Micronutrients: Unravelling the Mystery

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Micronutrients

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

- Micro's of interest for Sask include:

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

Micronutrients are a bit "mysterious" by nature!


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- 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.

Plant absorption of micronutrients

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

Taken up as <u>cations</u> (positively charged ions)

And as **<u>chelates</u>**: metal complexed with organic matter.

Chelates stay in solution, keeps them available 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.

Role of Micronutrients in Crop Nutrition

COPPER, ZINC, MANGANESE, IRON

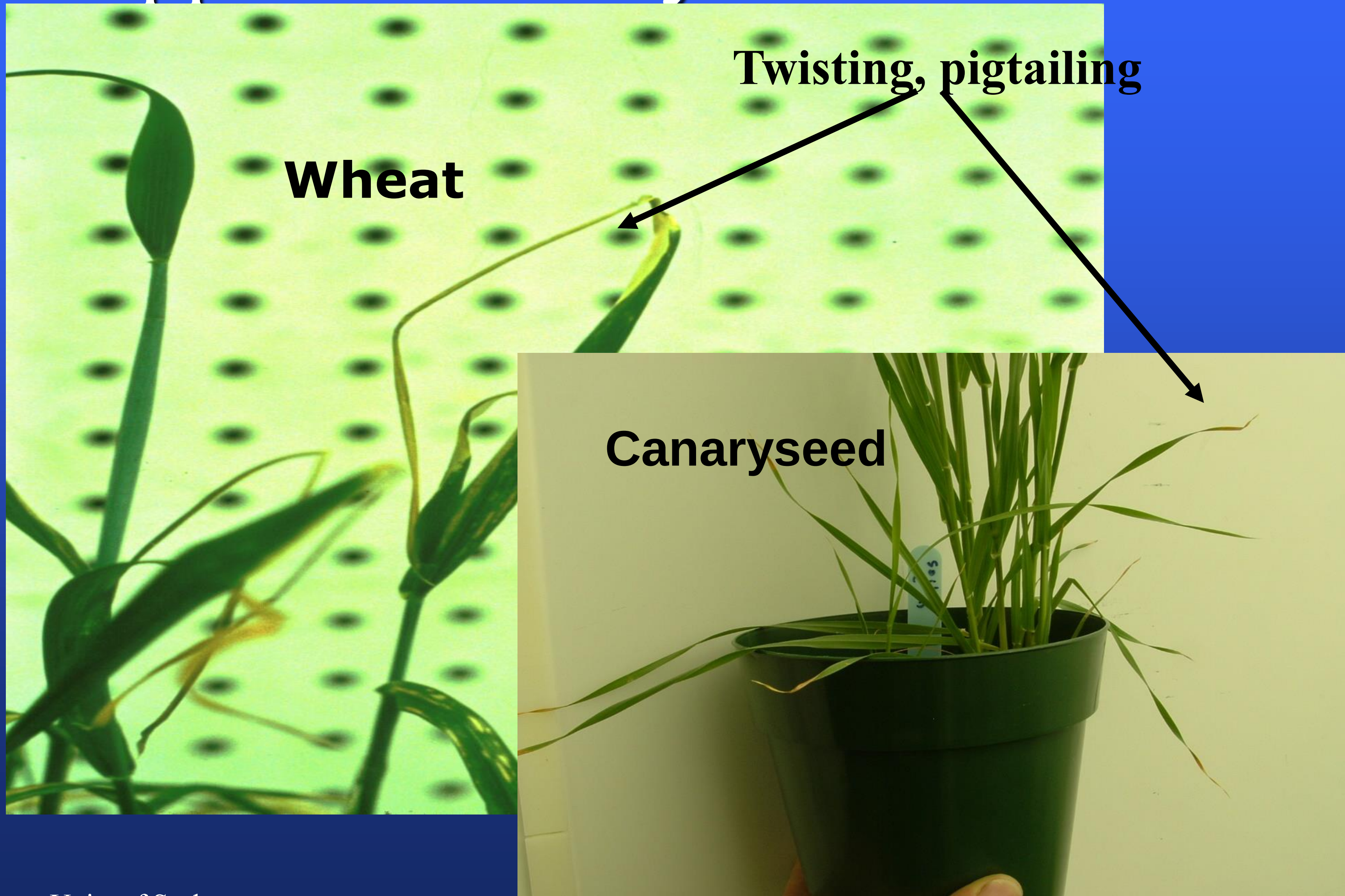
- Metals involved in electron transport, enzyme activation, hormone regulation
- Can also play roles in disease resistance.

Example: Copper deficiency may aggravate ergot infections.

