MICRONUTRIENT PRINCIPLES

MGGA Convention

Great Falls

December 1, 2015

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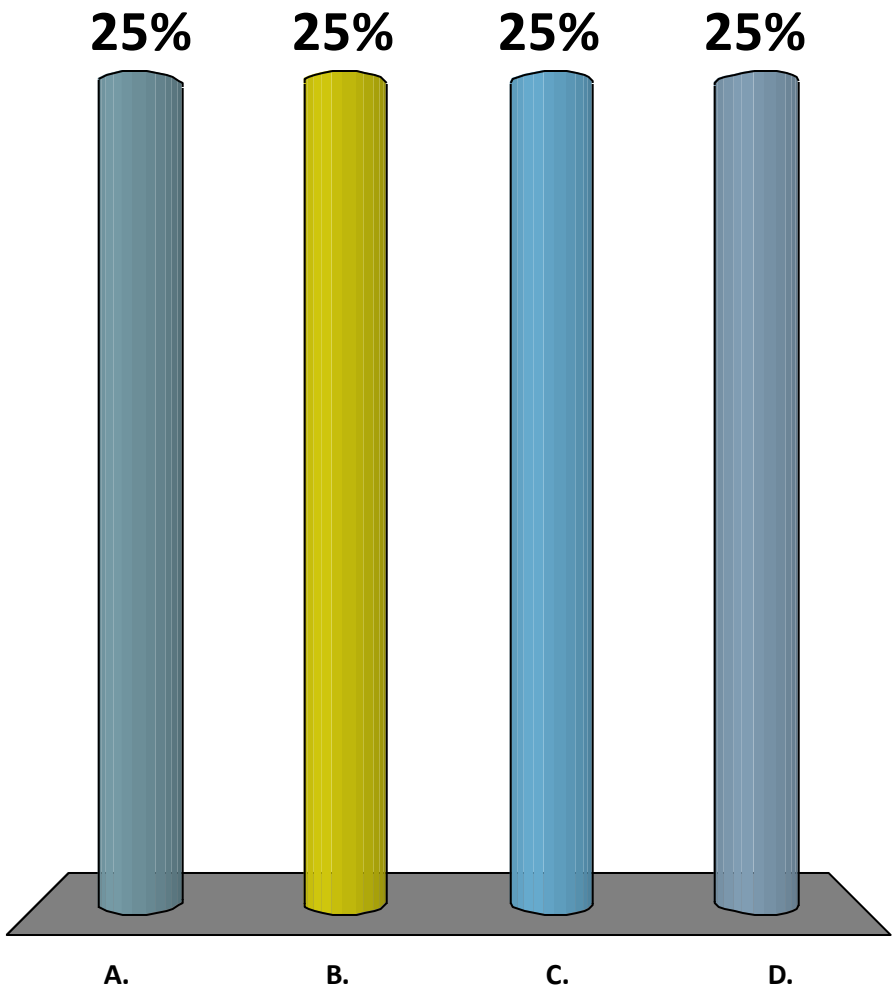
MONTANA STATE UNIVERSITY

MSU Soil Fertility Extension

Clickers are better than cell phones because:

A. You don't listen to Siri giving you wrong directions
B. They don't need to be turned off during a presentation
C. They screen calls from telemarketers
D. They make your dog obey



Response Counter

Goals Today

- Define micronutrients and their role in plants
- Illustrate micronutrient deficiency symptoms
- Discuss soil testing for micronutrients
- Explain which micronutrients may be deficient in MT soils and why

