Micronutrients: Are they worth getting up before 8:00 am?

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MONTANA STATE UNIVERSITY EXTENSION

Goals Today

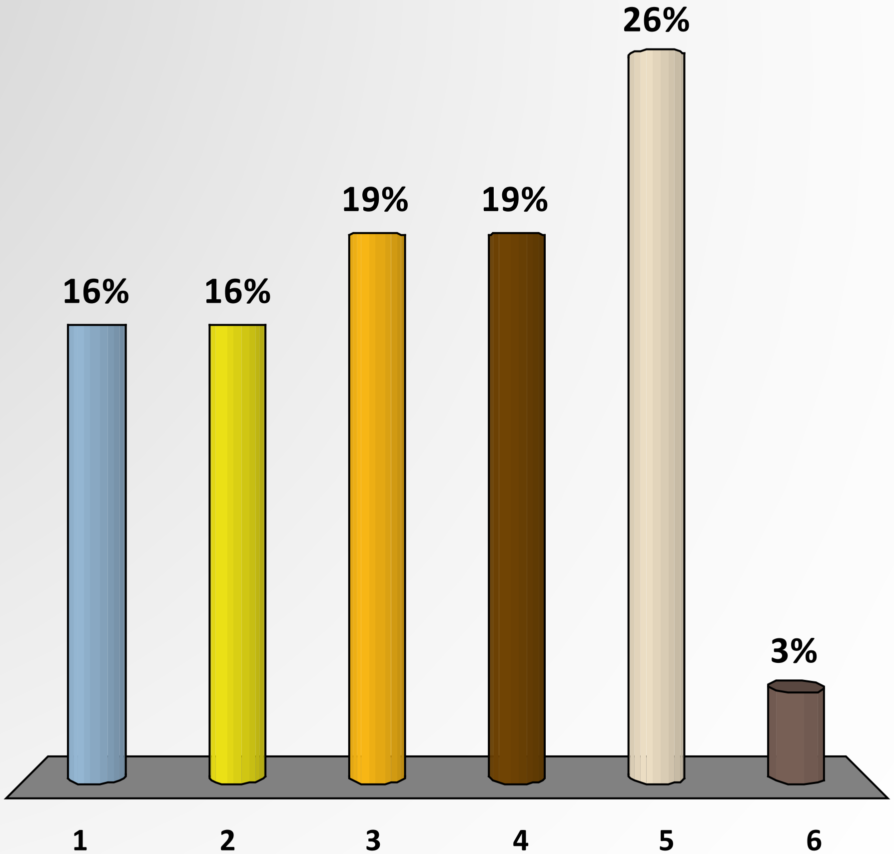
- Explain which micronutrients may be deficient in MT soils and why
- Describe ways to determine if micronutrients are deficient
- Determine micronutrient fertilization rates
- Discuss management options for adjusting these nutrients levels
- Help you make more informed recommendations to your clients on micros

But first, some questions to help us assess impact of Rick Engel's and my work on urea volatilization

What percentage of urea would you estimate is lost to the air from volatilization if urea is broadcast (no-till) between mid-fall and early spring and not incorporated into the soil, ON AVERAGE?

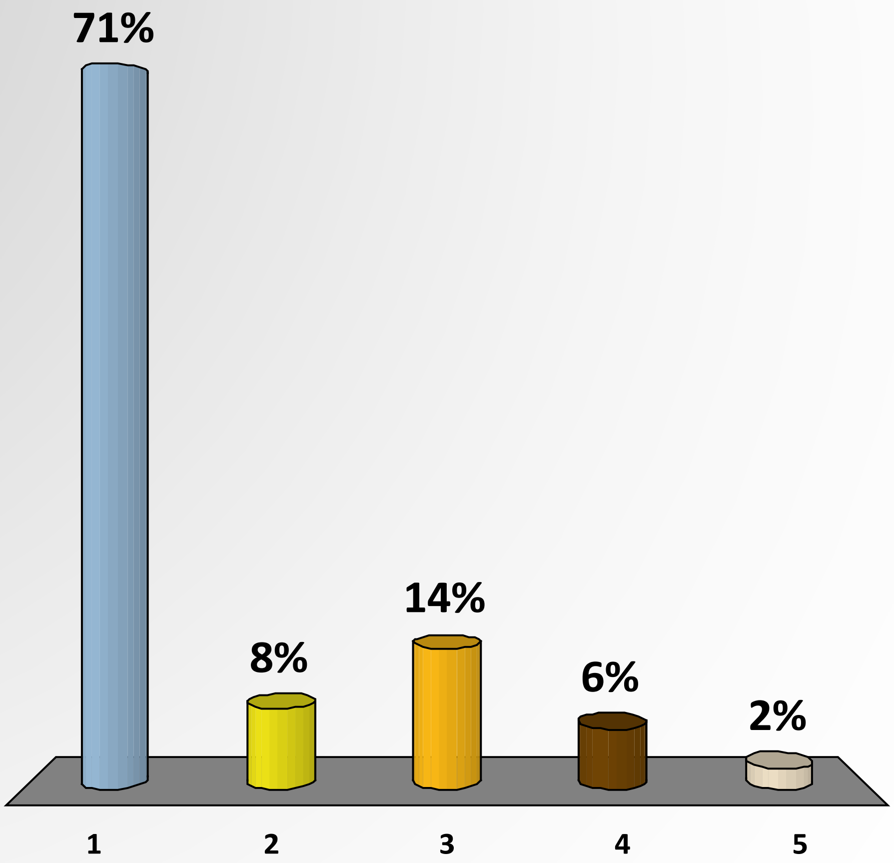
1. 0 to 10%
2. 10 to 20%
3. 20 to 30%
4. 30 to 40%
5. > 40%
6. I'm still asleep – ask me later

Based on 20+ studies: ~18%



What do you think are worst case conditions for urea volatilization?

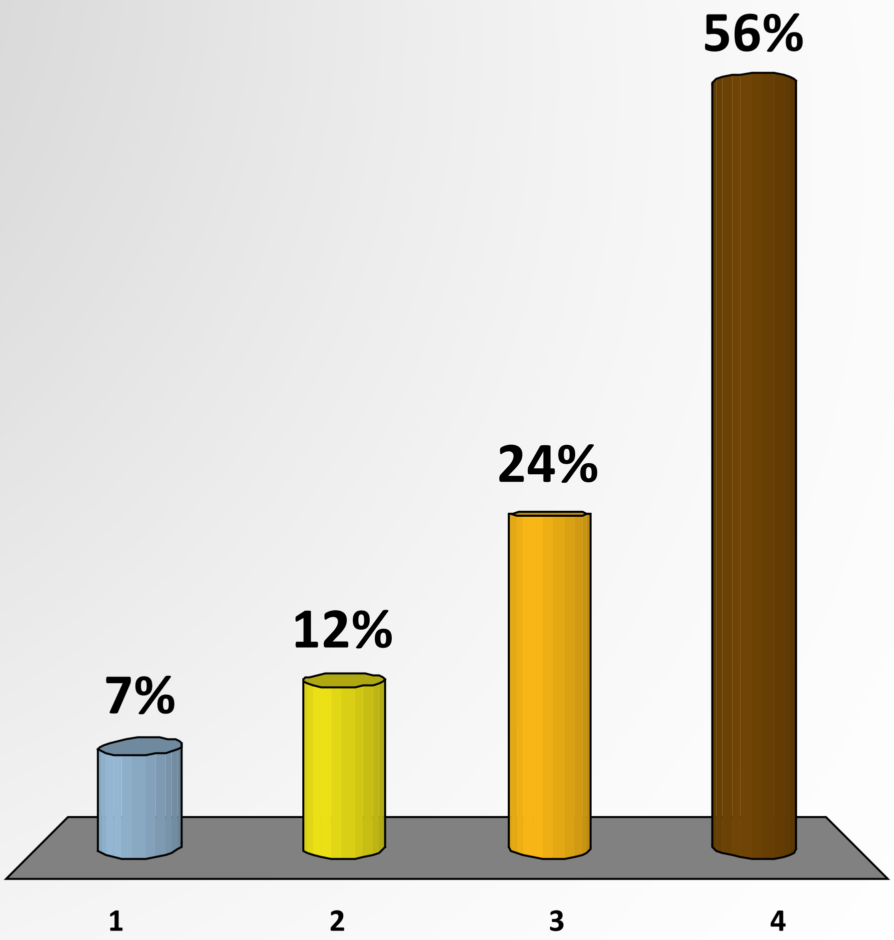
1. Warm and moist soil surface with only sprinkles for 2 weeks
2. Cold and moist soil surface with only sprinkles for 2 weeks
3. Warm and dry soil surface followed quickly by > 0.5 inches of rain or irrigation
4. Cold and dry soil surface followed quickly by > 0.5 inches of rain or irrigation
5. I don’t know