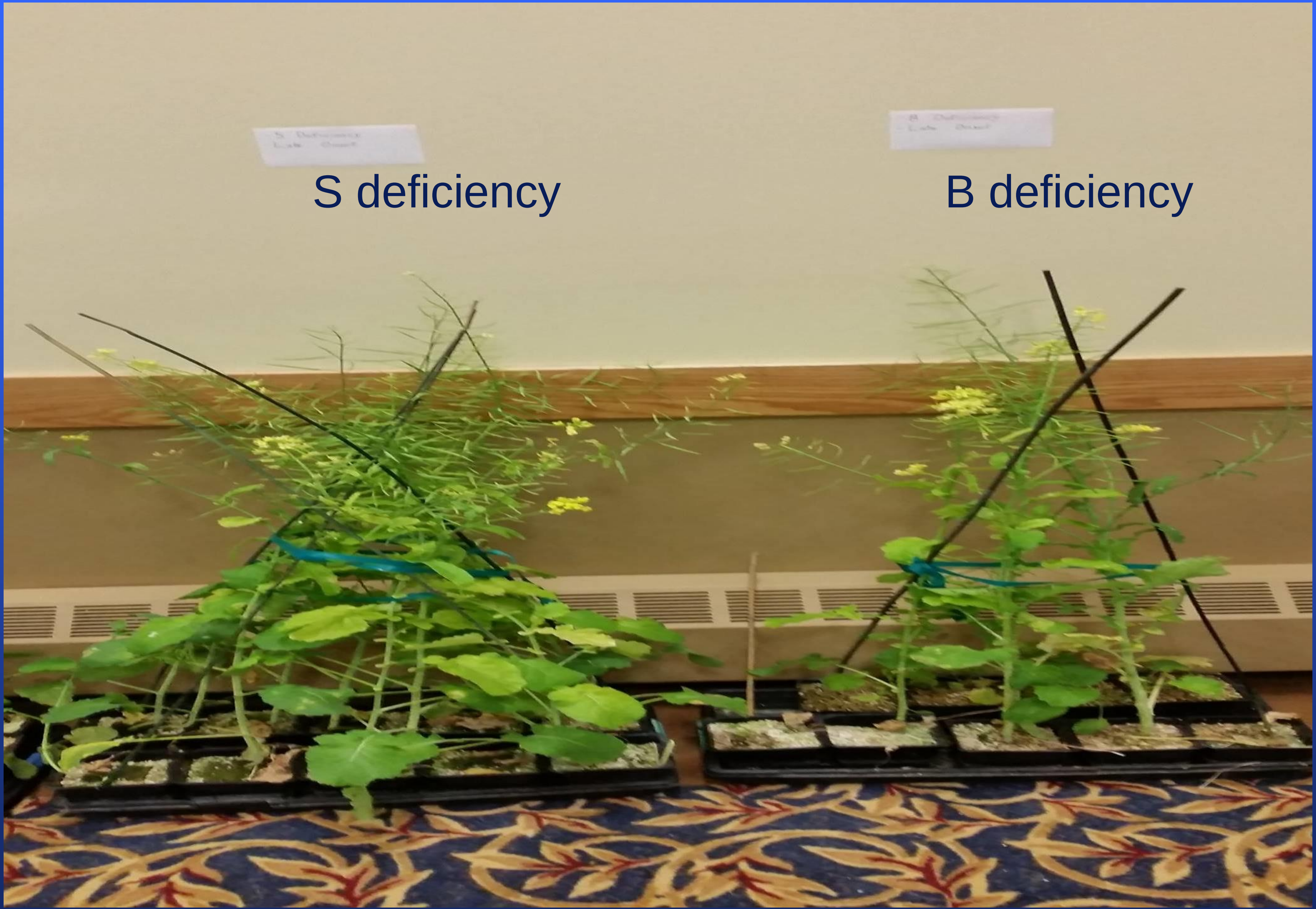
BORON: Cell wall extension, division at growing points, especially affects reproduction ie pollination.

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 or gravel lens.
- Sampling strategy must account for this.

Know Where to Look

Soil Conditions Contributing to Micronutrient Deficiencies

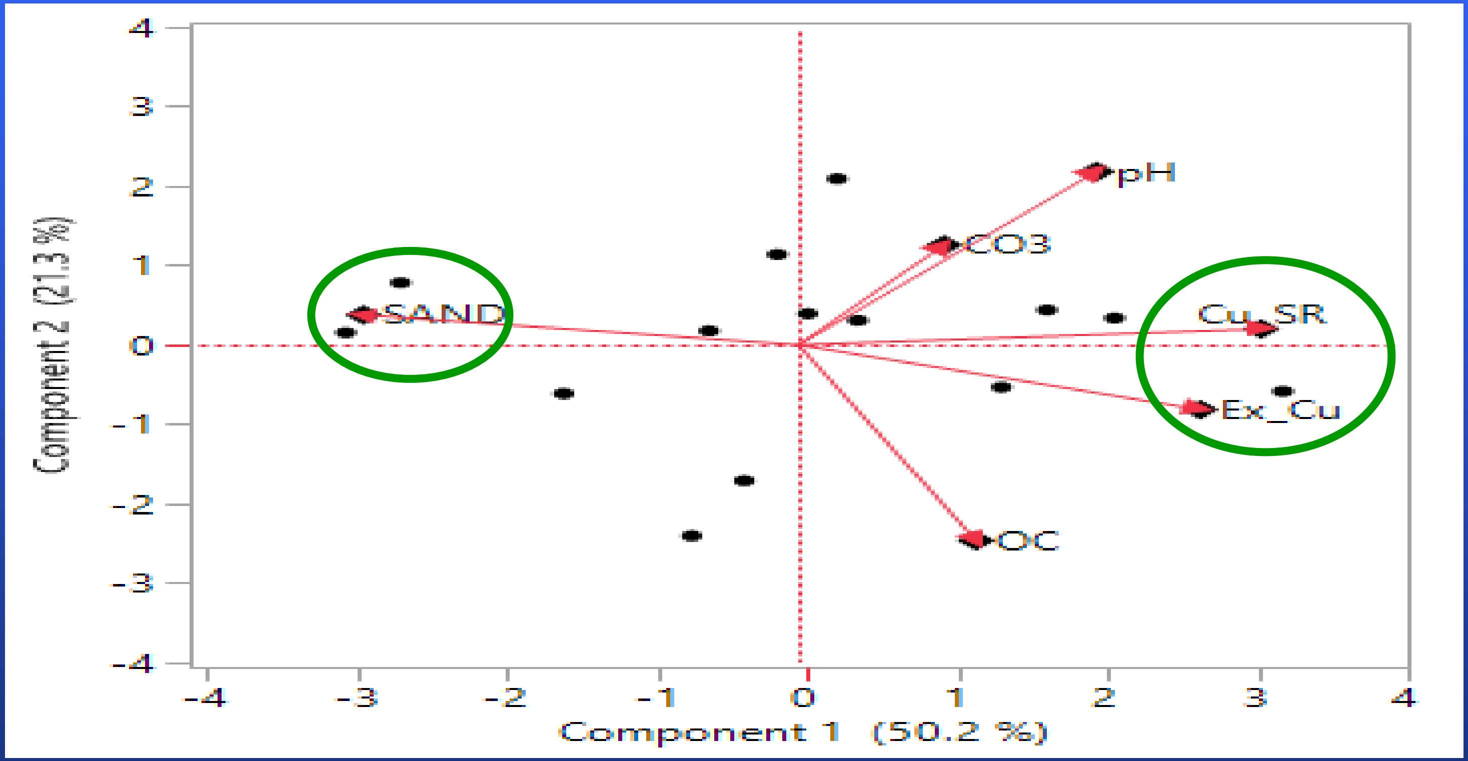
- **Sandy:**
  - low content of minerals capable of releasing micronutrients by weathering.

- **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 Cu in 14 Brown and Dk Brown SK soils (Rahman 2015)

Ex_Cu = DTPA Extractable Cu; Cu_SR= PRS Supply rate of Cu



Higher sand content equates with lower predicted Cu availability

- 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.