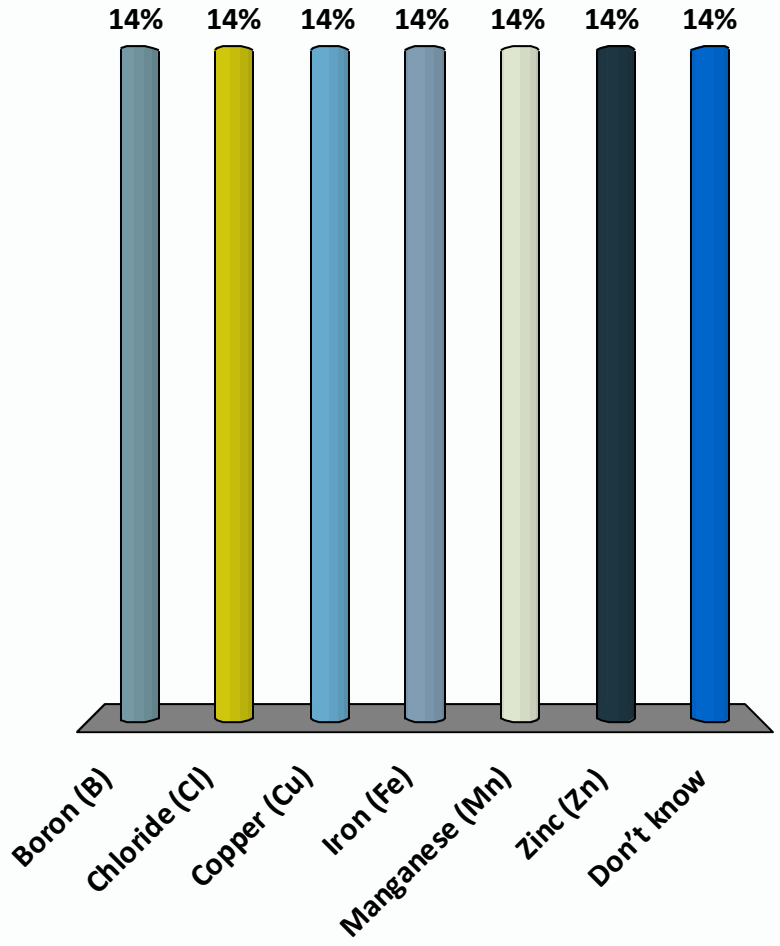
Your experience with micro deficiencies (select all that apply)

A. I don't think I've seen any	20%
B. I've suspected micro deficiencies based on symptoms, but didn't verify with tissue testing	20%
C. I've verified micro deficiencies through tissue testing	20%
D. I've verified micro deficiencies through fertilizer trials	20%
E. Other	20%

Response Counter

Of which micronutrients do you think you've seen deficiencies? Select all that apply

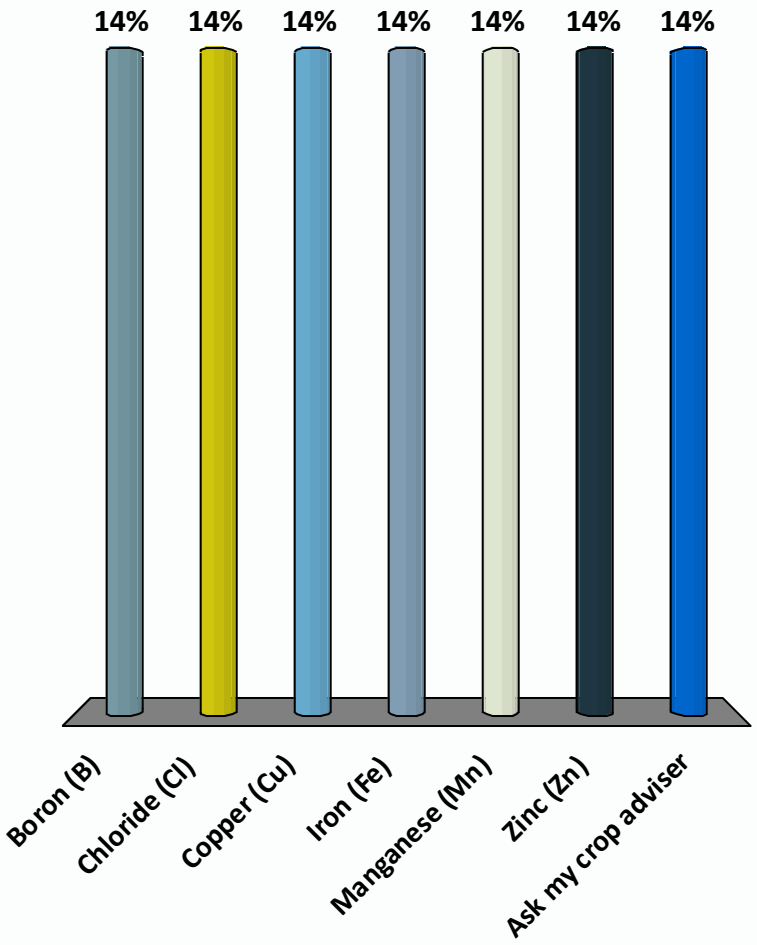
A. Boron (B)
B. Chloride (Cl)
C. Copper (Cu)
D. Iron (Fe)
E. Manganese (Mn)
F. Zinc (Zn)
G. Don't know