1 is correct based on ours and others research

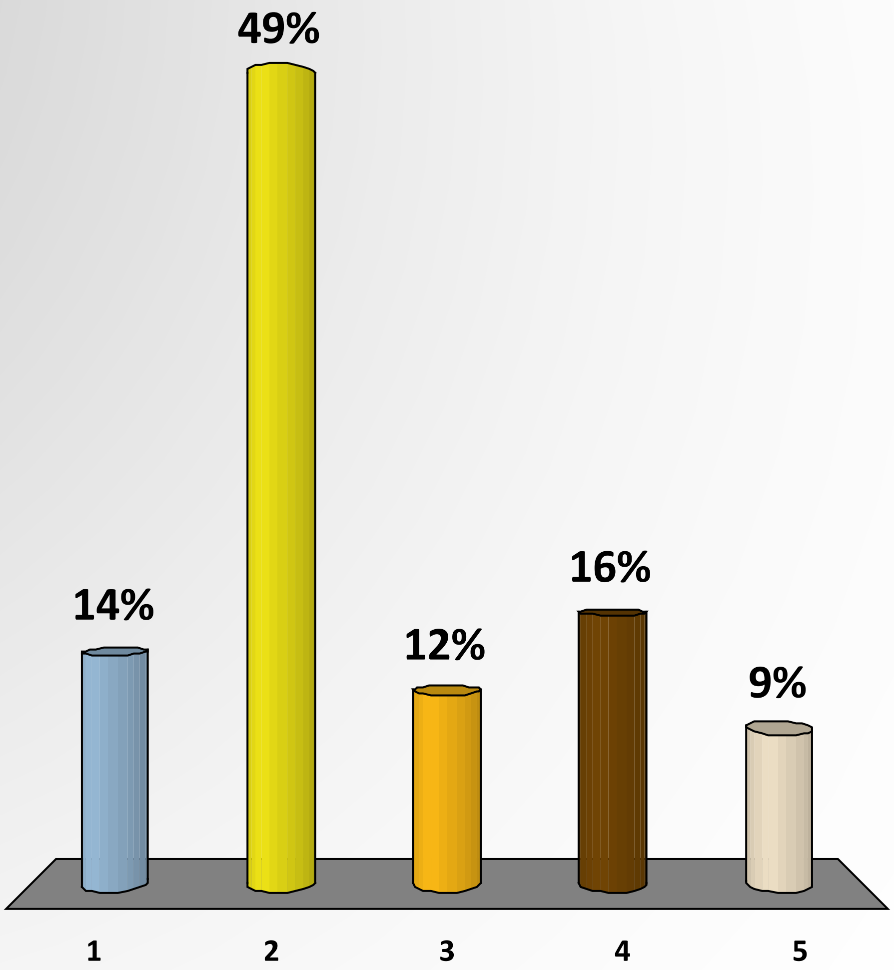
Have you made any management changes or recommended management changes based on MSU's urea volatilization research?

1. No, I didn't know about the research
2. No, but I plan to
3. Yes, but don't think they decreased volatilization
4. Yes, and think they decreased volatilization



If you have made management changes (answered 3 or 4 on previous question), what was your biggest change?

1. I now try to apply urea immediately before rain or irrigation
2. I now recommend use of a fertilizer designed to decrease volatilization (like Agrotain)
3. I now subsurface band or incorporate more of my client's urea
4. I now try to apply only to dry soil surfaces
5. Other



There are 8 mineral micronutrients that have been found to be essential for growth of most plants:

Deficiency observed in MT	No known deficiency in MT
Boron (B)	Molybdenum (Mo)
Chloride (Cl)	Nickel (Ni)
Copper (Cu)	
Iron (Fe)	
Manganese (Mn)	
Zinc (Zn)	

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*)

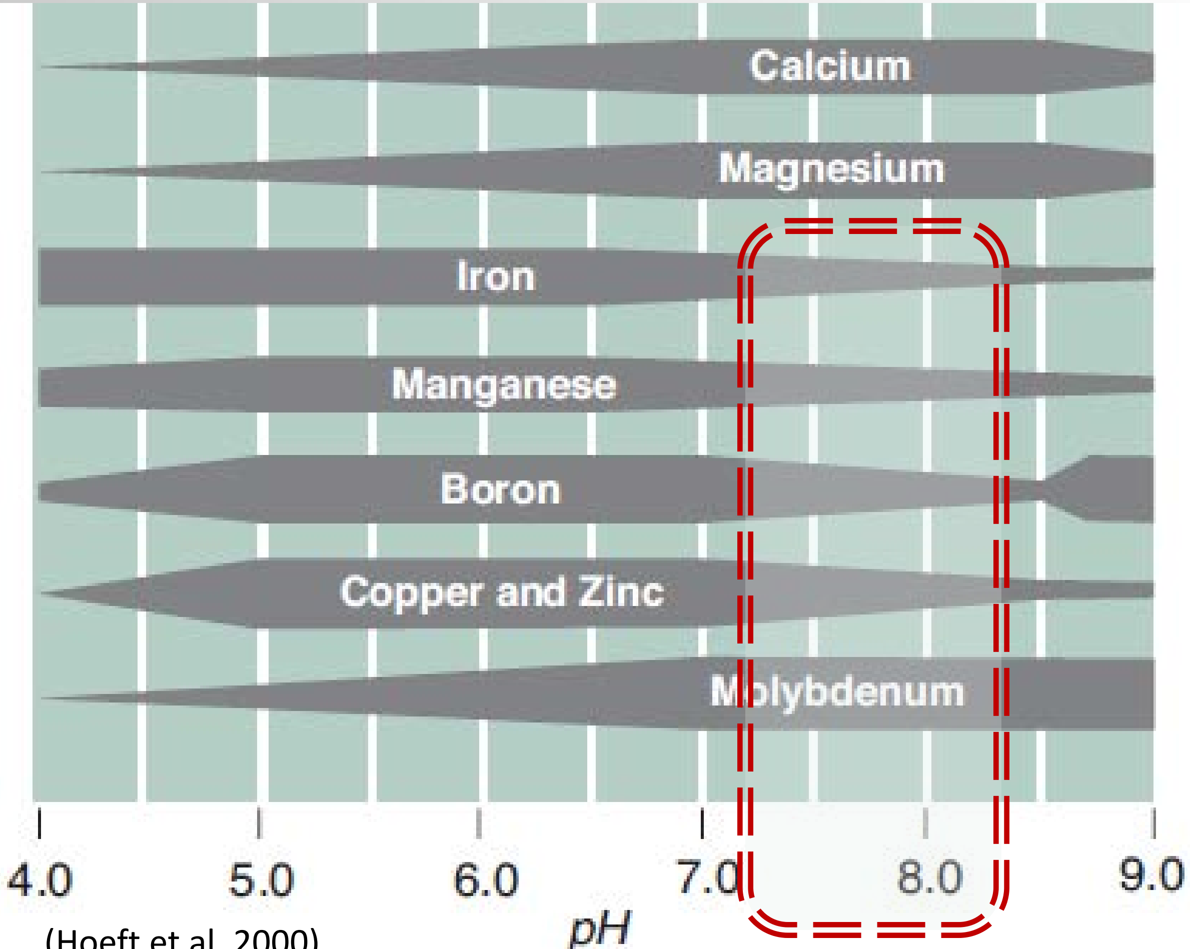
*example: 8-46-0 has 5.5 mg Cu/kg, 386 mg Zn/kg (Raven and Loeppert, 1997)

