Tonight's host and co-host

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Soil Micronutrient Management

Winter Soil Fertility Series: Week 4

Jan 27, 2021

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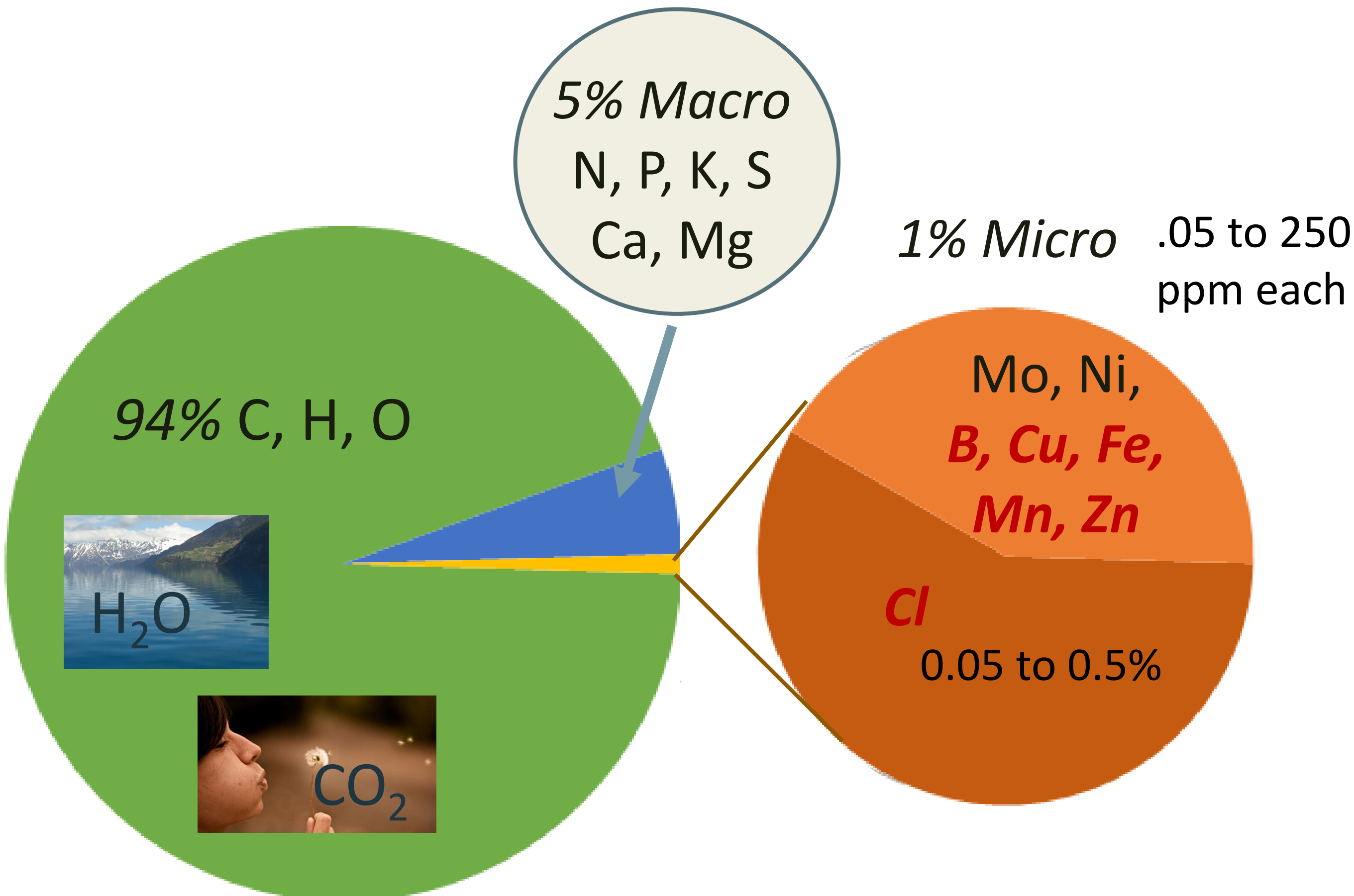
Photo by K. Olson-Rutz

Your experience with micro deficiencies? Read all answers before answering, and type answer in Chat box (e.g. ‘5’)

1. I don’t think I (or my crop adviser) have seen any
2. I’ve suspected micro deficiencies based on symptoms, but didn’t verify with tissue (or soil) testing
3. I’ve verified micro deficiencies through tissue testing
4. I’ve verified micro deficiencies through fertilizer trials
5. Both 3 and 4
6. Other

The micronutrients are simply needed in smaller amounts by the plant than the macronutrients, BUT still needed!

Nutrient amounts in dried plant material



Micronutrients found deficient in MT

0.05 ppm ≈ 1 ounce in 625 tons

Challenges with micronutrients

They are needed in very small amounts

Amount removed by an average yield per acre						
	K_2O	Fe	Zn	Mn	Cu	B
	------------------------------- lb -------------------------------					
Alfalfa (3 ton/ac)	159	1.14	0.33	0.33	0.06	0.06
Chickpea[1] (23 bu/ac)	20	0.08	0.07	0.02	0.01	--
Wheat grain[3] (45 bu/ac)	39	--	0.16	0.09	0.04	0.04
Potassium (K) is a macronutrient provided for comparison						

[1] Thavarajah & Thavarjah 2012; [2] North Carolina Extension; [3] Fertilizer Guidelines for MT Crops

Why might we be seeing, or eventually see, more micronutrient deficiencies?