Response Counter

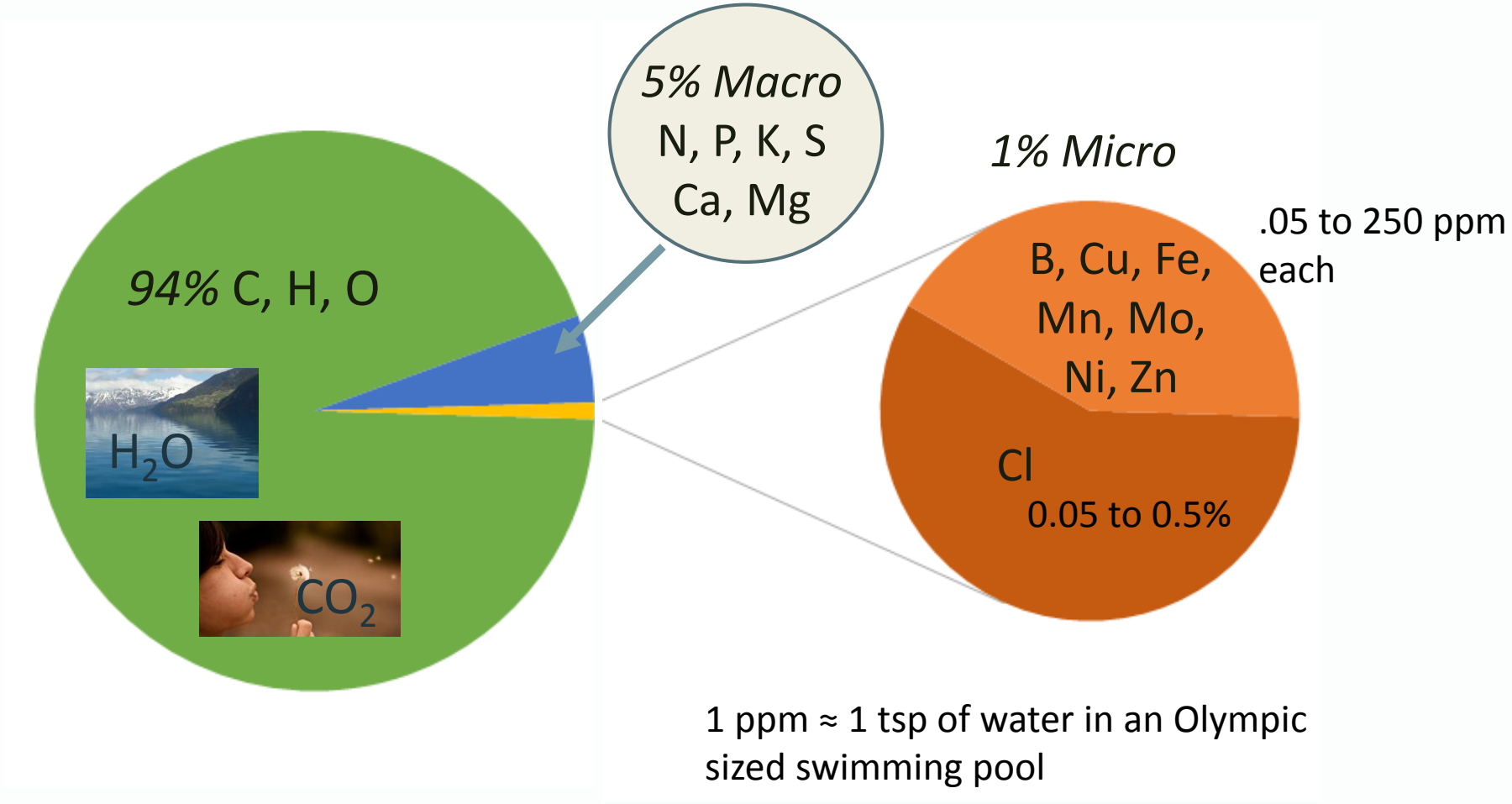
For which micronutrients have you applied fertilizer? Select all that apply.

