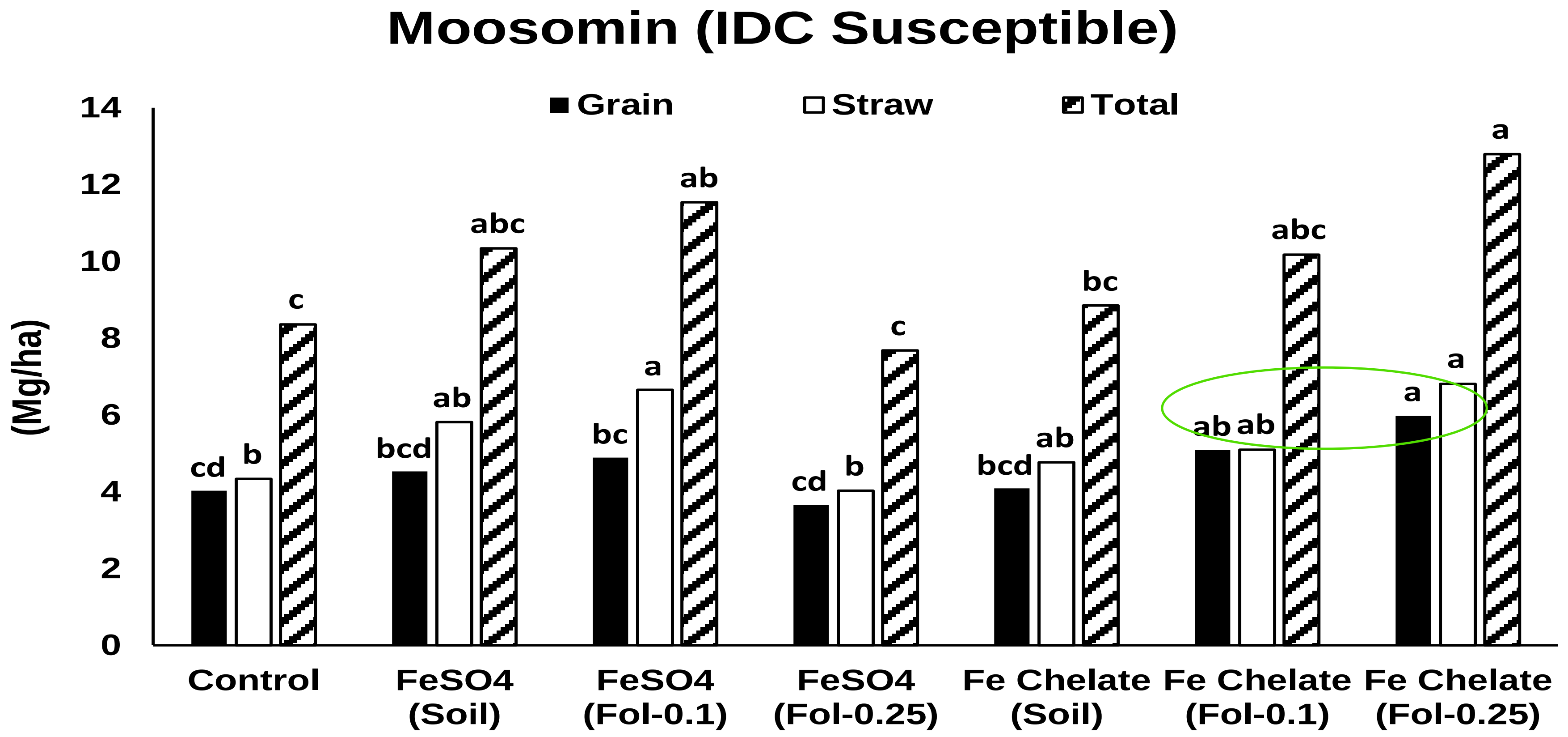
- Field trial conducted in southern SK near Central Butte in 2015 and 2016 on high pH, slightly saline, high nitrate, lower slope.
- Two soybean varieties: one IDC sensitive (Moosomin)
  one IDC tolerant (McLeod).

## *Findings:*

- 2015 very dry May, June, July. No response to Fe fertilization.

- 2016 was wetter, environment more conducive to IDC.