There is a finite amount of micronutrients in the soil. Micronutrient deficiencies will likely increase as:

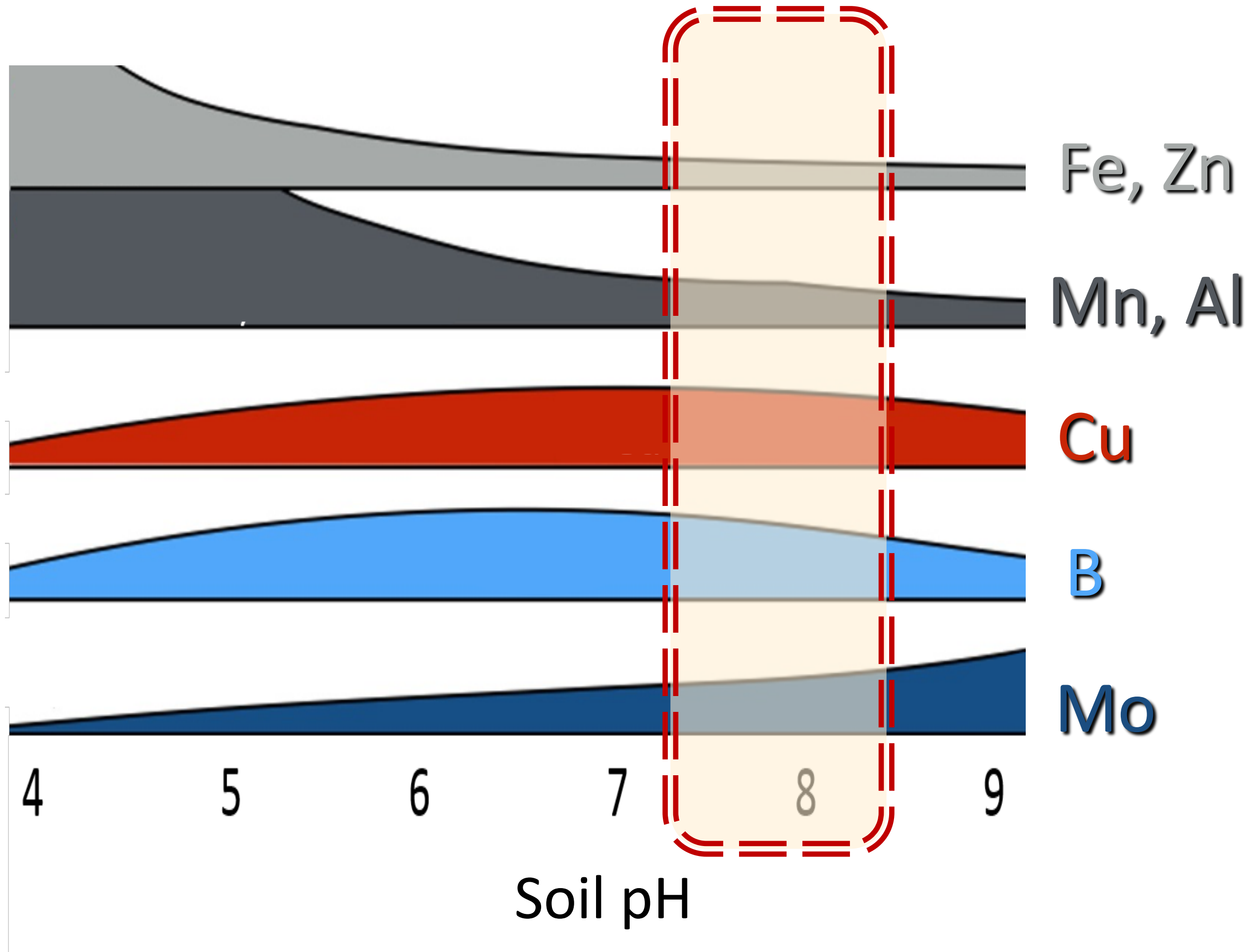
- Yields and amount removed from field increases
- No micronutrients are added (individually, in manure, or in P fertilizers*)

*example: 18-46-0 has 5.5 mg Cu/kg, 386 mg Zn/kg (Raven and Loeppert, 1997)

Micronutrient availability is limited by:

- Low SOM (<2%)
- pH > 7.5. Most Montana soils are generally pH > 7

Chloride is not affected by pH



- Cold and dry or very wet soils (poorly drained) = common MT early growing season conditions.

Mobility and processes that affect availability

Many are not mobile or very soluble in soil

Nutrient	Mobility	Limiting processes
Boron Chloride	Mobile Soluble	Leaching Harvest
Copper Iron Manganese Zinc	Immobile Insoluble	Harvest Binding to soil or forming minerals

Why is mobility important?

Affects fertilizer placement

Apply these foliar or in root zone

Total and available micronutrients in MT surface soils

Most metals are bound in minerals or soil organic matter, not immediately available to plants.

Nutrient	Total	Available
	ppm in top 0-6”	
Copper	30	2.0
Iron	38,000	15.8
Manganese	600	12.4
Zinc	50	1.2