A. Boron (B)
B. Chloride (Cl)
C. Copper (Cu)
D. Iron (Fe)
E. Manganese (Mn)
F. Zinc (Zn)
G. Ask my crop adviser



Response Counter

Nutrient amounts in dried plant material



The micronutrients are simply needed in smaller amounts by the plant than the macronutrients.

Role of micronutrients

Nutrient	Role in plant
Boron (B)	Sugar transport, carbohydrate metabolism
Chloride (Cl)	O_2 production in photosynthesis
Copper (Cu)	Catalyst for respiration; component of enzymes
Iron (Fe)	Chlorophyll synthesis and in enzymes for electron transfer
Manganese (Mn)	Controls oxidation-reduction systems and photosynthesis
Molybdenum (Mo)	N-fixation and nitrate to ammonium transformation
Nickel (Ni)	Urease enzyme function and seed germination
Zinc (Zn)	Enzymes for metabolic activities

The 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)	

Visual tissue assessment

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

MOBILE NUTRIENTS

Older/lower leaves affected — NO → Next page

YES

Effects mostly generalized; plants dark or light green — NO → Effects mostly localized; chlorosis with or w/out spotting

YES

Plants dark green, often becoming purple or red

YES → PHOSPHORUS (P)

NO

Plants light green with leaves light green or yellow; no necrotic spotting

YES → NITROGEN (N)

NO

Plants light green; necrotic spotting on leaves; pale leaves sometimes scorched, cupped or rolled

YES → MOLYBDENUM (Mo)

YES

Interveinal chlorosis; leaves sometimes red or with dead spots

YES → MAGNESIUM(Mg)

NO

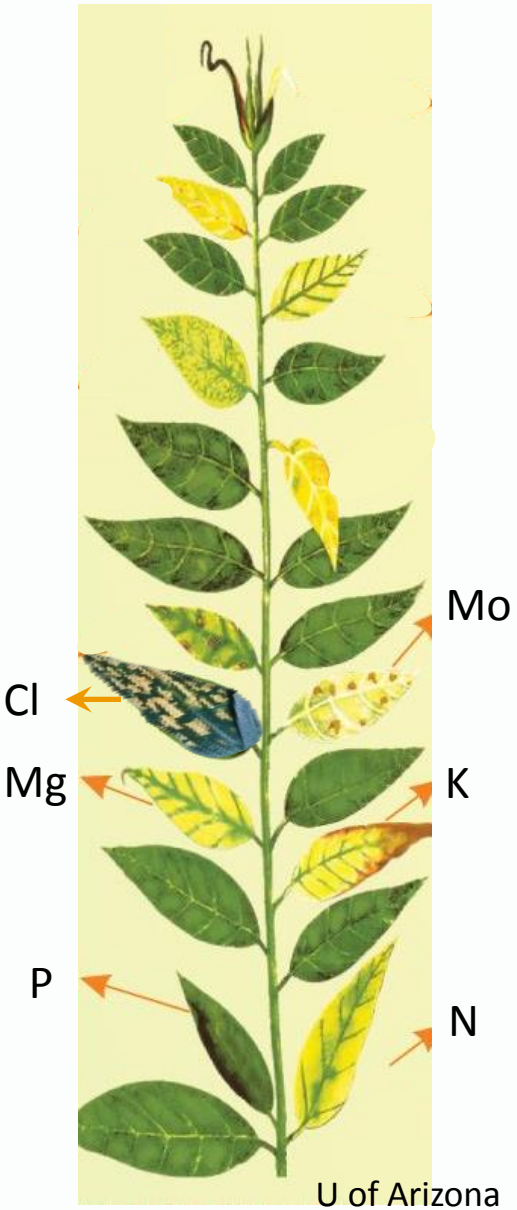
No interveinal chlorosis; chlorotic areas with a burning or spotting along leaf margins