Conditions that affect availability

Nutrient	Limiting conditions
Boron Chloride	Low Cl in rain (MT) Very wet or very dry Coarse, sandy <2% SOM (B) pH >7.5 (B)
Copper Iron Manganese Zinc	Cool and wet <2% SOM Poorly drained (Fe) Coarse and dry (Cu) pH >7.5

Soil pH affects micronutrient availability

Chloride is not affected by pH



(Hoeft et al. 2000)

Mobility and processes that affect availability

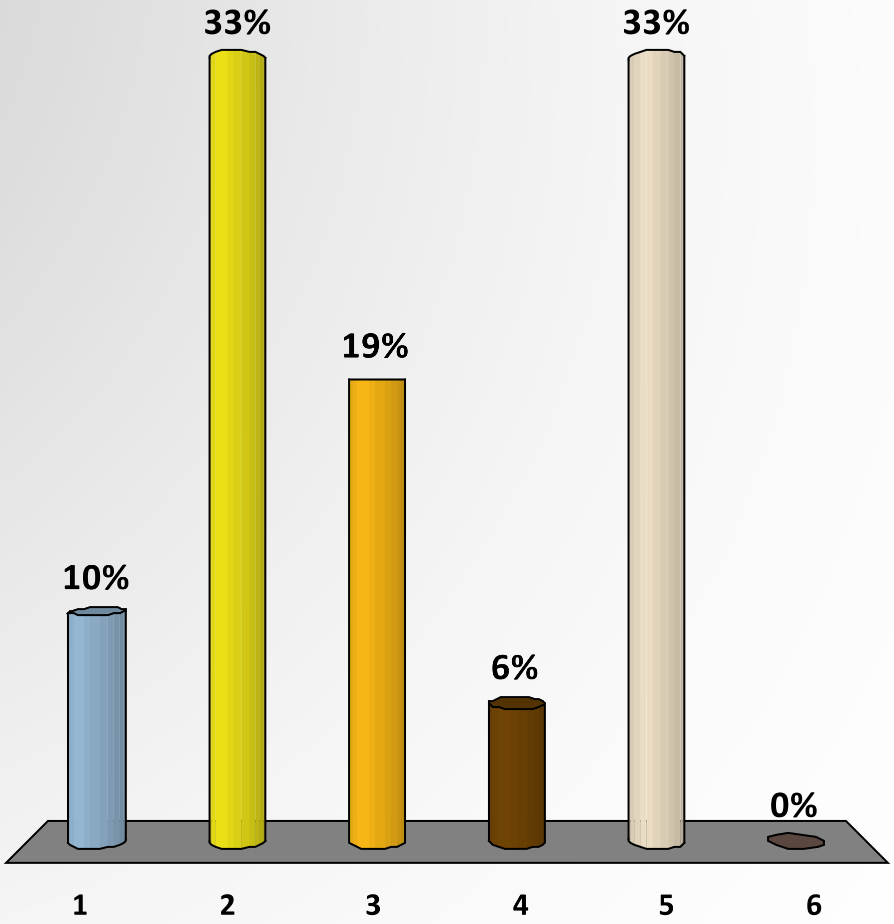
Nutrient	Mobility	Limiting processes
Boron Chloride	Mobile Soluble	Leaching Harvest
Copper Iron Manganese Zinc	Immobile Insoluble	Harvest Binding to soil or forming minerals

Why is mobility important?

Affects fertilizer placement

Your experience with micro deficiencies (read all answers before answering)

1. I don't think I've seen any
2. I've suspected micro deficiencies based on symptoms, but didn't verify with tissue 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



Micronutrient fertilizer guidelines based on soil analysis (EB0161)

	Soil test (ppm)					
	< 0.25	0.25 – 0.5	0.5 – 1.0	1.0 – 2.5	2.5 – 5.0	> 5.0
Nutrient	**Fertilizer rate (lb/acre)**					
Boron	2	2	1	0	0	0
Copper	2	2	0	0	0	0
Iron	4	4	4	4	2	0
Manganese	20	20	10	0	0	0
Zinc	10	5	0	0	0	0
Chloride	30 lb /acre is generally considered critical level					

See *Micronutrients: Cycling, Testing and Fertilizer Recommendations*
http://landresources.montana.edu/soilfertility

Under “Extension Publications” then “Nutrient Management Modules”

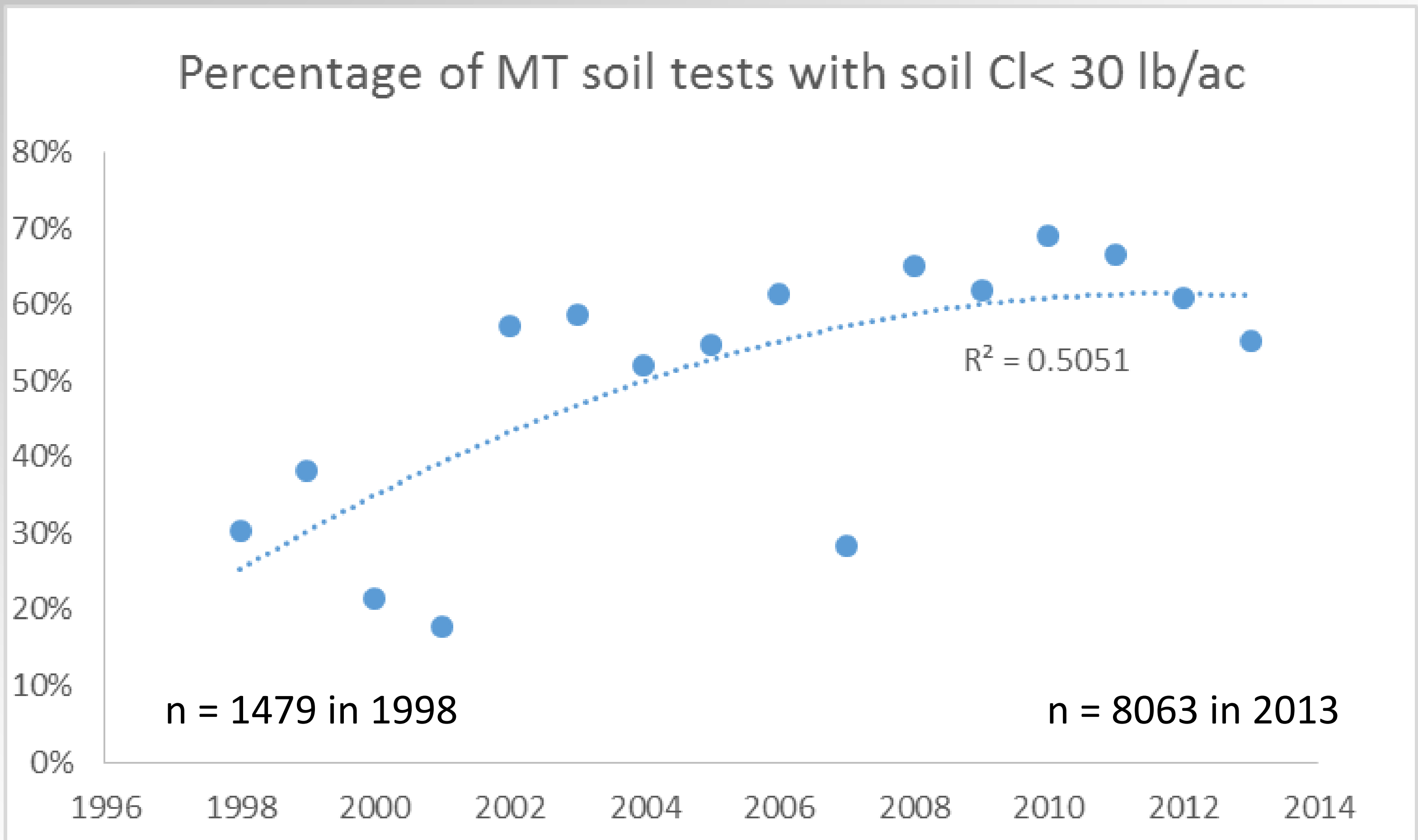
Selected total and available micronutrients in MT surface soils in past 34 years