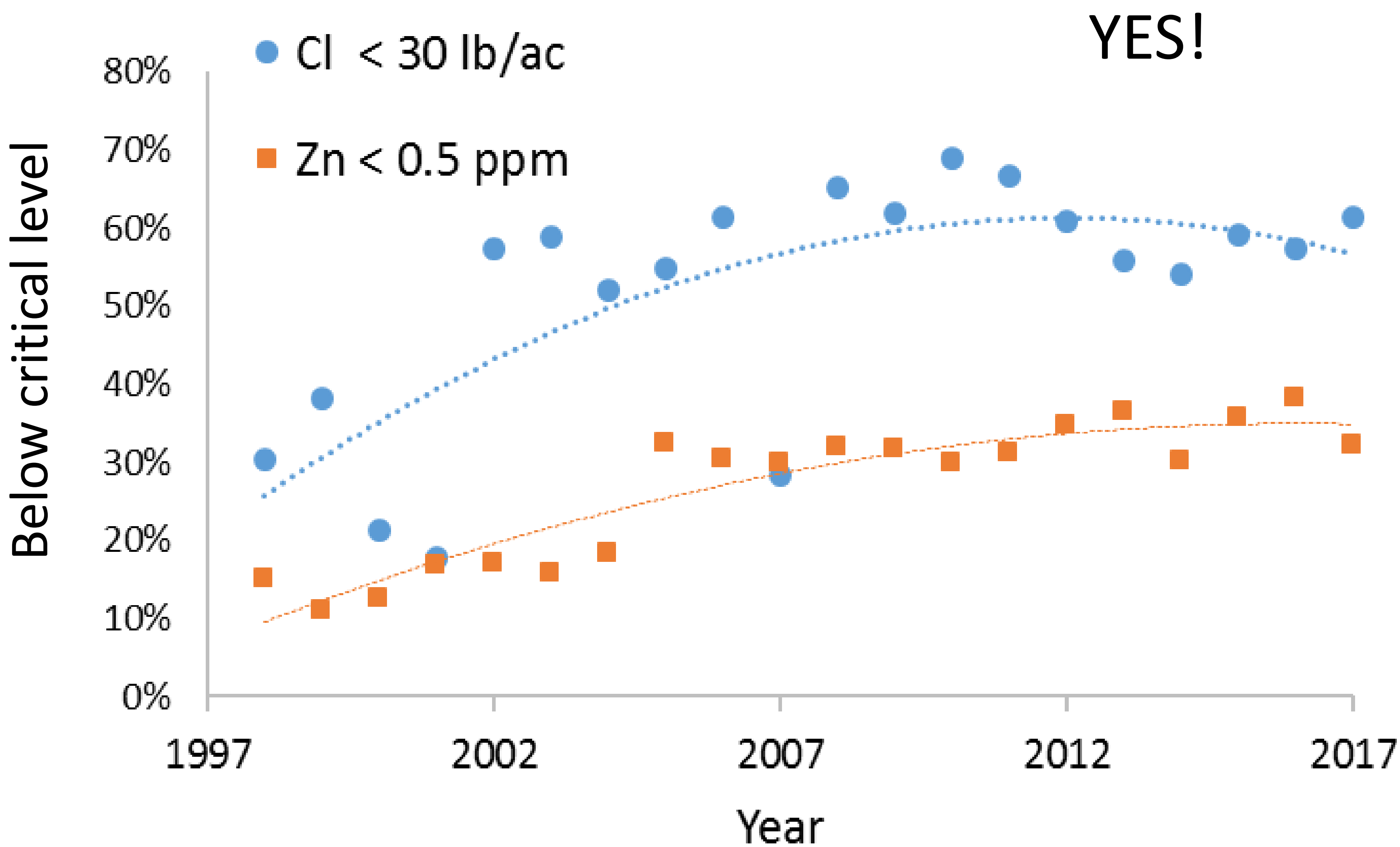
*Haby and Sims 1979, 301 samples

B, Cl, Mn and Zn most likely micronutrients deficient in MT surface soils

Nutrient	Crit level (ppm in top 0-6”)	% < Crit level*
Boron	0.8	50
Chloride	30 lb/ac	57
Copper	0.5	0.3
Iron	5	1.4
Manganese	1	34.2
Zinc	0.5	32.1

*Agvise Laboratory, 2017, 4,000 to 13,000 samples

Have % of soil chloride or zinc levels below MSU's 'critical level' increased in last 15 years in Montana?



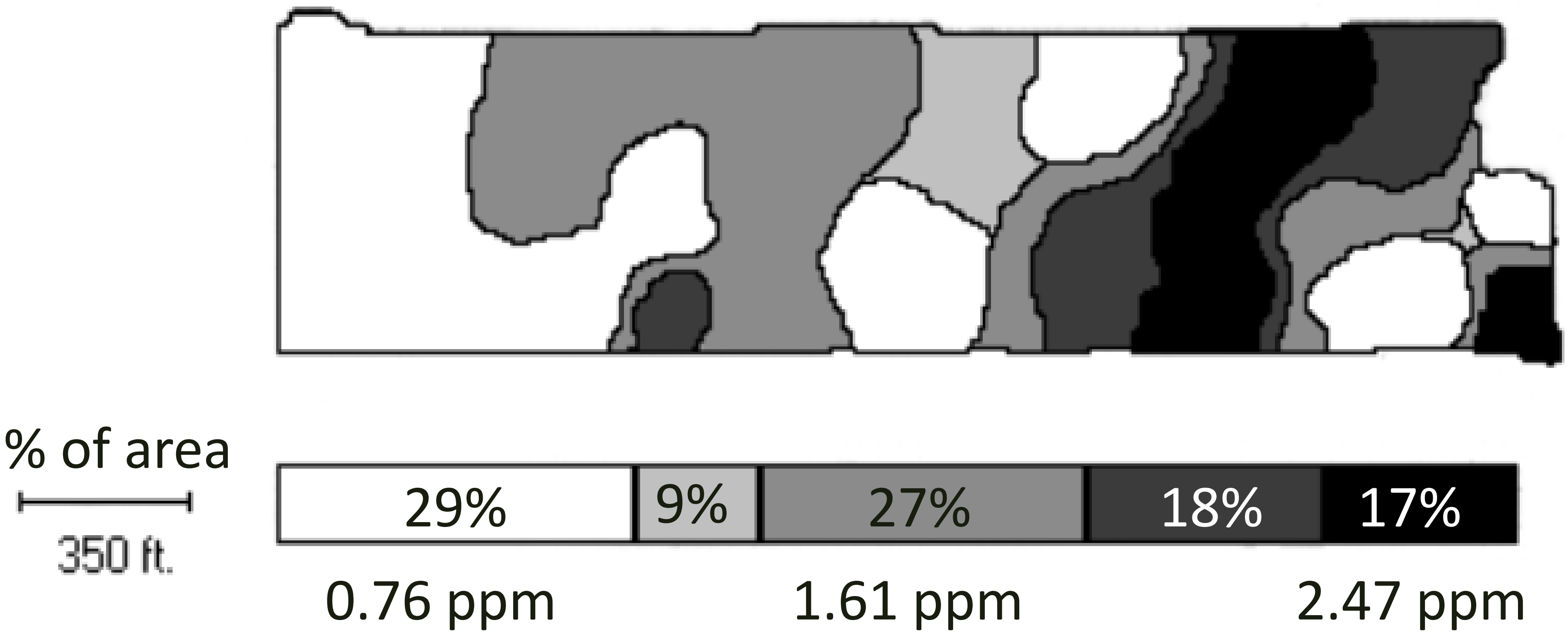
Source: Agvise, unpub. data

Soil testing for micronutrients

- Use in combination with other tools
- Tests are not highly accurate, precise, or consistent among labs
- Although published
  - Critical soil levels are not well established. Dry pea response to Fe and Mn when soil test > crit level (Fertilizer eFact No. 77); alfalfa did not respond to B on 'low' B soils (Fertilizer eFact No. 75).
  - Correlations between soil (& tissue test) levels and fertilizer rate guidelines are not well established