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

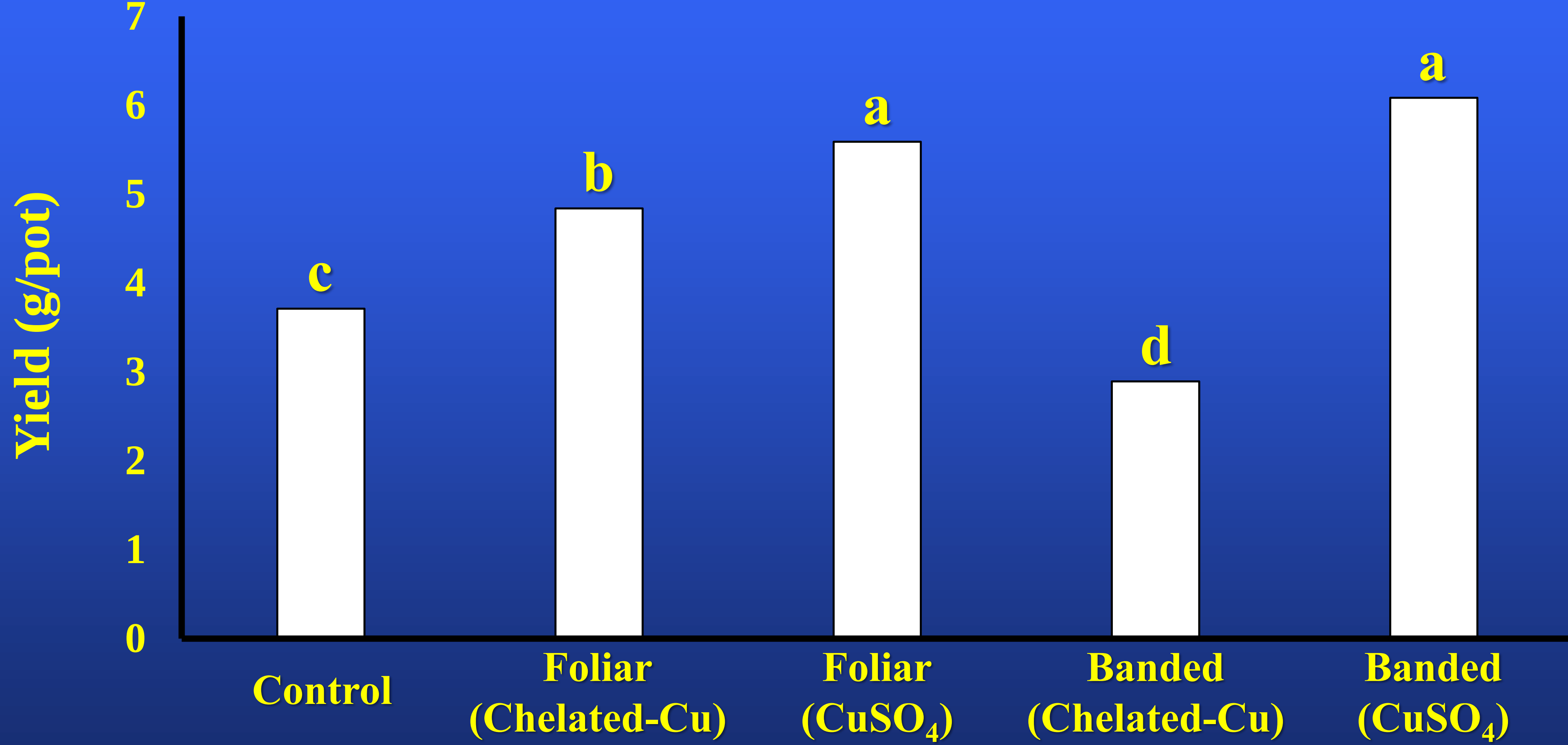
Control	1566 kg/ha (a)
2 kg Cu/ha Soil incorp at seeding	1591 kg/ha (a)
0.25 kg Cu/ha Foliar at flagleaf	2555 kg/ha (b)

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


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

Wheat Grain Yield Yr 1 2015

(12 mineral soils; n = 48) R. Hangs



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

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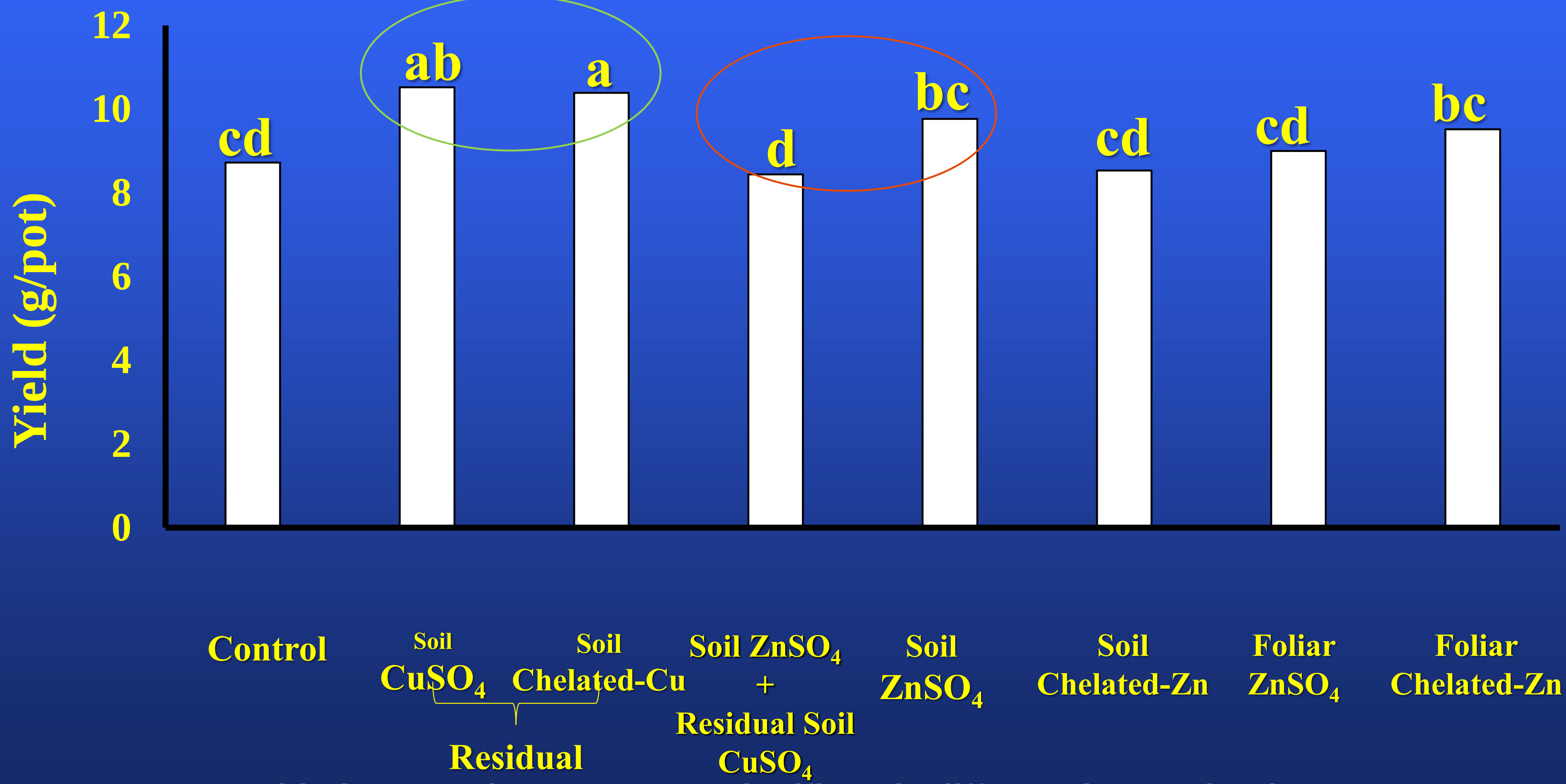
Pea Grain Yield Yr 2 2016