	1979* (n=301)		2013 (n=5330)
	Total	Available	Available
Nutrient	(ppm in top 0-6")		
Copper	30	2.0	1.1 (0.5 crit lev)
Iron	38,000	15.8	20.1 (5 crit lev)
Zinc	50	1.2	0.9 (0.5 crit lev)

The majority of metals are bound in minerals or soil organic matter, not immediately available to plants. *Haby and Sims 1979

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

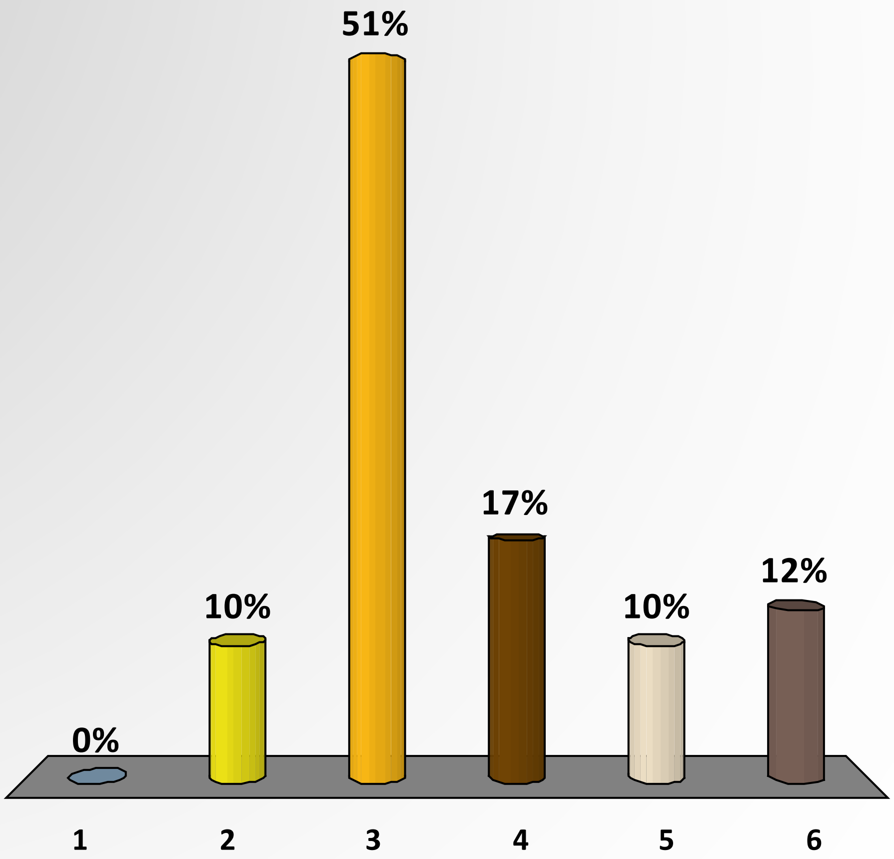
YES!



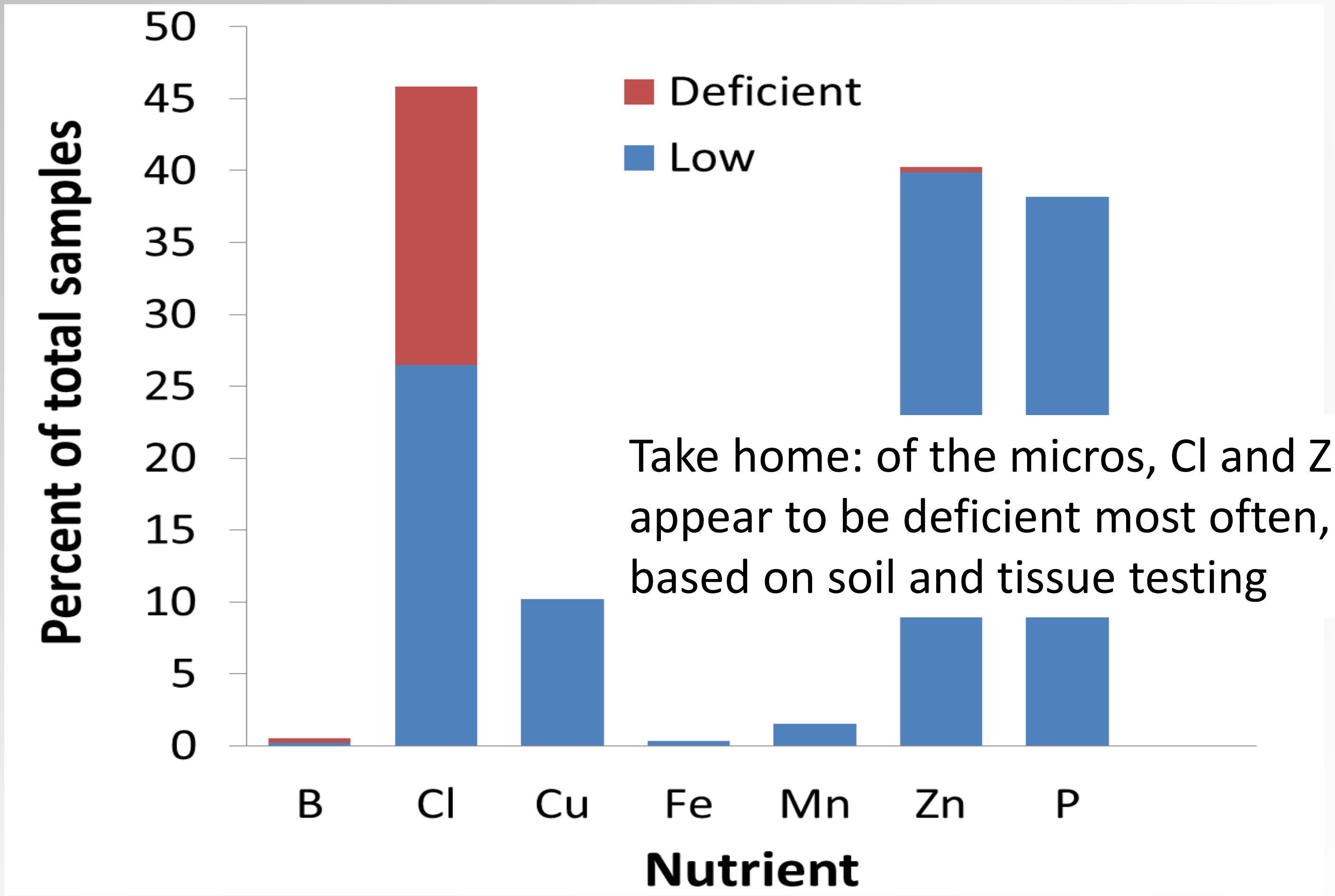
Source: Agvise, unpub. data

What has been your percent change in soils submitted to labs in last 10 years?