Spatial variation of soil test results

Cu levels on a 2-acre sampling grid of a 40-acre field near Rosetown, SK



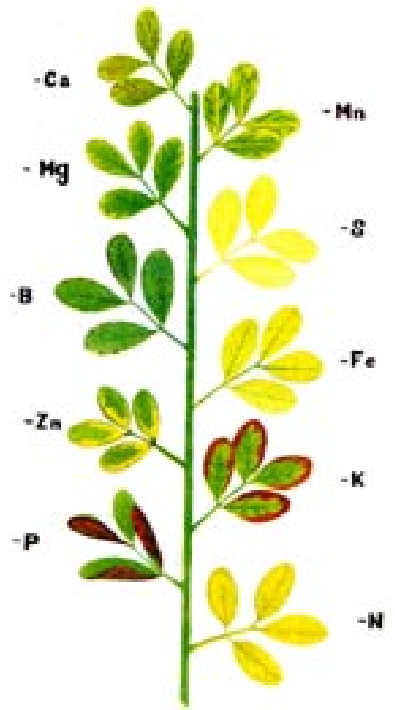
What would a field composite Cu level be?

In Flaten et al. 2000, map by Bulani Agro, Rosetown, SK

Questions?

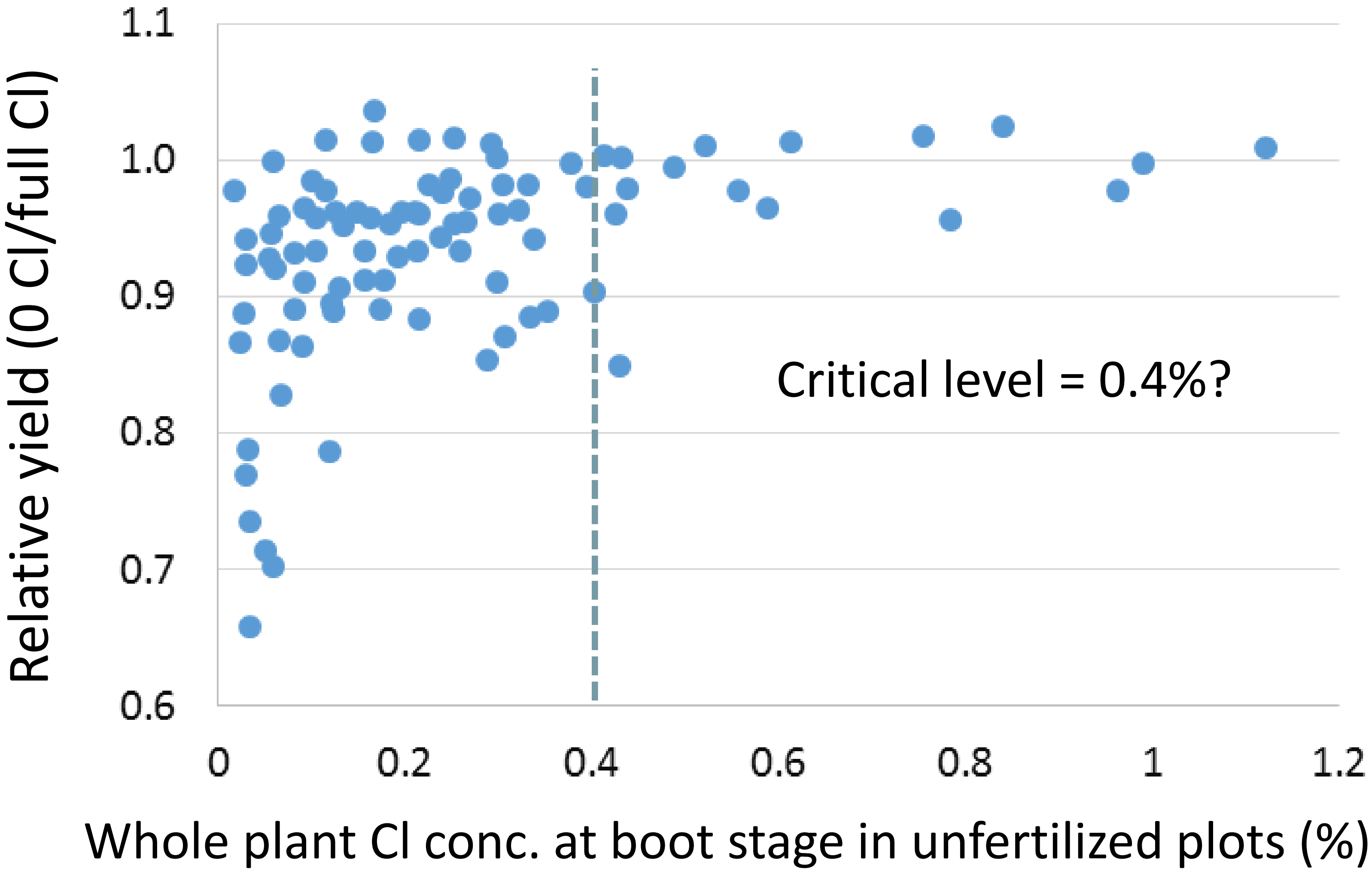
On to tissue analysis

Tissue analysis for in-season micronutrient adjustments



- Visual tissue assessment for potential deficiency See *Plant Nutrient Functions and Deficiency and Toxicity Symptoms (NMM 9):* http://landresources.montana.edu/nm
- Tissue concentrations
  - Critical tissue concentrations hard to find
  - Other than Cl, no MT guidelines based on micronut tissue tests. In 87 corn fields, only positive correlation between tissue test and yield for Cu (Stewart 2016), not for B, Fe, Mn, or Zn
  - Vary by time of day, plant part, growth stage, variety
- Once deficiency observed, potential yield may already be reduced

Wheat tissue Cl concentration



Fertilizer Fact No.3
96 variety x size trials over 4 Great Plains states

Base decision to fertilize micronutrients on multiple sources

- Soil test alone not reliable: for ex. 1 lb Zn/ac foliar on pea in veg stage (Mohammed and Chen 2018)
  - Soil test levels adequate, yield increase at one site (wet and dry year), not at other site (dry year), grain Zn no change
  - Soil test level low, no yield increase, grain Zn varied (wet year)
- Field scout for visual deficiency See *Plant Nutrient Functions and Deficiency and Toxicity Symptoms*, or online https://landresources.montana.edu/soilfertility/nutrientdeficiencies.html
- Test plant tissue: few guidelines for tissue test and fert recommendation, and test results vary with plant part and maturity, time of day, handling

➢ Do on-farm strip test trials

Questions?