YES → POTASSIUM (K)

NO

No interveinal chlorosis; distinct chlorotic and necrotic lesions (spotting) with abrupt boundary between dead and alive tissue

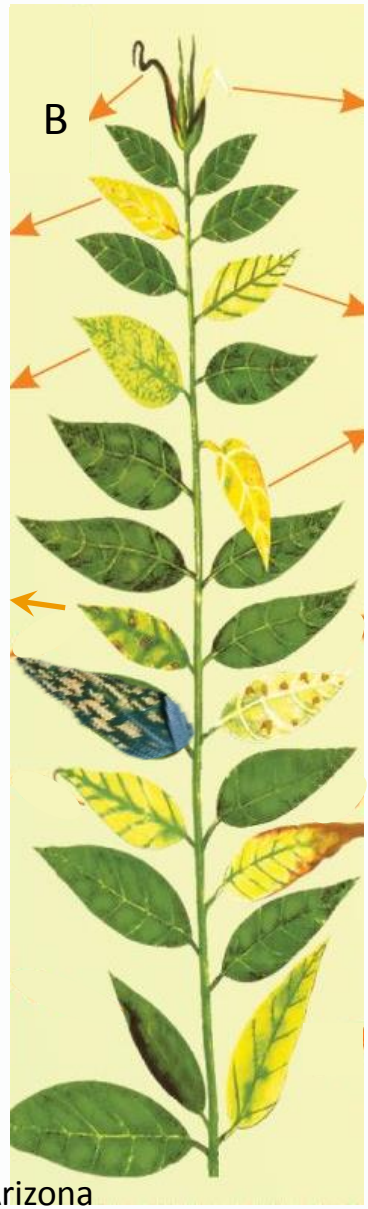
YES → CHLORIDE (Cl)



U of Arizona

IMMOBILE NUTRIENTS

Newer or younger leaves



U of Arizona

Growing point (terminal bud) dies — NO → Growing point typically stays alive

YES

Leaves of terminal bud become light green at bases; leaves become twisted and brittle and die back at growing point; chlorosis of young leaves

YES → BORON (B)

NO

Young leaves of terminal bud hooked at first, finally turning brown and dying

YES → CALCIUM (Ca)

NO

Dark green zone next to blunted necrotic leaf tip, thickened curling leaves

YES → NICKEL (Ni)

Growing point typically stays alive

YES

Chlorosis w/out interveinal chlorosis — NO → Young leaves with interveinal chlorosis

YES

Leaves light green; typically no chlorotic spotting or striping

YES → SULFUR (S)

NO

Chlorosis of young leaves; tips appear withered and will eventually die

YES → COPPER (Cu)

YES

Sharp distinction between veins and chlorotic areas

YES → IRON (Fe)

NO

No sharp distinction between veins and chlorotic areas; spotty appearance

YES → MANGANESE (Mn)

NO

Middle leaves with interveinal chlorosis; stunted growth

YES → ZINC (Zn)

(Initially in middle leaves, young and/or old leaves become chlorotic in later stages of deficiency)

Questions?