1. > 25% fewer in 2013
2. Little change (+/- 25%)
3. 25 – 100% more
4. 100 – 200% more
5. > 200% more
6. Do I look that old? I haven’t been crop advising for that long.



Small grain tissue nutrient concentrations from Montana in 2013 (source: Agvise, n=589)



Take home: of the micros, Cl and Zn appear to be deficient most often, based on soil and tissue testing

There may be error b/c many samples are not the correct plant part and there may be bias because more samples with deficiency symptoms are submitted than w/o symptoms

Questions so far?

Response to micronutrients

	Response to micronutrient				
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

Voss 1998

Micronutrient fertilizer application timing and method

Timing

- Borate, chelated or sulfate forms: Spring
- Oxysulfate forms: Fall

Method

- Preferred method is broadcast and incorporated – except chelated iron and manganese are best foliar
- Seed-placed and subsurface band is generally not recommended (due to toxicity)
- Foliar applications use less than ½ the suggested rate. Can be done with borate, and chelated copper, iron, manganese and zinc

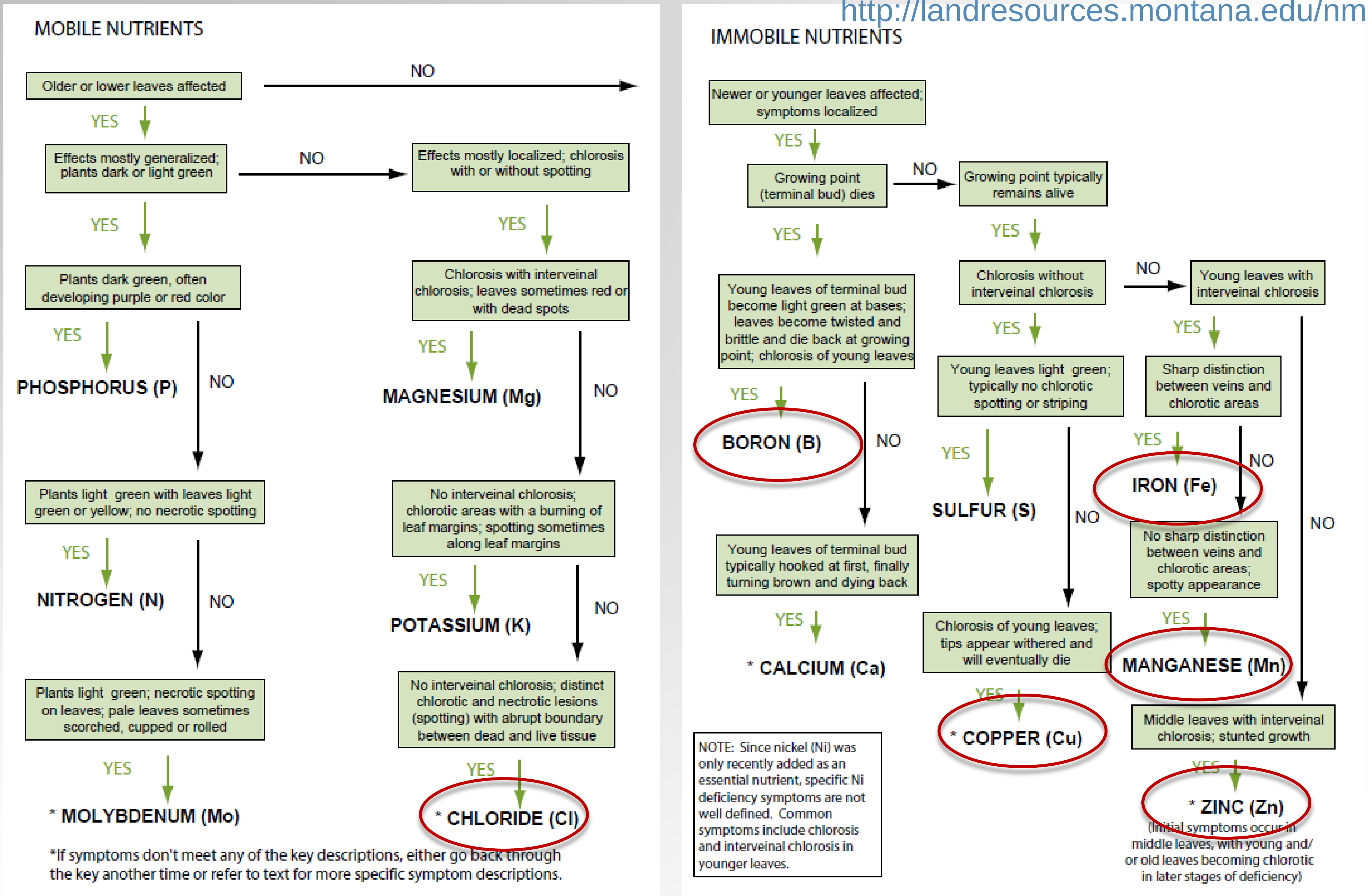
Karamanos 2000, Gerwing and Gelderman 2005

In-season micronutrient adjustments

- Use visual tissue assessment for potential deficiency – See *Plant Nutrient Functions and Deficiency and Toxicity Symptoms* http://landresources.montana.edu/soilfertility Under “Extension Publications” then “Nutrient Management Modules”
- 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