(12 mineral soils; n = 48)

R. Hangs



- Trend to pea yield positively responding to soil and foliar Zn application, but not significant @ $p<0.05$.
- Pea yield responded positively and significantly to soil applied Cu fertilizer applied the year before to wheat.
  - Fungicidal or nutritional effect?
- A negative interaction effect is observed when Zn + Cu applied on P deficient soil.
  - Effect observed on wheat (N. Rahman), also on peas grown the year after (R. Hangs).

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).

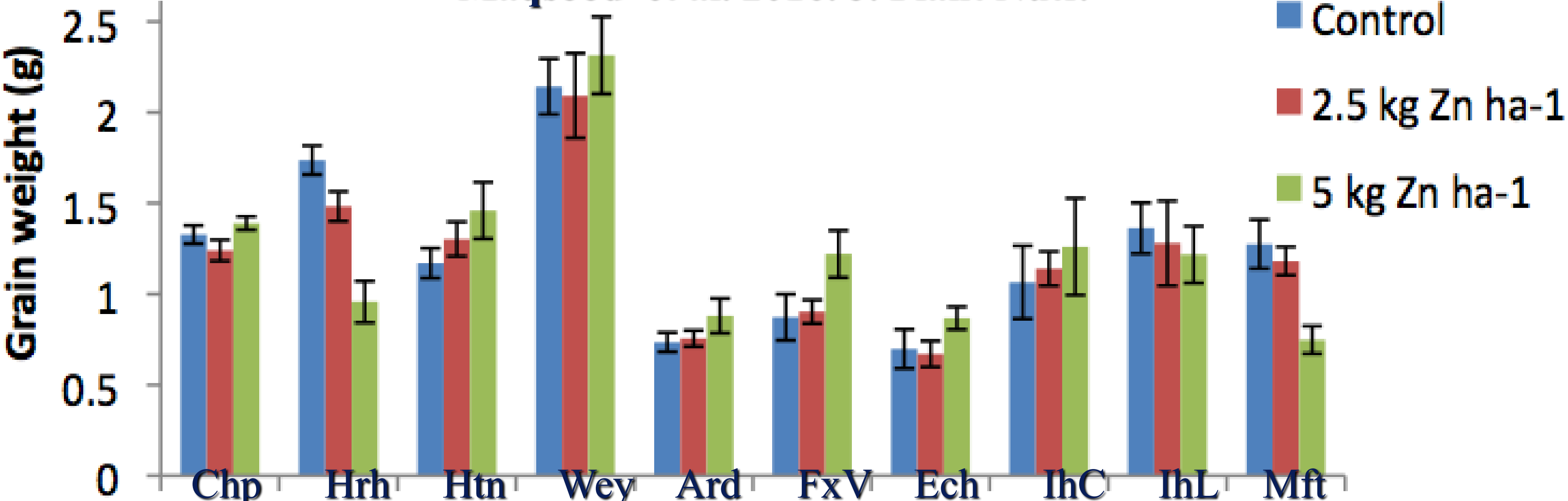
Lentils grown in polyhouse on 10 southern SK soils showed variable response to zinc (Maqsood et al., 2016).

No significant response of lentil in 2 field trials (Anderson, 2015) or polyhouse studies (Anderson et al. 2018) .

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

Grain Yield of Lentil as Influenced by Application of Zinc Sulfate on Ten SK Soils

Maqsood et al. 2016. J. Plant Nutr.