Soil testing is a reliable basis on which to make micronutrient fertilization decisions:

A.	Because nothing other than soil deficiency causes symptoms to appear	20%
B.	Because there are reliable soil test critical levels for most micronutrients	20%
C.	Because taking soil samples is better than the gym to build muscles	20%
D.	Because critical soil levels are the same for all varieties within a species	20%
E.	When used in combination with other tools	20%

Micronutrients on soil test reports

Date Sampled | Date Received **08/28/2014** | Date Reported **8/28/2014**

Nutrient In The Soil		Interpretation			
		VLow	Low	Med	High
0-6" / 6-24" / 24-42" Nitrate	15 lb/ac / 24 lb/ac / 63 lb/ac	********			
0-24" Nitrate	39 lb/ac				
TOTAL N =	102#				
Olsen Phosphorus	4 ppm	******			
Potassium	368 ppm	********	********	********	********
0-24" Chloride	20 lb/ac	********			
0-6" / 6-24" Sulfur	14 lb/ac / 36 lb/ac	********** / **********	**********	**********	**********
Boron					
Zinc					
Iron					
Manganese					
Copper	0.5 ppm	**********	**********		
Magnesium					
Calcium					
Sodium					
Org.Matter	2.3 %	**********	**********		
Carbonate(CCE)					
0-6" / 6-24" Sol. Salts	0.36 mmho/cm / 0.35 mmho/cm	******** / ********			

1st Crop Choice		
Wheat-High Pro.		
YIELD GOAL		
50 Bu		
SUGGESTED GUIDELINES		
Band		
LB/ACRE		APPLICATION
N	111	50
P_2O_5	36	Band *
K_2O	10	Band (Starter)*
Cl	20	Broadcast
S	9	Band (Trial)
B		
Zn		
Fe		
Mn		
Cu	2	Band
Mg		
Lime		

2nd Crop Choice		
Wheat-High Pro.		
YIELD GOAL		
60 Bu		
SUGGESTED GUIDELINES		
Band		
LB/ACRE		APPLICATION
N	141	80
P_2O_5	43	Band *
K_2O	10	Band (Starter)*
Cl	20	Broadcast
S	9	Band (Trial)
B		
Zn		
Fe		
Mn		
Cu	2	Band
Mg		
Lime		

3rd Crop Choice		
Barley-Malting		
YIELD GOAL		
70 BU		
SUGGESTED GUIDELINES		
Band		
LB/ACRE		APPLICATION
N	45	Customized
P_2O_5	35	Band *
K_2O	10	Band (Starter)*
Cl	20	Broadcast
S	9	Band (Trial)
B		
Zn		
Fe		
Mn		
Cu	2	Band
Mg		
Lime		

Soil pH	Buffer pH	Cation Exchange Capacity	% Base Saturation (Typical Range)				
			% Ca	% Mg	% K	% Na	% H
0-6" 8.1 6-24" 8.4							

Nutrient In The Soil		Interpretation			
		VLow	Low	Med	High
Cl	0-24'' 20 lb/ac	********			
S	0-6" 14 lb/ac 6-24" 36 lb/ac	**********	**********	**********	**
B					
Zn					
Fe					
Mn					
Cu	0.5 ppm	**********	**********		
Mg					
Ca					