Visual tissue assessment

In Nutrient Management Module 9
http://landresources.montana.edu/nm

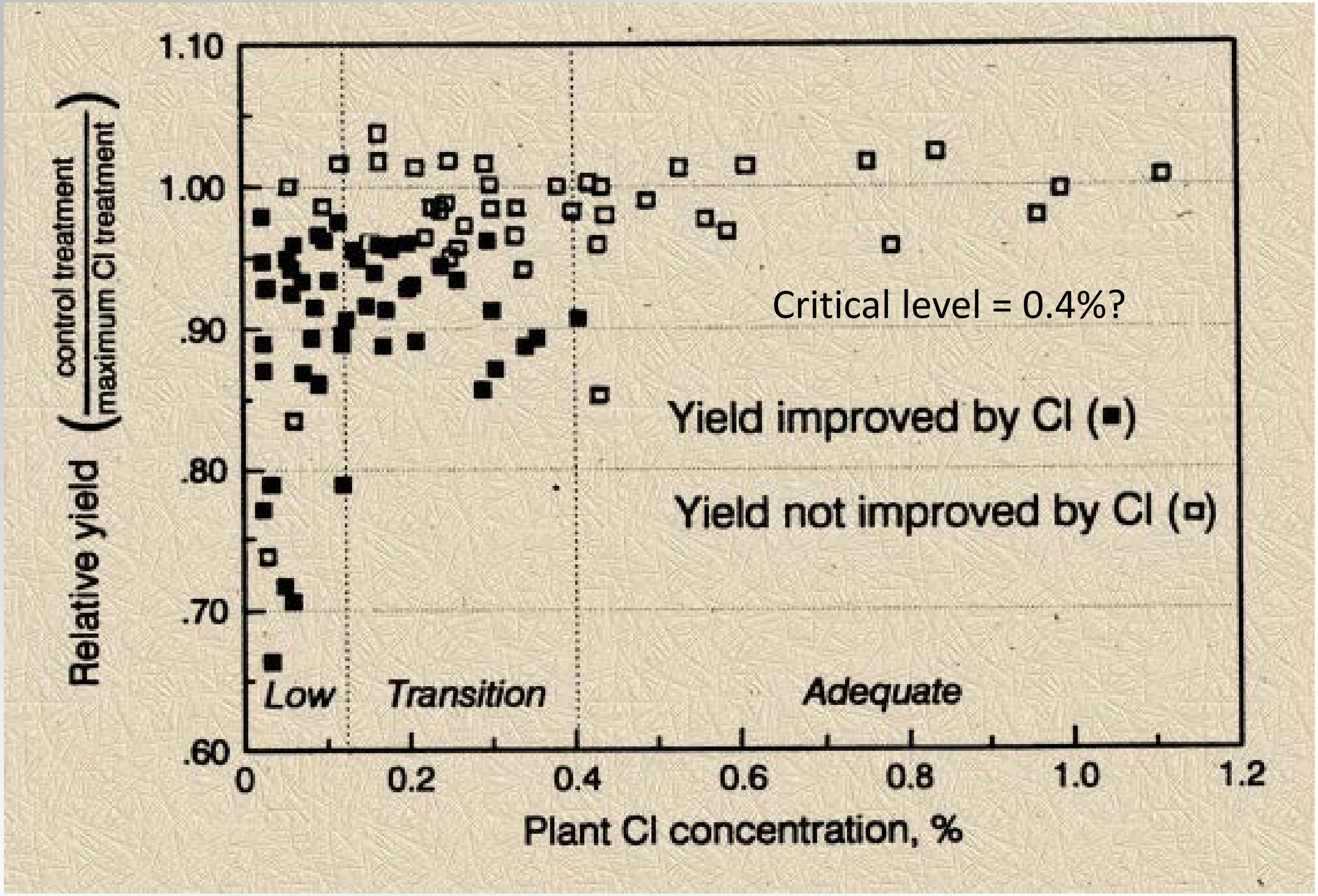


What do Cl and Zn deficiency look like?

Cl deficiency (wheat)

Zn deficiency

Wheat and barley tissue Cl concentration



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

Typical minimum sufficient micronutrient levels in plant tissue

Crop	Sample	B	Cu	Fe	Mn	Zn
		(ppm)				
Alfalfa	Upper 6" of leaves at bloom	30	8	30	25	20
Small grains	Whole plant prior to grain filling	5	3.7 (barley) 4.5 (oat) 2.5 (wheat)	20	15	15
Canola	Leaves at flowering	30	2.7	20	15	15

McKenzie 2001

Common micronutrient sources

Micronutrient	Fertilizer name	Fertilizer Formula	Solubility *	Micronutrient content (%) **
Boron	Borax Boric acid	$Na_2B_4O_7 \cdot 10H_2O$ H_3BO_3	Low Medium	11 10
Chloride	Potassium Chloride	KCl	High	47
Copper	Copper sulfate	$CuSO_4 \cdot 5H_2O$	Medium	25
Iron	Ferrous sulfate Iron oxalate Iron EDTA	$FeSO_4 \cdot 7H_2O$ $Fe_2(C_2O_4)_3$ Varies	Medium High Varies	20 30 5-14
Manganese	Manganous sulfate	$MnSO_4 \cdot 4H_2O$	High	25
Zinc	Zinc sulfate Zinc EDTA	$ZnSO_4 \cdot H_2O$ Varies	Medium Varies	36 6-14

* Low: < 5 lb product/100 lb water, Medium: 5-50 lb/100 lb water, High: > 50 lb/100 lb water (CPHA, 2002).

** The range of micronutrient content for EDTA forms are based on common liquid forms for the low number up to common dry forms for the high number (CPHA, 2002).

From Nutrient Management Module No. 7 (4449-7)

Common micronutrient forms

Form	Availability	Nutrients	Application surface	Residual > 1 year
Sulfate (salts)	Water soluble, plant available	Cu, Fe, Mn, Zn B (borate)	Soil or Foliage	Yes
Oxysulfate	Oxide portion not very available, sulfide portion is, should be > 50% water soluble	Cu, Fe, Mn, Zn	Soil	Yes
Oxide	Bound with O_2, not soluble, needs to be converted	Cu, Fe, Mn, Zn	Soil	Yes, but is not plant available
Chelate	Plant available form	Cu, Fe, Mn, Zn	Soil or Foliage	No
Manure	Bound in OM	Cu, Zn	Soil	Yes

Micronutrient fertilizer considerations

- Micronutrient “guarantee analysis” ≠ “guarantee availability”
- Zn availability in granular fertilizer is related to water solubility and not total Zn content (Westfall et al. 2005). >50% water soluble to be effective with current crop
- Relative Availability Coefficient (RAC) – are these available for nutrients other than Zn?
- Some fertilizers contain heavy metals in excess of safe levels (Westfall et al. 2005)

Questions?

Examples of responses

Cl on small grains

- Cl is very mobile so may need to add more if leaching or yield potential are high. 20 lb KCl/acre annually may provide enough.
- 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*

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

Yield increase from Cl may be due to disease suppression

- Wheat: take-all root rot, common root rot, fusarium root rot, stripe rust, leaf rust, septoria, tanspot
- Barley: common root rot, fusarium root rot, spot blotch