Lentil Response to Zn Fertilization in Field

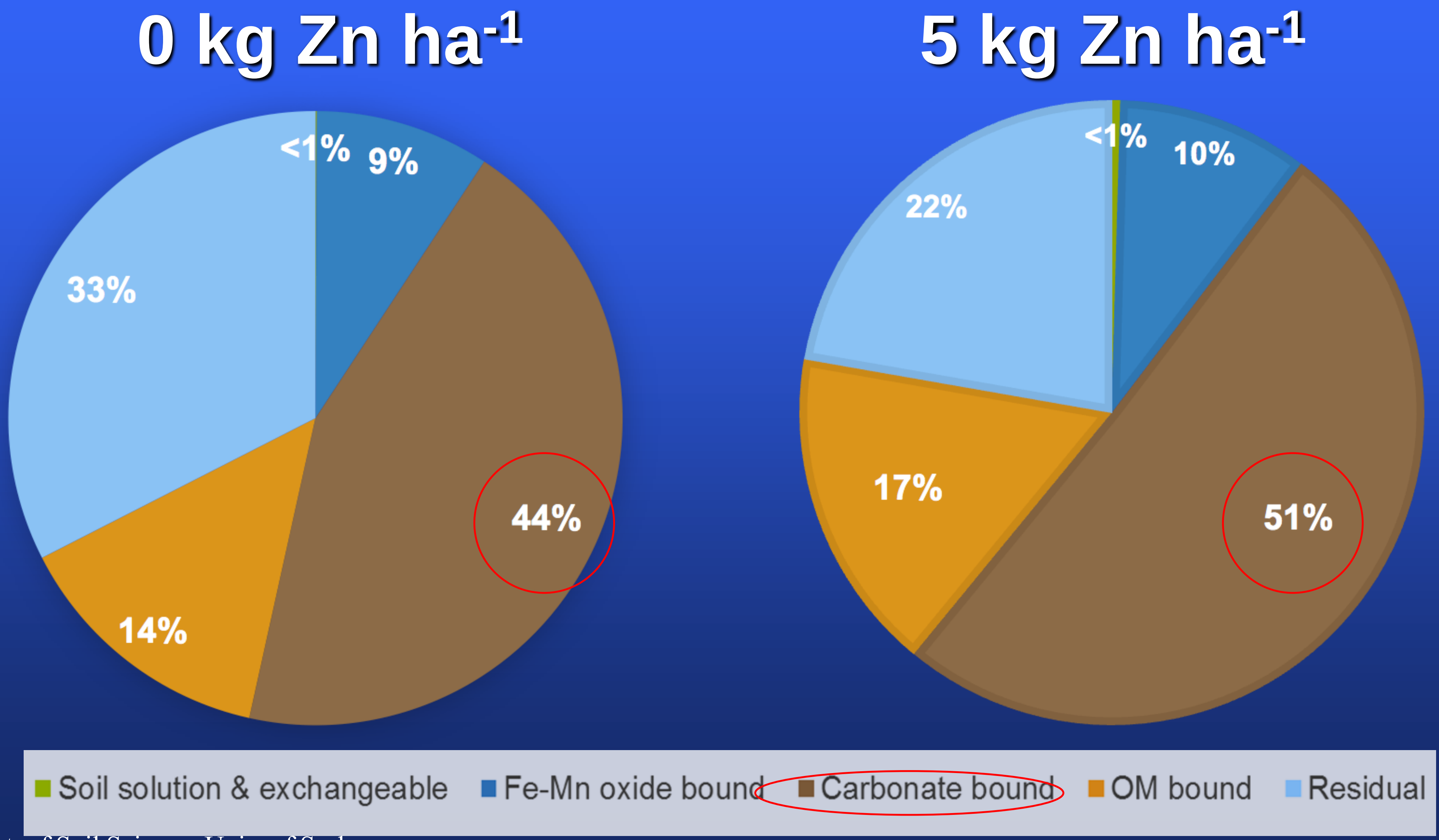
Anderson, 2015

Site	Yield[†]	Zn Rate (kg ha^{-1}) 0	2.5	5	SEM[‡]	P values: Rate (R)	Cultivar (C)	R*C Interaction
Central Butte	Grain	2919	2880	2913	359	0.9944	0.5542	0.9250
	Straw	2597	2502	2508	194	0.9285	0.1982	0.5882
Saskatoon	Grain	4104	4355	4172	183	0.6089	0.8774	0.7352
	Straw	3743	3946	3872	168	0.6907	0.6904	0.7619

DTPA Zn:0.5 mg/kg

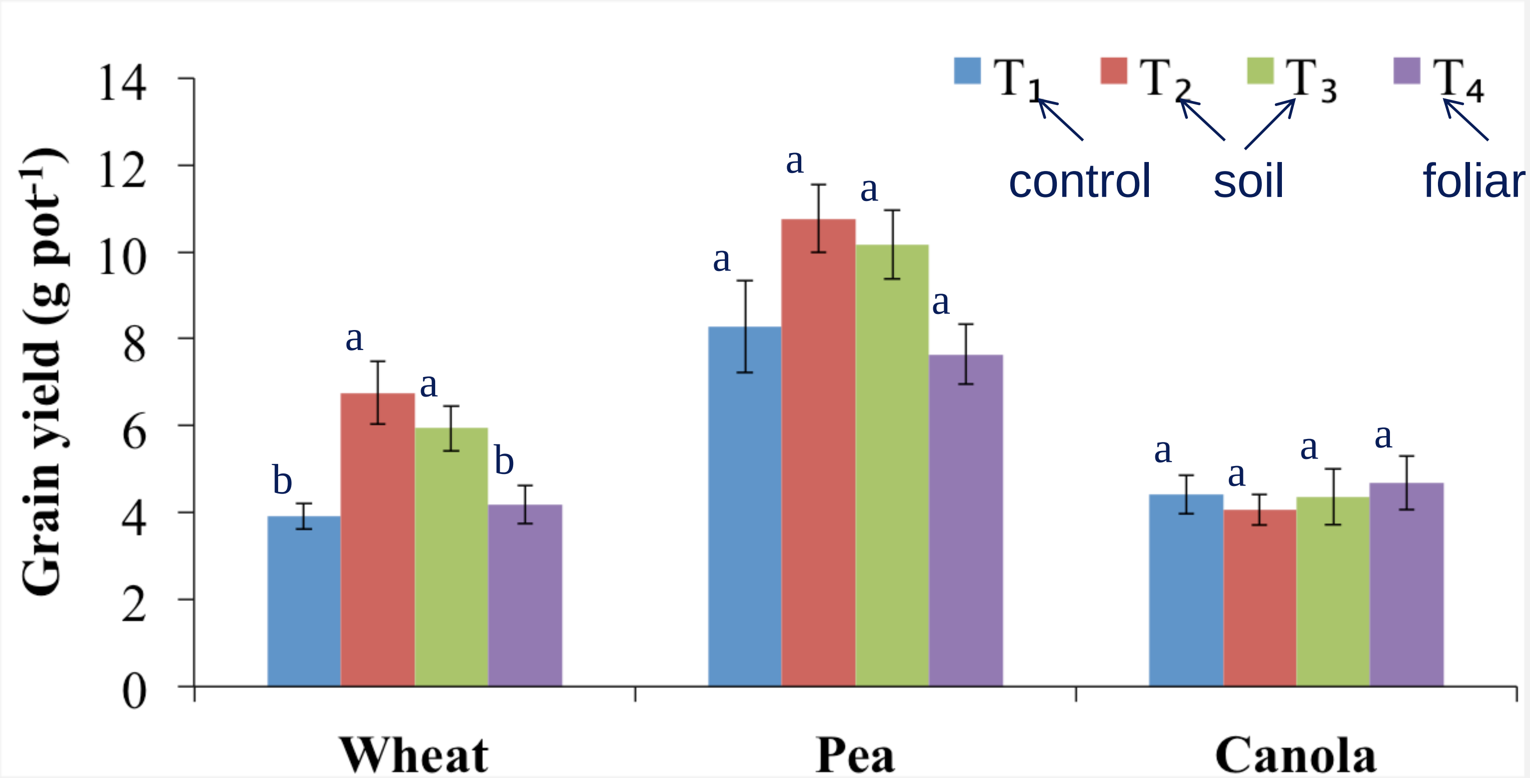
DTPA Zn: 1.9 mg/kg

Effect of Zinc Fertilization Rate on Soil Zinc Fractions



2015 Polyhouse 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
	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.