On to sources, timing, placement

Micronutrient fertilizers

- Micronutrient "guarantee analysis" ≠ "guarantee availability"
- Availability in granular fertilizer related to water solubility and not total nutrient content
- Relative Availability Coefficient (RAC) – for Zn >50% to be effective with current crop (Westfall et al. 2005)
- Some fertilizers contain heavy metals in excess of safe levels (Westfall et al. 2005)

Iron sulfate (Miracid)

Iron oxide

Common micronutrient forms (Source: Gov. of SK)

Form	Availability	Nutrients	Apply to:
Sulfate (salts)	Water soluble, plant available but less so at high pH	Cu, Fe, Mn, Zn	Soil
Chelate	Plant available form	Cu, Fe, Mn, Zn	Soil or Foliage
Oxysulfate	Oxide portion not very available, S portion is, should be > 50% water soluble	Cu, Fe, Mn, Zn	Soil
Oxide	Bound with O_2, not soluble, needs to be converted	Cu, Fe, Mn, Zn	Soil
Manure	Bound in OM, but slowly released	Cu, Zn	

Micronutrient source affects application timing and method

Timing

- Soluble in spring: Borate, chelated, sulfate, or high solubility (>40%) oxysulfate
- Low soluble in fall: Oxide and low (<40% soluble) oxysulfate

Method

- Broadcast and incorporated ideal, challenge to get even distribution of a very small quantity
- **B should not** be seed-placed or subsurface band (toxicity)
- Foliar applications:
  - Safe with borate at low levels, chelated Cu, Fe, Mn, Zn
  - Caution with sulfate, oxysulfate

Karamanos 2000, Gerwing and Gelderman 2005

Foliar application of micronutrients

Micronutrients should not be applied unless deficiency is identified through:

- soil analysis (see *Fertilizer Guidelines for MT Crops* for soil applied fertilizer guidelines)
- tissue sampling
- visual deficiency symptoms (see *Plant nutrient functions and deficiency and toxicity symptoms*)

In-season micronutrient adjustments

- Use visual tissue assessment for potential deficiency See *Nutrient Deficiency and Toxicity* website

https://landresources.montana.edu/soilfertility/nutrientdeficiencies.html

- Use tissue concentrations – other than for chloride there are no MT guidelines for micros based on tissue tests

- Once plant shows deficiency, potential yield may already be reduced

Questions?