Source: Cindy Grant, Agriculture and Agri-Food Canada

Cl effects leaf spot severity, yield and shoot Cl concentration in durum wheat

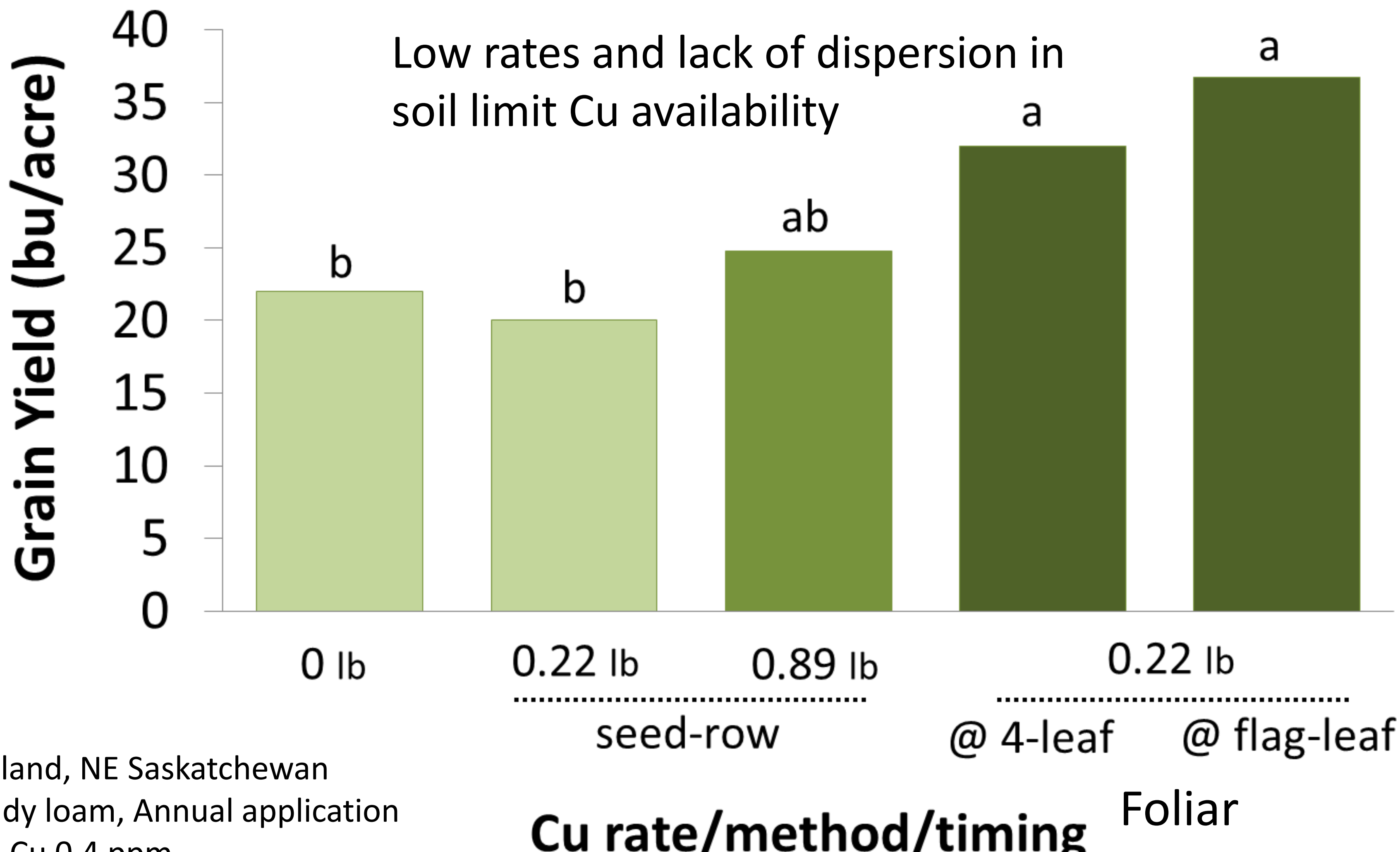
Fertilizer Cl (lb/ac)	Flag Leaf Spot Severity (%)	Yield (lb/ac)	Shoot Cl (ppm)
0	87	2954	540
40	6	3615	5520

Note: All differences are significant at a 95% confidence interval.

Initial soil Cl was 0.6 to 0.7 ppm in the upper 3 feet. From Engel et al., 2001.

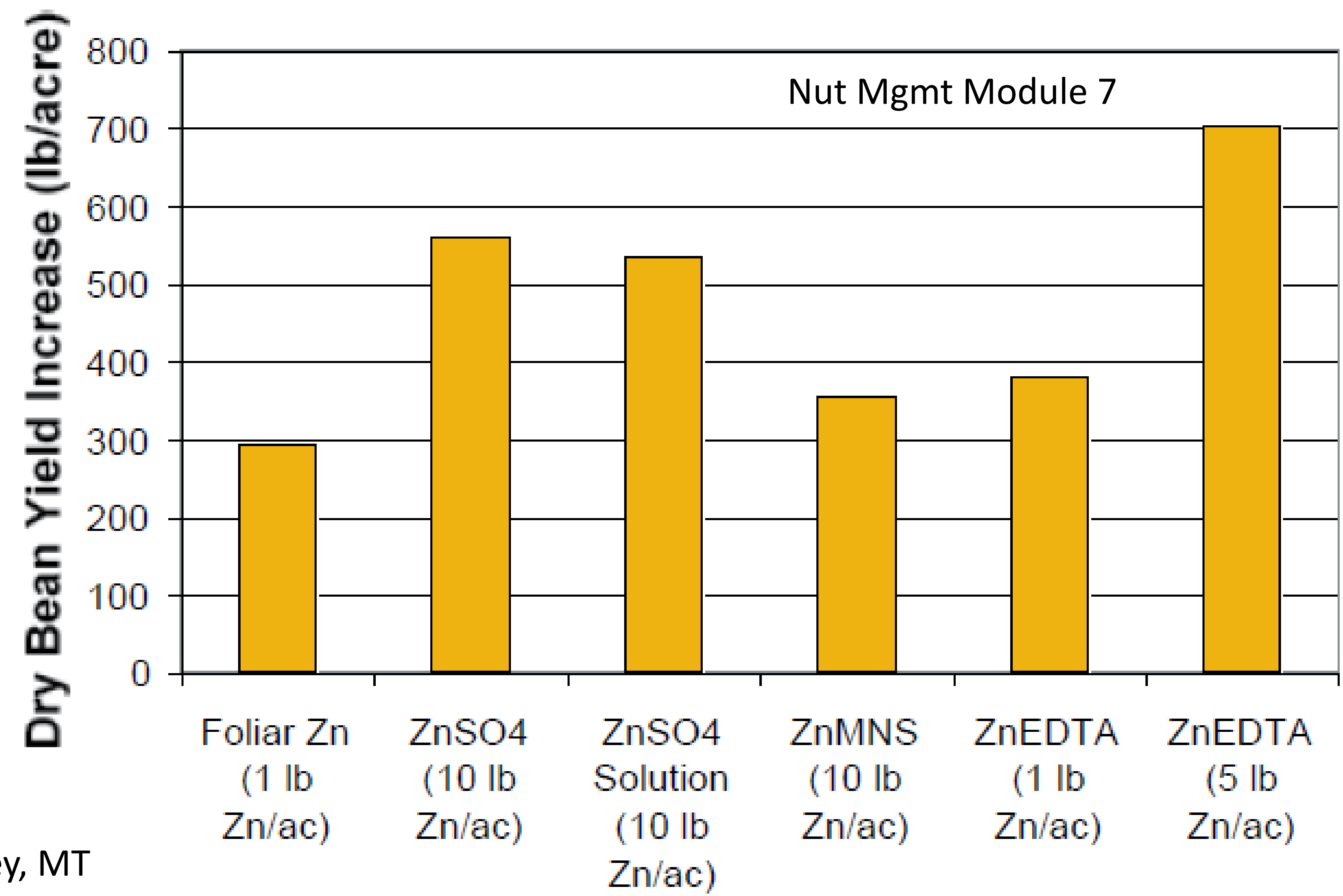
Poplar, MT

Copper rate, method and timing affects spring wheat grain yield



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

Banding, seed band, and foliar Zn applications increase irrigated dry bean yields in low Zn soils