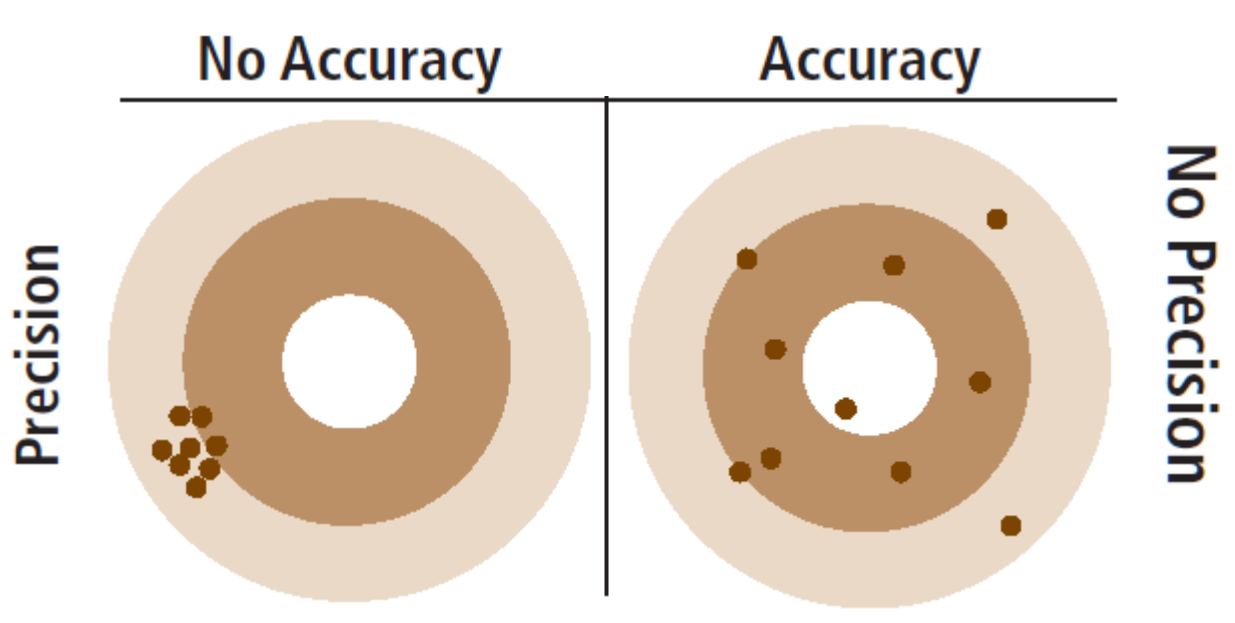
1st Crop Choice		
Wheat-High Pro.		
YIELD GOAL		
50 Bu		
SUGGESTED GUIDELINES		
Band		
LB/ACRE		APPLICATION
N	111	50
P_2O_5	36	Band *
K_2O	10	Band (Starter)*
Cl	20	Broadcast
S	9	Band (Trial)
B		
Zn		
Fe		
Mn		
Cu	2	Band
Mg		
Lime		

Look for notes provided by laboratory, e.g.,

- Crop 1: 44 lbs of 0-0-60 = 20 lbs of Cl
- Caution: Seed placed fertilizer can cause injury

Soil test considerations

- If comfortable with choice, use same lab repeatedly
- Accuracy and precision = reliability, varies with lab, nutrient and method used



Based on the following table, what could be the 'true' amount of Cu in the soil?

Soil nutrient & method	Concentration range (accuracy)	Uncertainty (precision)
Zn -DTPA (ppm)	0.5 – 1.0	± 0.12
Cu – DTPA (ppm)	0.2 – 1.0	± 0.08
B – Hot water (ppm)	0.2 – 1.8	± 0.12
Based on 95% confidence, from 95 soil samples evaluated in the ALP Program 2006-2012. Miller, 2013.		

A. Enough to sell as wire and buy a new truck — 33%

B. 0.2 – 1.0 ppm — 33%

C. 0.12 – 1.08 ppm — 33%

Questions?