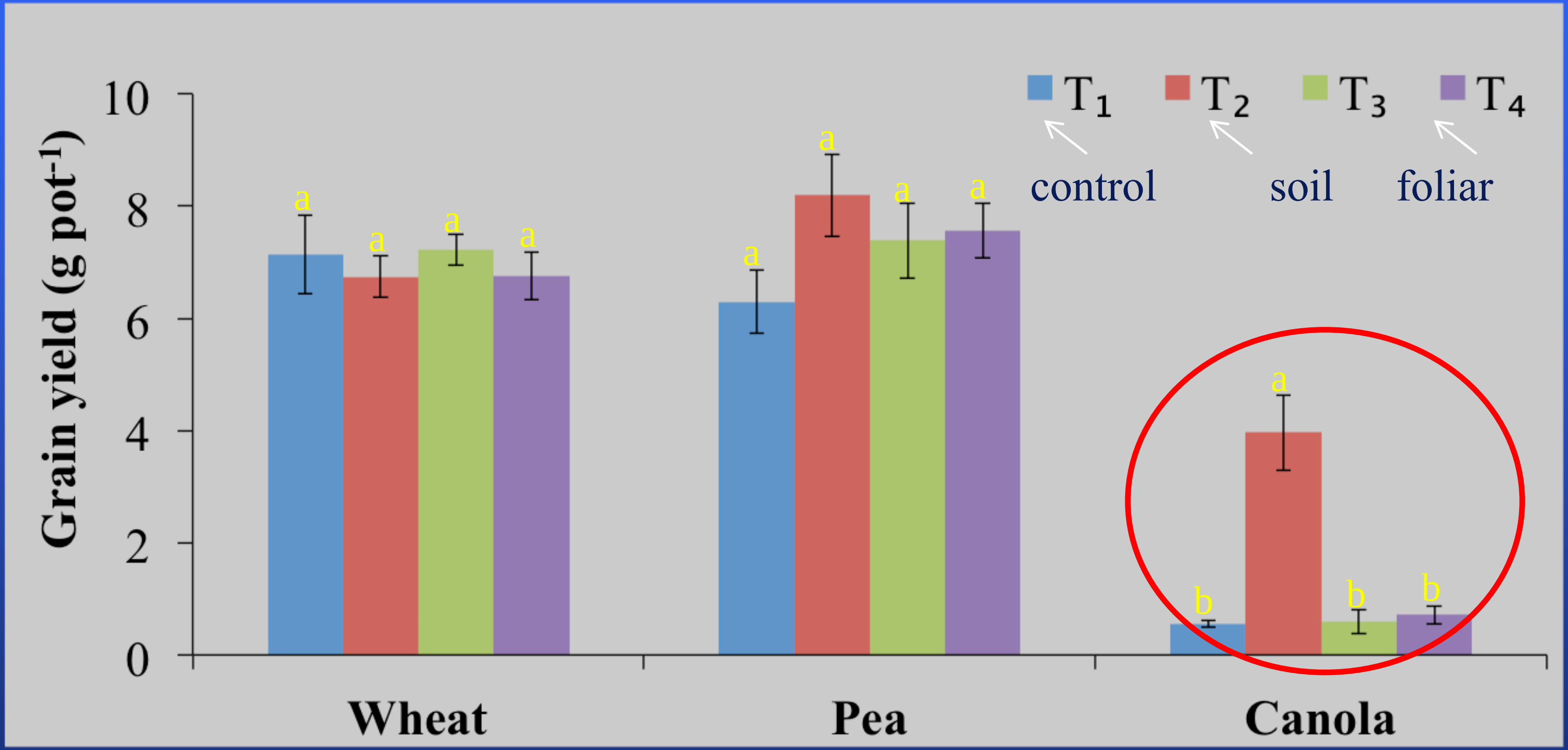
Large yield responses to B fertilization in W. Canada reported in literature are quite rare.

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

In polyhouse, two of twelve mineral soils responded positively to B fertilization (Hangs and Schoenau, 2018 Soils and Crops poster)

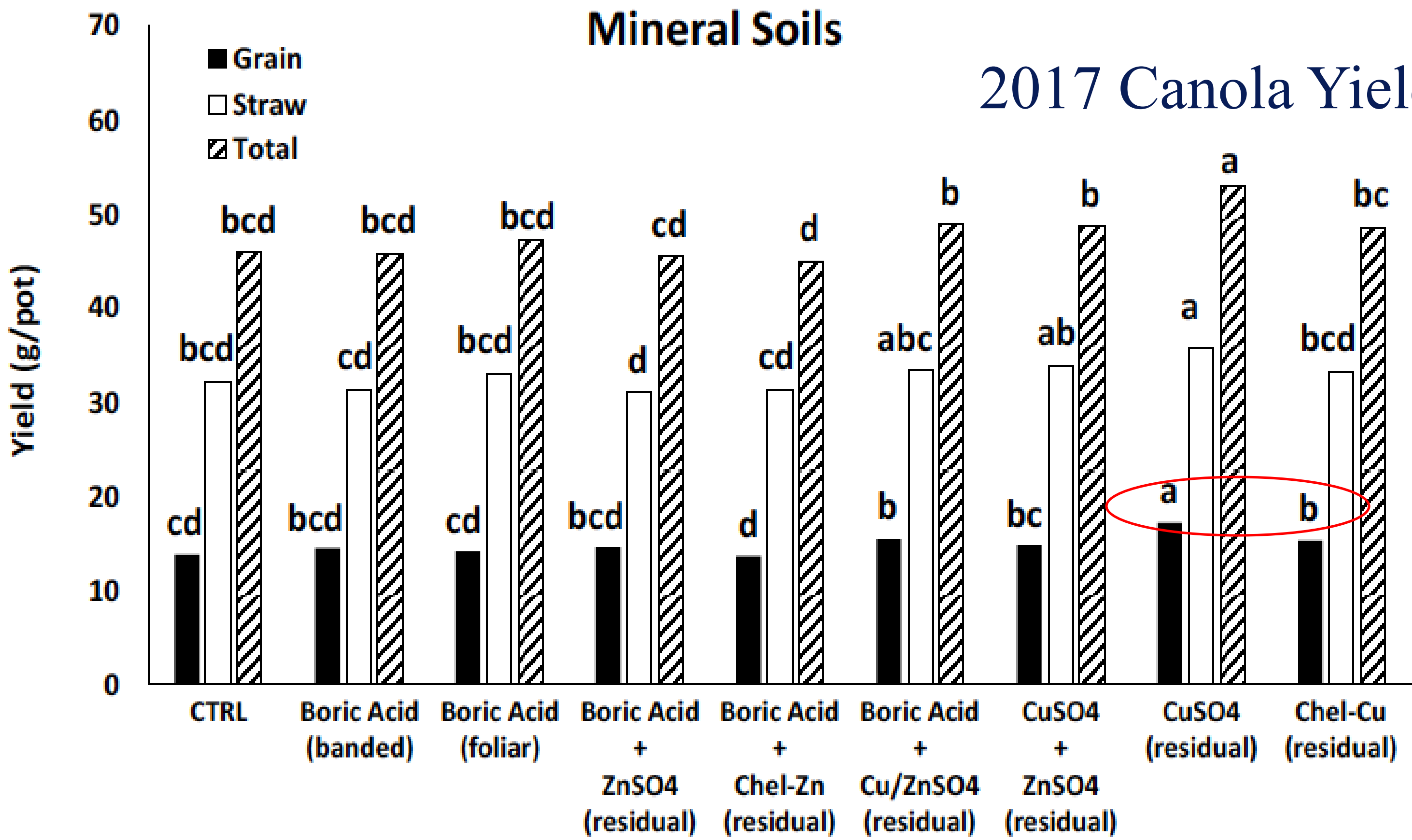
WHITEFOX O.DGC (Nipawin, SK) Rahman 2016