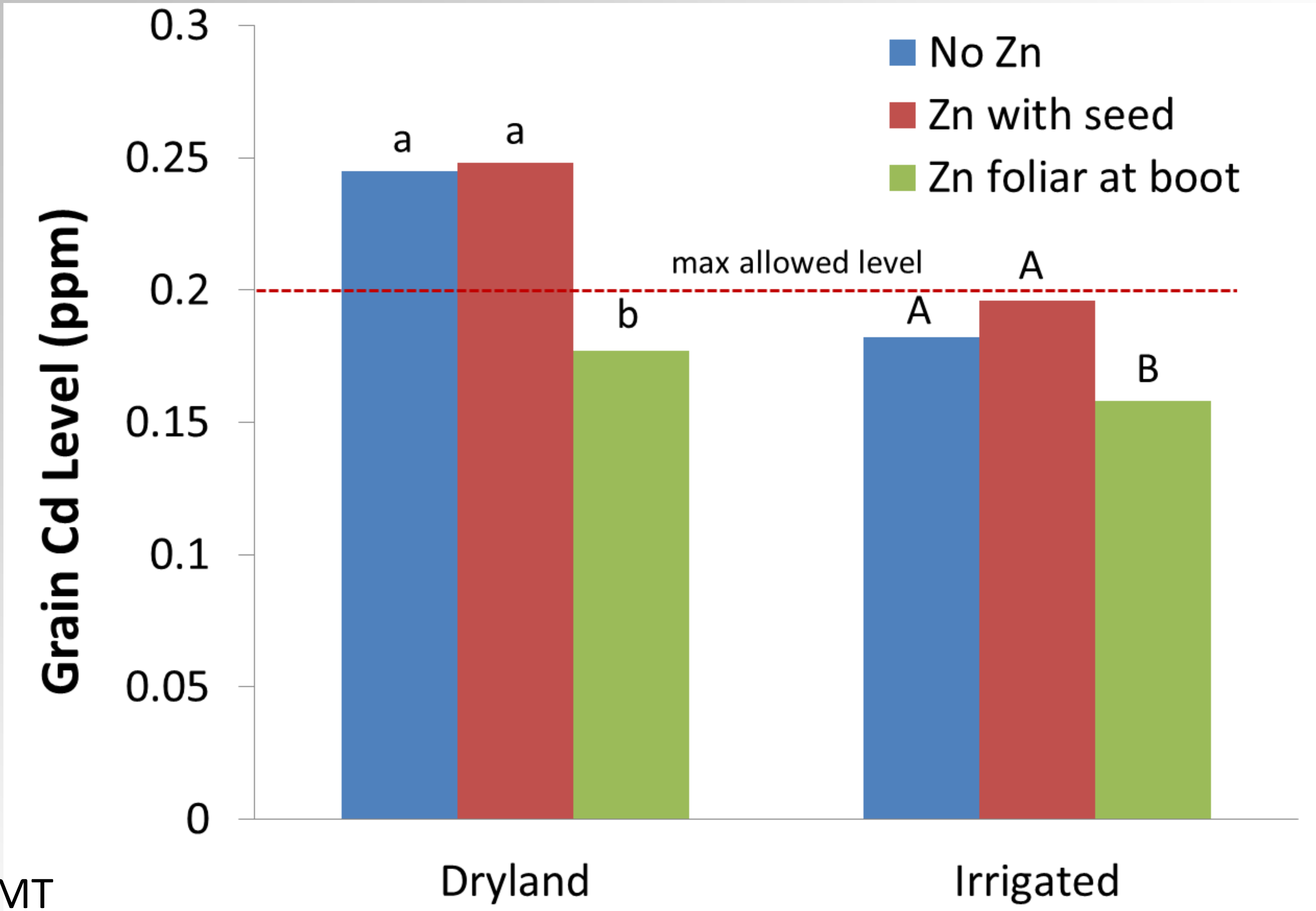


Sidney, MT

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)

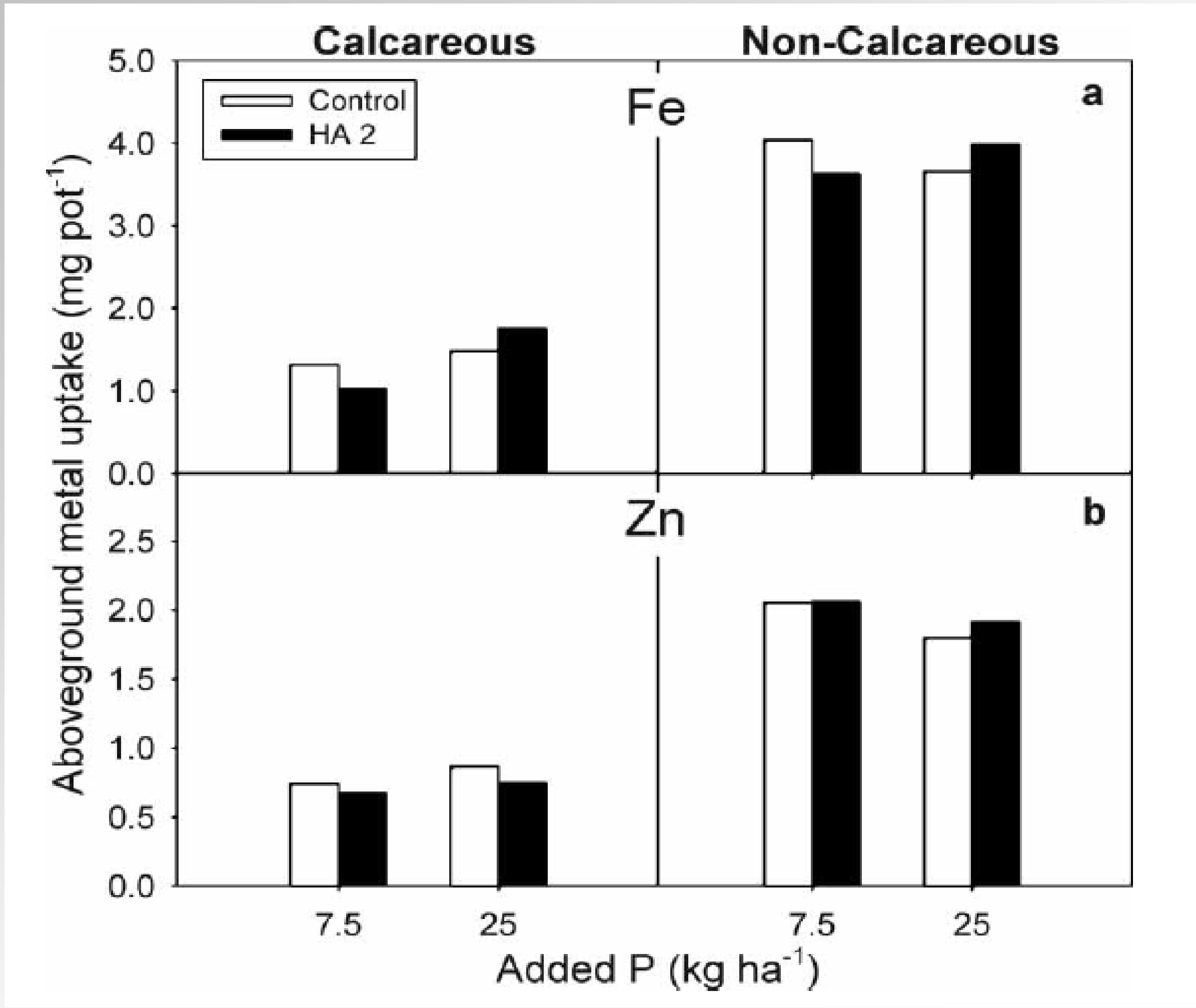


Sidney, MT
2 varieties, 3 years
Fertilizer Fact 54

Soil Zn = 0.58 ppm

Soil Zn = 0.72 ppm

Humic acid treated MAP banded to side of seed did not increase Fe or Zn uptake



Greenhouse study
Jones et al. 2007

Either too little HA or potential effect was negated by another process

Summary

- Low or deficient levels of boron, copper, molybdenum, iron, manganese, and nickel in Montana are rare based on tissue testing.
- Low or deficient levels of chloride and zinc appear to be more common and may approach levels found with P.
- A combination of deficiency symptoms, soil testing, and tissue testing may be best approach at identifying deficiencies
- Chloride deficiencies can be overcome with sufficient 61-0-0 or possibly foliar sprays
- Zinc deficiencies can be overcome with foliar sprays, or possibly Zn-coated seed? or Zn in each granule?

For more information

Additional soil fertility information is available at

http://landresources.montana.edu/soilfertility

- For plant nutrient functions and deficiency symptoms, see Nutrient Management Module 9.
- For more information on micronutrients, see NMM 7
- For fertilizer placement, look at NMM 11.

http://landresources.montana.edu/nm


Questions?
Watrous, SK, 1920's