On to crop response

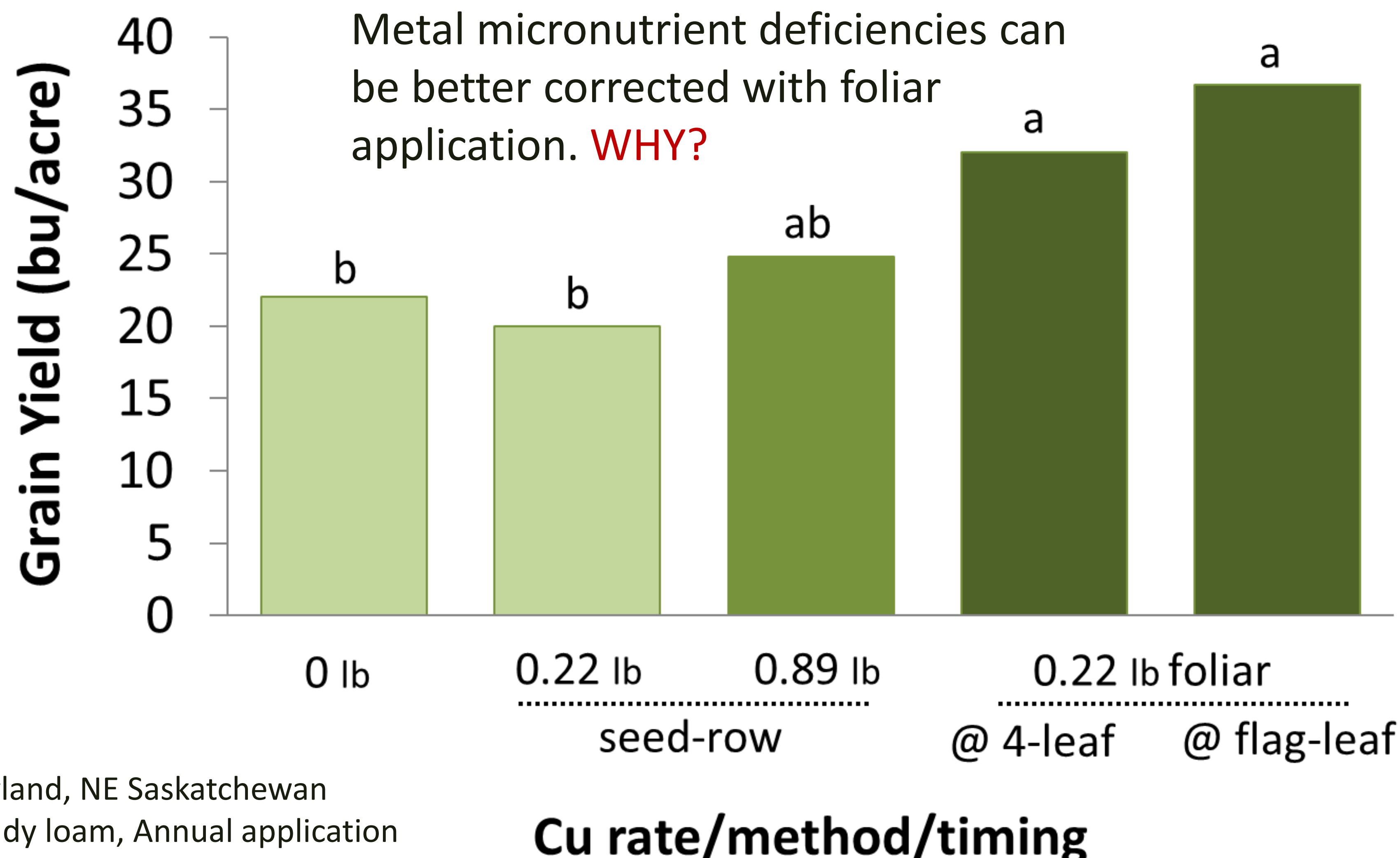
Relative response to micronutrients

	Response to micronutrient (Voss 1998)				
Crop	Boron	Copper	Iron	Manganese	Zinc
Wheat	Low	High	Low	High	Low
Barley	Low	Medium	Medium	Medium	Low
Sugar beet	Medium	Medium	High	High	Medium
Alfalfa	High	High	N/A	Low	Low
Grass	Low	Low	High	Medium	Low

Karamanos pers. com. Zn response low in oat, pea, canola, even when plants and soils show deficiency. High response by corn

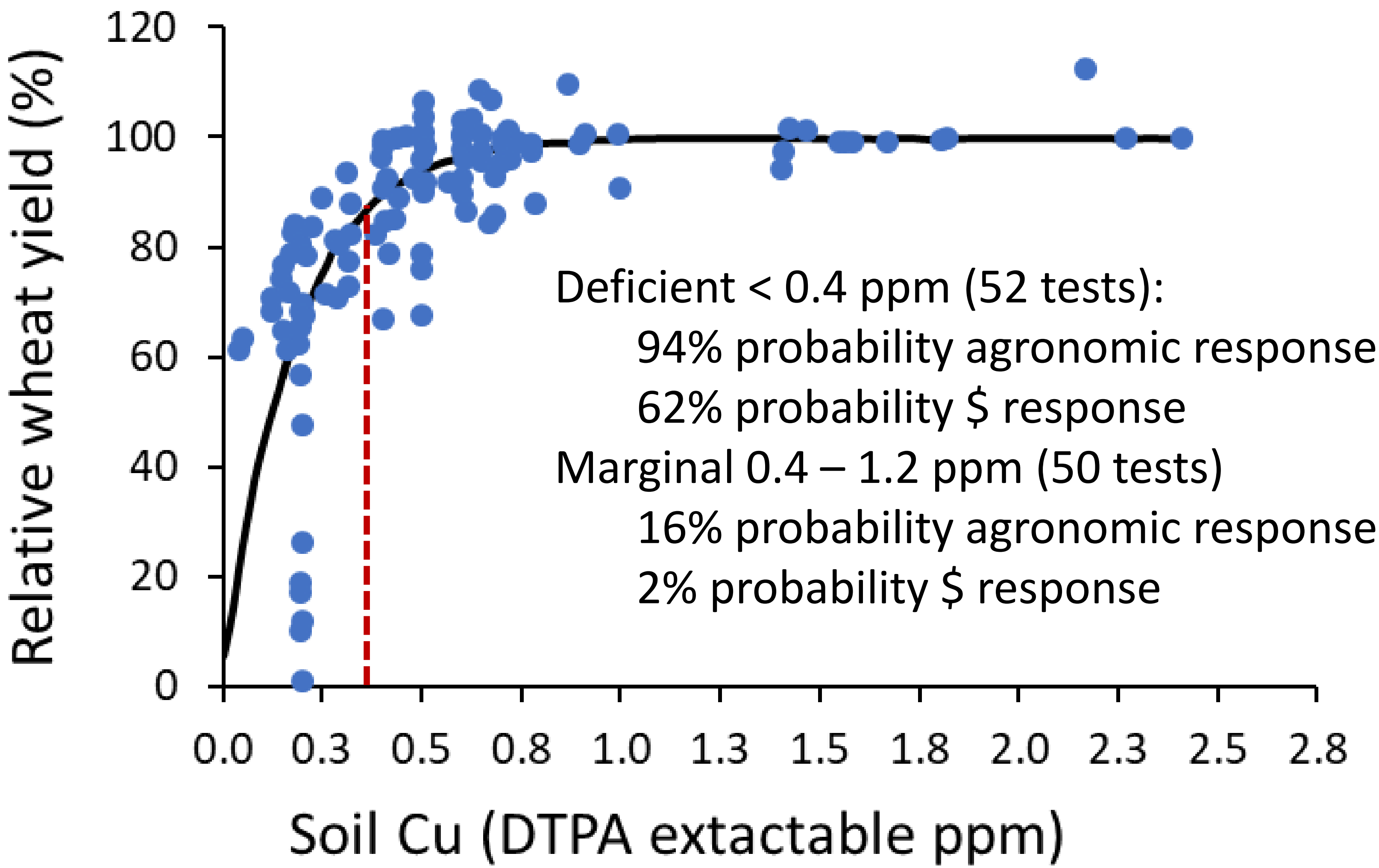
Copper Rate, Method and Timing Affects SW Grain Yield

Metal micronutrient deficiencies can be better corrected with foliar application. WHY?



Dryland, NE Saskatchewan
Sandy loam, Annual application
Soil Cu 0.4 ppm
Malhi et al. 2005

Soil tests for Cu



100+ wheat trials in AB, SK, MB, assorted soils

Karamanos et al. 2003

Cu sources and rates

Image courtesy PPI

- Economic responses only with:
  - 0.2 lb Cu/ac **foliar** as $CuSO_4 \cdot 5H_2O$ or Cu-chelate
  - 2 to 4.5 lb Cu/ac ($CuSO_4 \cdot 5H_2O$) or 0.4 to 1.8 lb Cu/ac (Cu-sulfonate) **soil applied and incorporated**
- Chelates generally do not make $ sense soil applied
- Low soluble sources do not correct deficiency
- > 4.8 lb Cu/ac $CuSO_4 \cdot 5H_2O \rightarrow$ yield decline

Karamanos et al. 2003, Goh and Karamanos 2006

Cl on small grains

- Cl is very mobile - may need more if leaching or yield potential is high. 20 lb KCl/acre annually should provide enough.