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

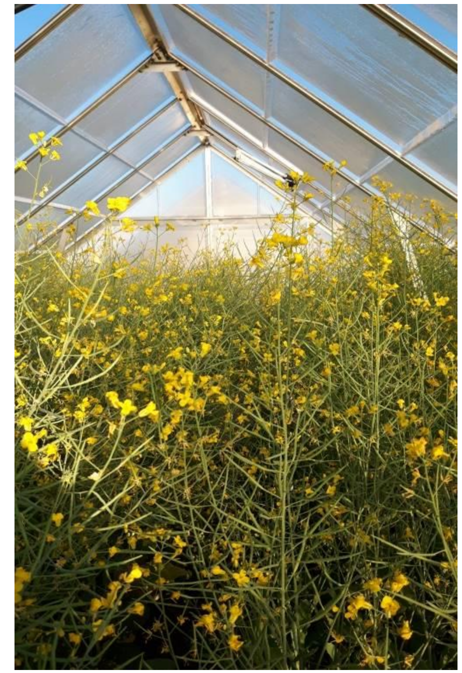


Response to Cu **Response to Zn** **Response to B**

Response of canola to added boron on 12 SK mineral and 2 organic soils in 2017 polyhouse study (R. Hangs)



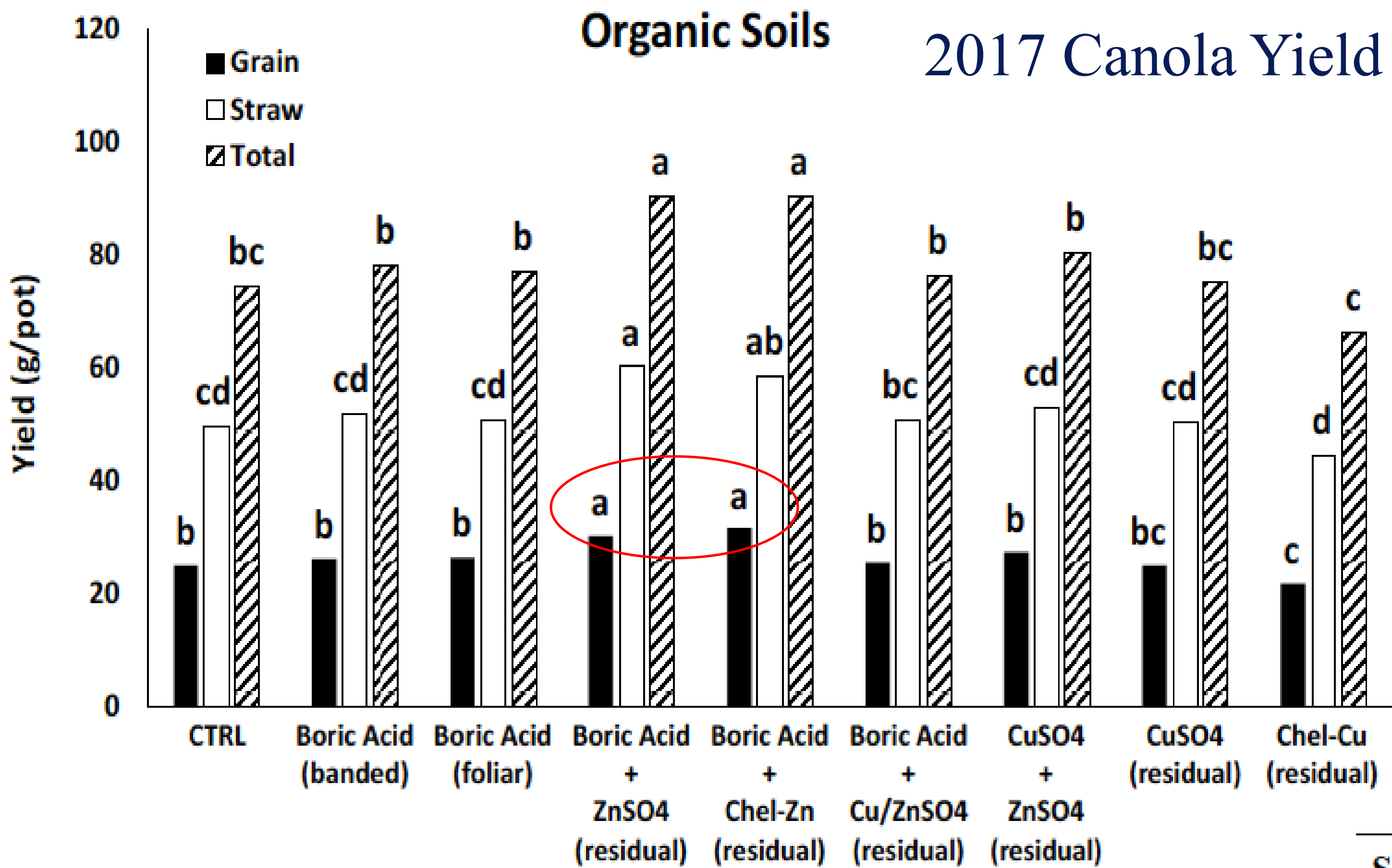
2017 Canola Yield



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 available B)
- Residual Cu from 2015 produced a canola yield increase