***In 2016, IDC sensitive variety (Moosomin) responded significantly to foliar Fe while IDC tolerant variety (McLeod) did not.***




*The Fe treatments included seed-placed (Soil) Fe sulphate or chelated Fe (5 and 0.25 kg Fe/ha, respectively) or foliar (Fol) application of Fe sulfate and chelated Fe (0.1 kg and 0.25 kg Fe/ha) @V2-V3.*

**Genetics best defense when IDC is a concern,**

**Foliar Fe may be suitable rescue treatment.**

# CHLORIDE

Potential for response of cereals in highly leached soils with low extractable Cl. Response may be associated with disease pressure.

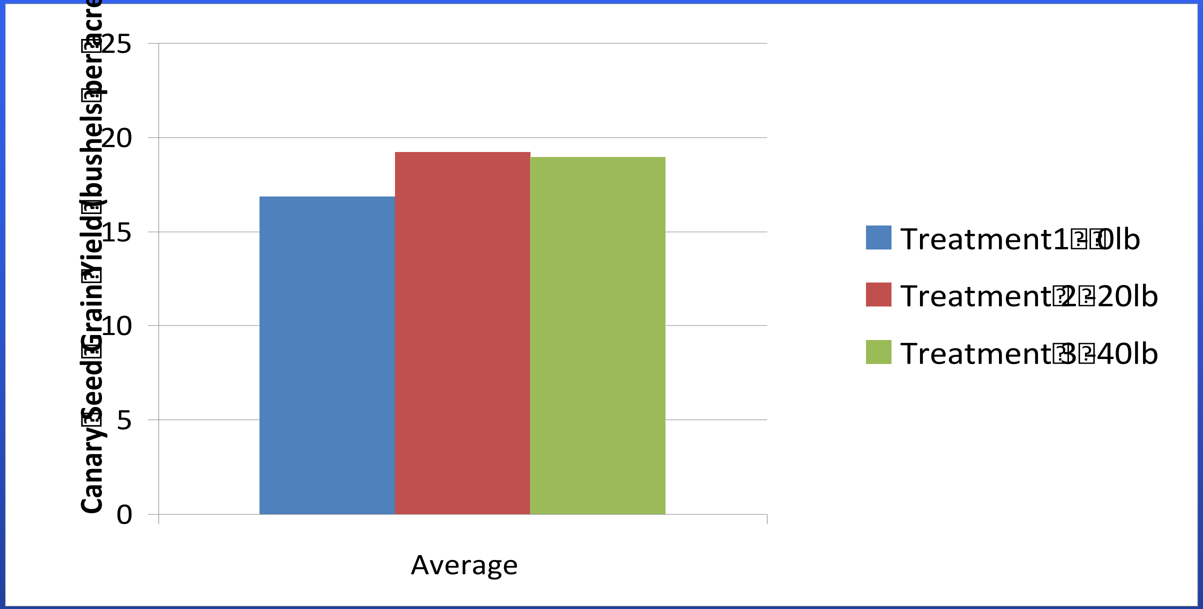
## *Responses to Cl are variable*

Application of 40 lb/ac of KCl increased wheat yield in highly leached depressions of a landscape in southern Saskatchewan in a wet year but had no influence the following dry year (Schoenau et al., 1997).

More widespread use of KCl in recent years has likely reduced the incidence of Cl as a limitation.

Nearly all Cl remains in straw and is recycled.

# Response of Canary Seed to KCl Addition (Theaker 494.6 2011)




Also, May et al. 2012 showed seed yield increase of ~ 24% from chloride added to canaryseed in Dk Brown soil zone of SK.

# Final Thoughts

- Micronutrients must be considered as **part of the overall balance** of nutrients required to optimize yield and economic return.
- Consider in both short-term (this season) and over a number of years in rotational cycle. May be residual benefit to following crops.
- Become a more important consideration when aiming for the top of the yield curve.

- **“Patchy”** and variable nature of micronutrient deficiencies makes them obvious target for precision fertilization. Even cultivars of same crop may differ in response.
- Multiple evidence approach best for identifying and verifying deficiency.
- Complexity of factors affecting micro availability and nutrition makes prediction of likelihood of response challenging!

# Thanks for the opportunity to participate!