Image courtesy R. Engel

- Over 210 trials in KS, MN, MT, ND, SD, MB and SK have evaluated Cl-response in wheat and barley*
- Significant yield response in 48% of trials*
- Average response of 5 bu/acre*
- Especially consider KCl for barley varieties with low disease tolerance

*Source: Cindy Grant, Agriculture and Agri-Food Canada

Cl reduces leaf spot, increases yield and shoot Cl concentration in durum wheat

Fertilizer Cl (lb/ac)	Flag Leaf Spot Severity (%)	Yield (lb/ac)	Shoot Cl (ppm)
0	87	2954	540
40	6	3615	5520
All differences are significant with 95% confidence. Initial soil Cl was 0.6 to 0.7 ppm in upper 3 ft (~8 lb Cl/ac)			

Poplar, MT, Engel et al. 2001

Questions?

Zn for grain yields and human health

Image courtesy IPNI

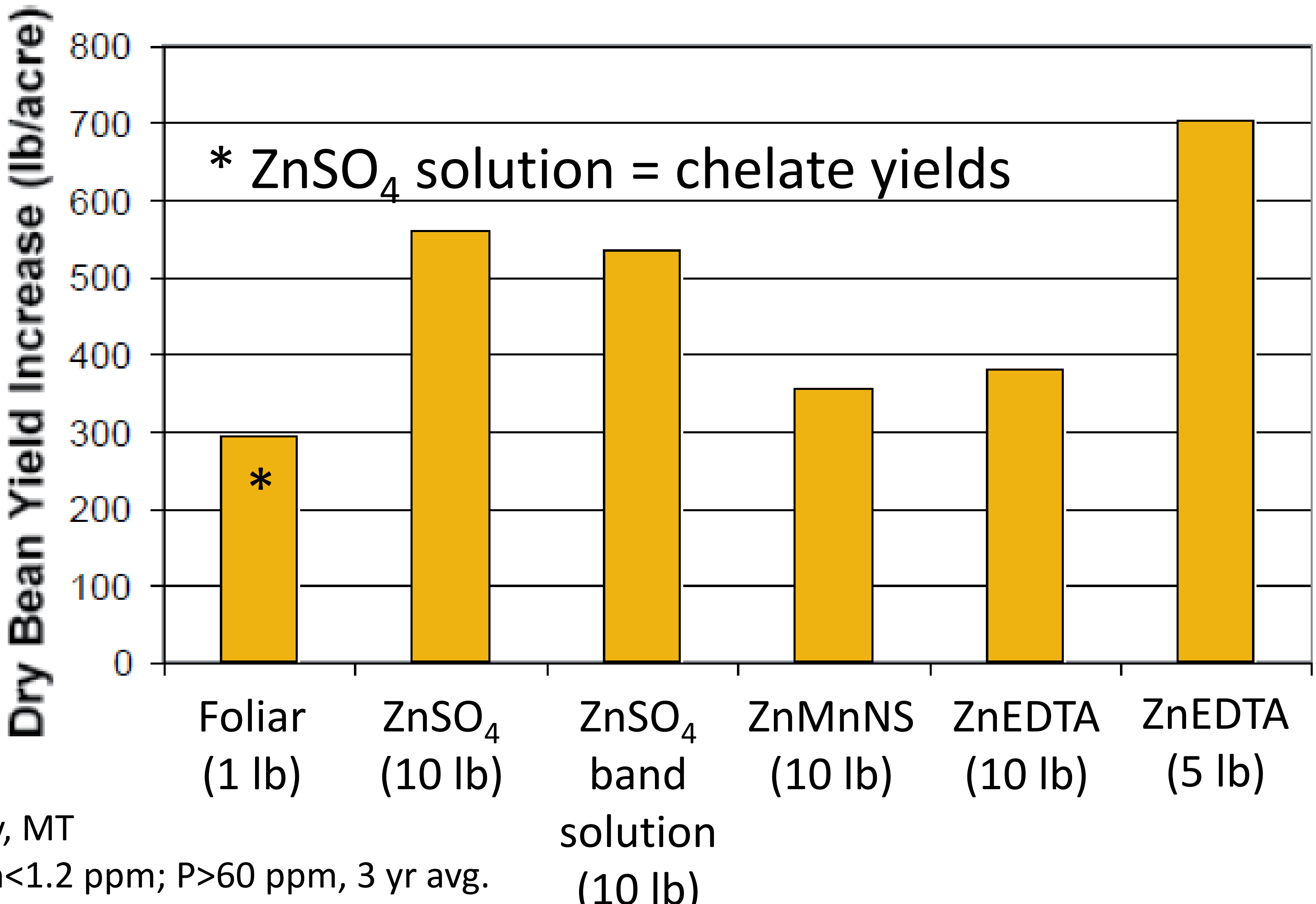
- Foliar Zn before flowering → increase grain yield and Zn concentration (Budak et al. 2018).
- Selecting for high yield → decreased seed Zn concentration (Ippolito 2020). Potential to select for high Zn in spring wheat.
- >20% world's children suffer stunted growth from Zn deficiency (The International Zinc Nutrition Consultative Group)
- 26 countries have mandatory minimum wheat grain Zn concentration standard (average 47 ppm)
- MT's grain could contribute to improved health worldwide

Zn for wheat grain yield and Zn concentration

Foliar Zn	Yield increase (%)	Grain Zn concentration increase (%)	Net return ($/ac)
1 lb/ac at heading	5	17 – 47	- $0.40
1 lb/ac heading + 1 lb/ac at flowering	14	35 – 95	$5.25
Afshar et al. 2020, MT			