2017 Canola Yield



Effect	P-value
Soil	<.0001
Fert Cu	<.0001
Fert Zn	<.0001
Fert B	0.6674

- B in 2017 + Zn in 2016 increased canola yield

MANGANESE

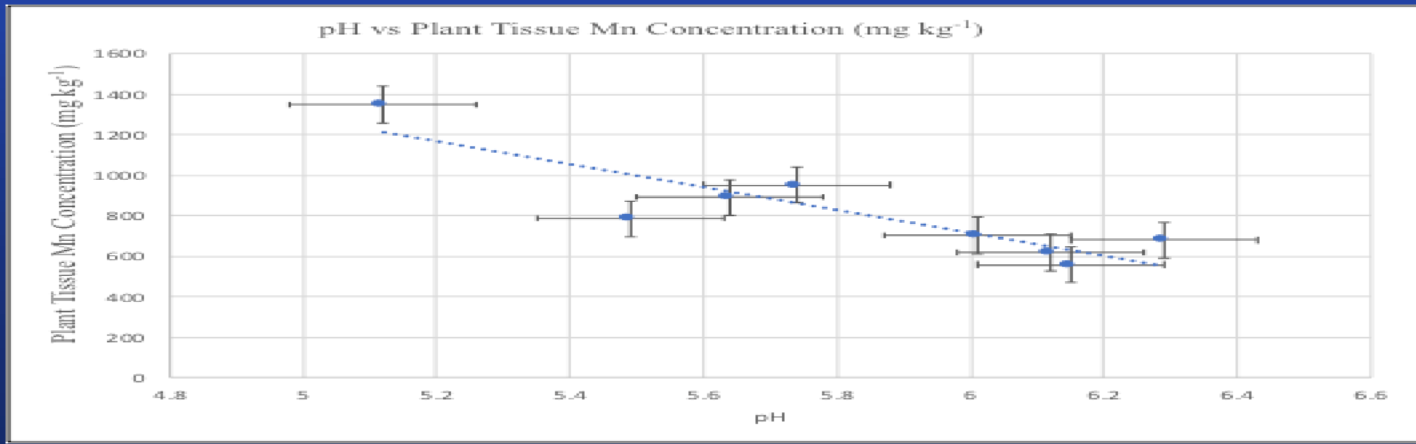
Cereals, especially oats, grown on peaty soils at northern agricultural fringe could respond to manganese.

Deficiencies of Mn not an issue in mineral soils.

But Mn toxicity suspected and confirmed in a few very sandy, acidic, Gray soils in east-central SK (L. Cowell 2016 & 2017; K. Lamb 492.3 thesis work 2018)

K. Lamb 492.3 2018 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"

Soybean plant with IDC. First yellow trifoliolate. Cotelydon and unifoliate remain green.

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.

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, one IDC tolerant.

Findings:

- 2015 very dry May, June, July. No response to Fe fertilization.
- 2016 was wetter, environment more conducive to IDC.

IDC sensitive variety (Moosomin) responded significantly to foliar Fe while IDC tolerant variety (McLeod) did not. No response to soil applied Fe fert.

Genetics best defense when IDC is 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.

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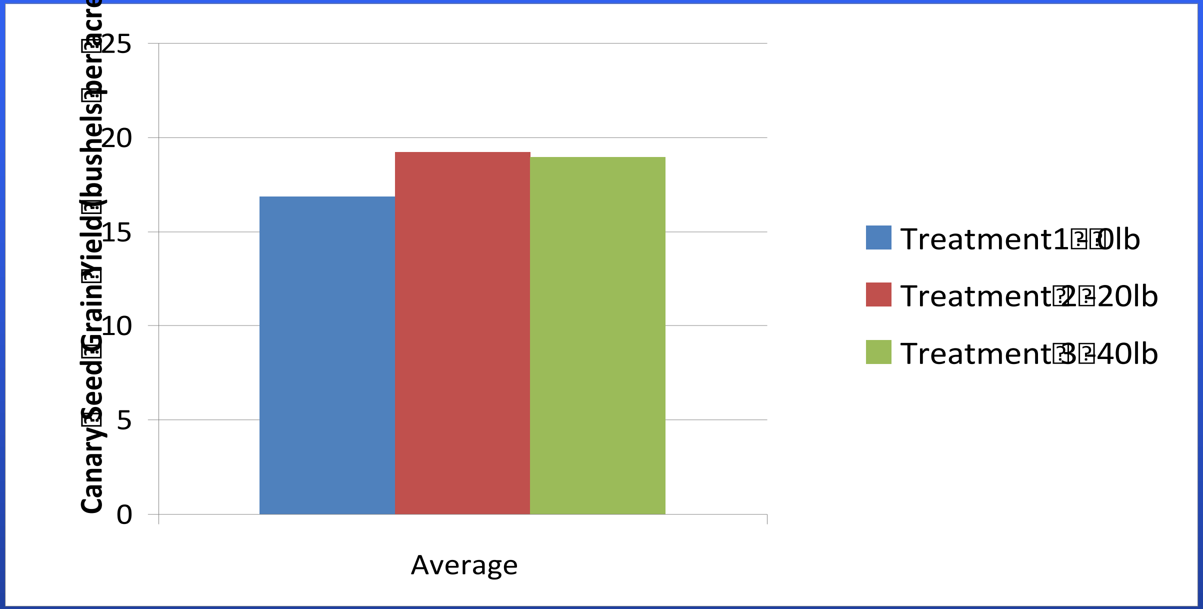
Application of 40 lb/ac of KCl increased wheat yield in foot slope positions of a landscape in southern Saskatchewan with less than 30 lb/ac of Cl 0-60cm (Schoenau et al., 1997).

More widespread use of KCl 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.
- 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.
- Multiple evidence approach best for identifying and verifying deficiency.

Will We Ever Be Able to Predict Response to Micronutrient Fertilization with High Degree of Accuracy?

http://bestpaperz.com

We’ve still got some ghost-busting to do!

unilad.co.uk

Thank you

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