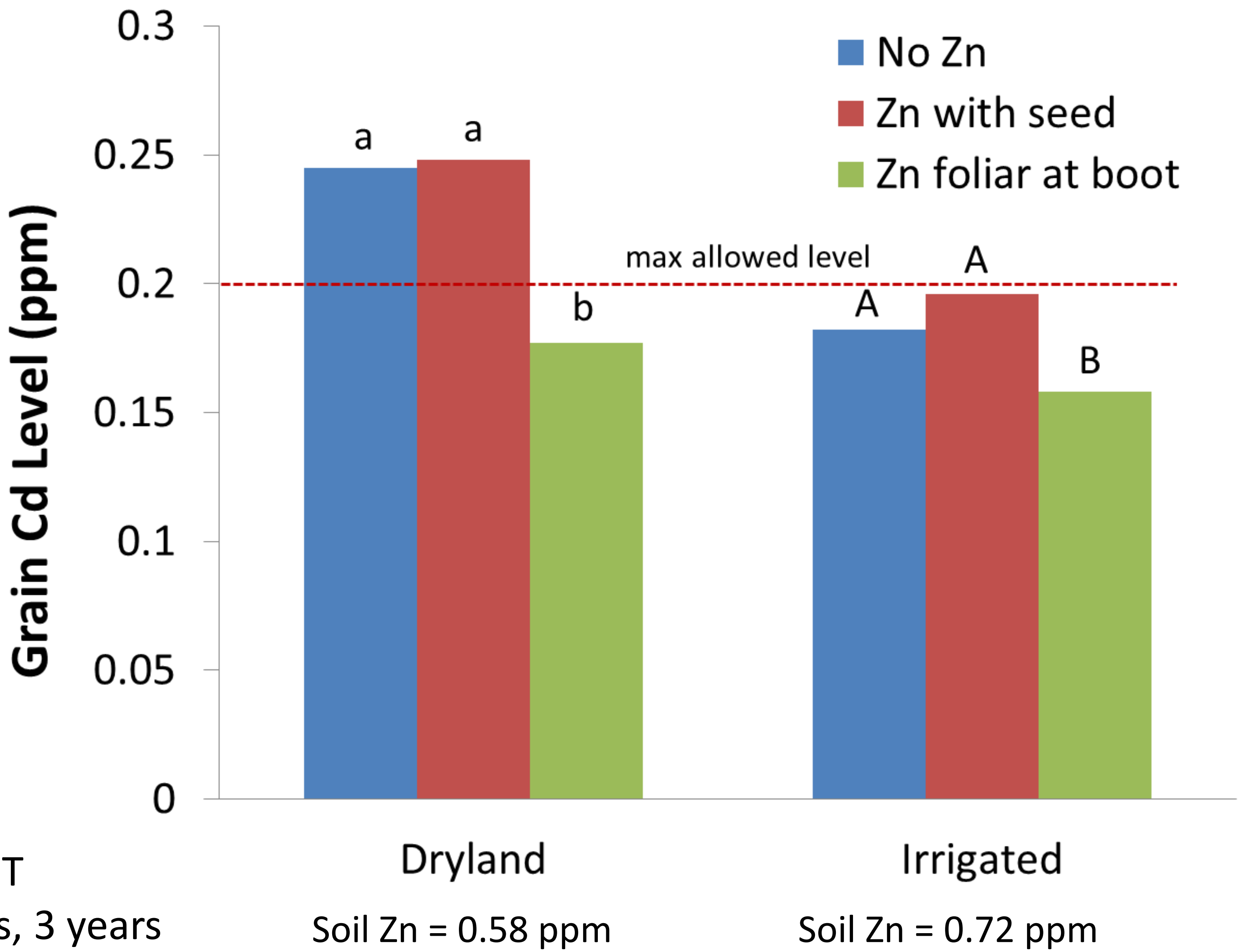
- 2 lb/ac required to bring grain Zn > 40 ppm
- Price incentives for high Zn grain would help encourage farmers to grow more nourishing wheat

Foliar (2-4 weeks after emergence), fall broadcast-incorporated or banding Zn (lb/acre) increased irrigated dry bean yields



Sidney, MT
Soil Zn<1.2 ppm; P>60 ppm, 3 yr avg.
Halvorson and Bergman 1983

Foliar Zn at boot decreases durum wheat grain cadmium (Cd) level (though did not increase yield)

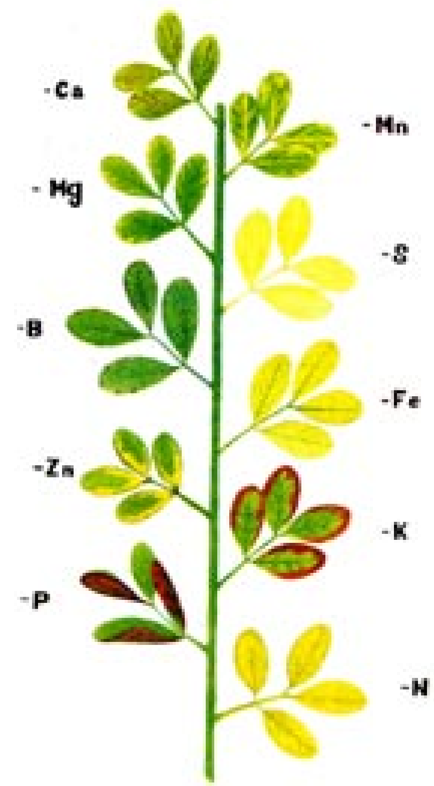


Sidney, MT
2 varieties, 3 years
Fertilizer Fact 54

Conclusions: micronutrients

- A combination of deficiency symptoms, soil testing, and tissue testing (for Cl) may be best approach.
- Micronutrient deficiencies are exception, not rule, and are variable within fields
- Cool wet conditions can cause deficiency
- Too much micronutrient (e.g. B) may hurt yield more than not enough
- Read product label: look for ‘available’ micronutrients and watch for heavy metal contamination
- *Most conclusive test is your own field strip trials*

For additional information



Soil Fertility Website:

http://landresources.montana.edu/soilfertility

Nutrient Management Module #7 on micronutrients

Nutrient Management Module #9 on deficiency symptoms

Nutrient Management Module #11 on fertilizer placement
http://landresources.montana.edu/nm

Photo by Ann Ronning

Thank you!
Questions?

Future sessions
Feb 3: Forage Nutrient Mgt
Feb 10: Sustainable Nutrient Mgt
Feb 13: Cover crops

This presentation and more information on soil fertility is available at http://landresources.montana.edu/soilfertility