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)

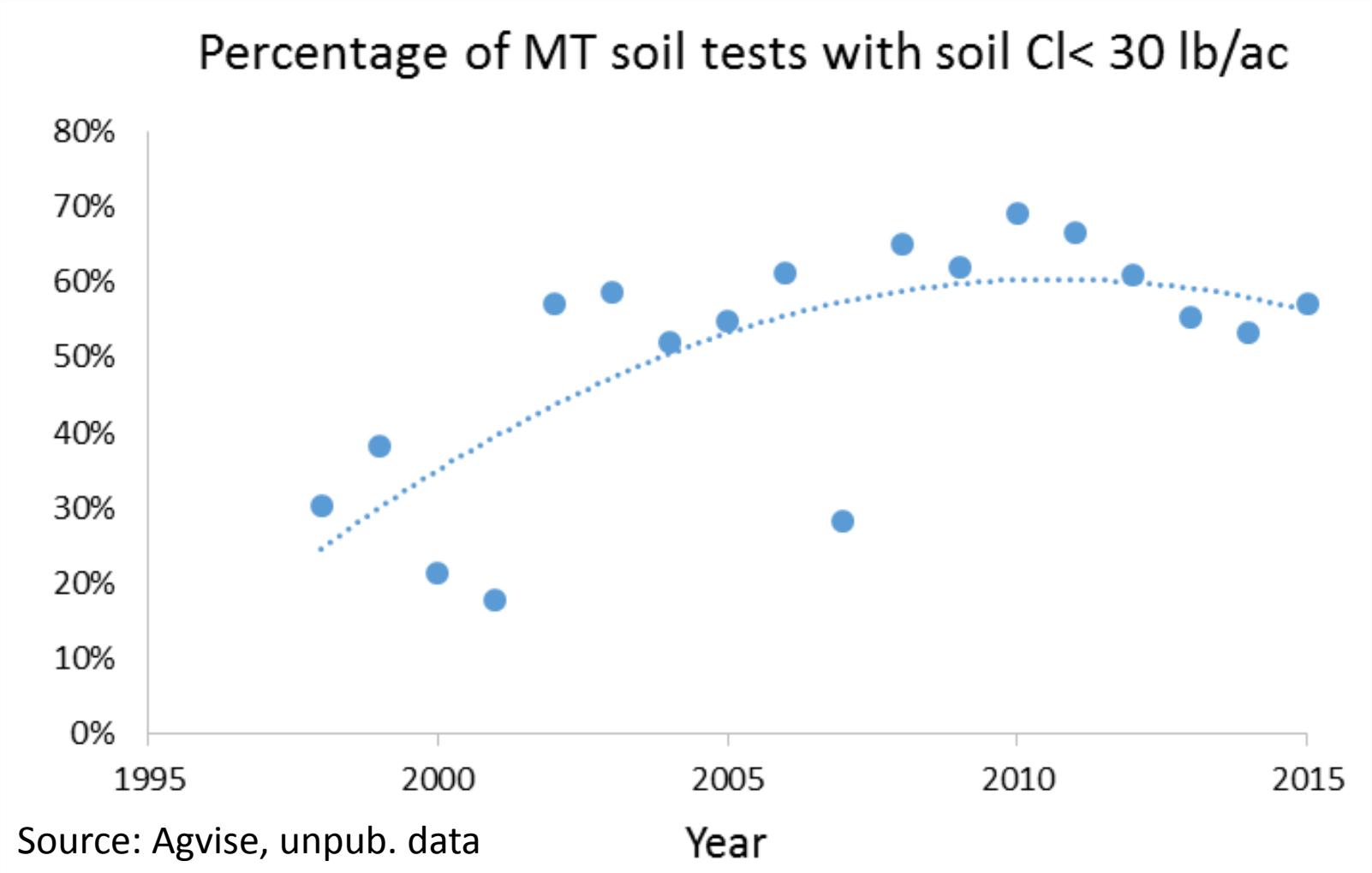
Selected total and available micronutrients in MT surface soils in past 34 years

	1979* (n=301)		2015** (n=4000-8000)
	Total	Available	Available
Nutrient	(ppm in top 0-6”)		
Copper	30	2.0	1.2 (0.5 crit lev)
Iron	38,000	15.8	20.5 (5 crit lev)
Manganese	600	12.4	3.7 (1 crit lev)
Zinc	50	1.2	1.0 (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, **Agvise

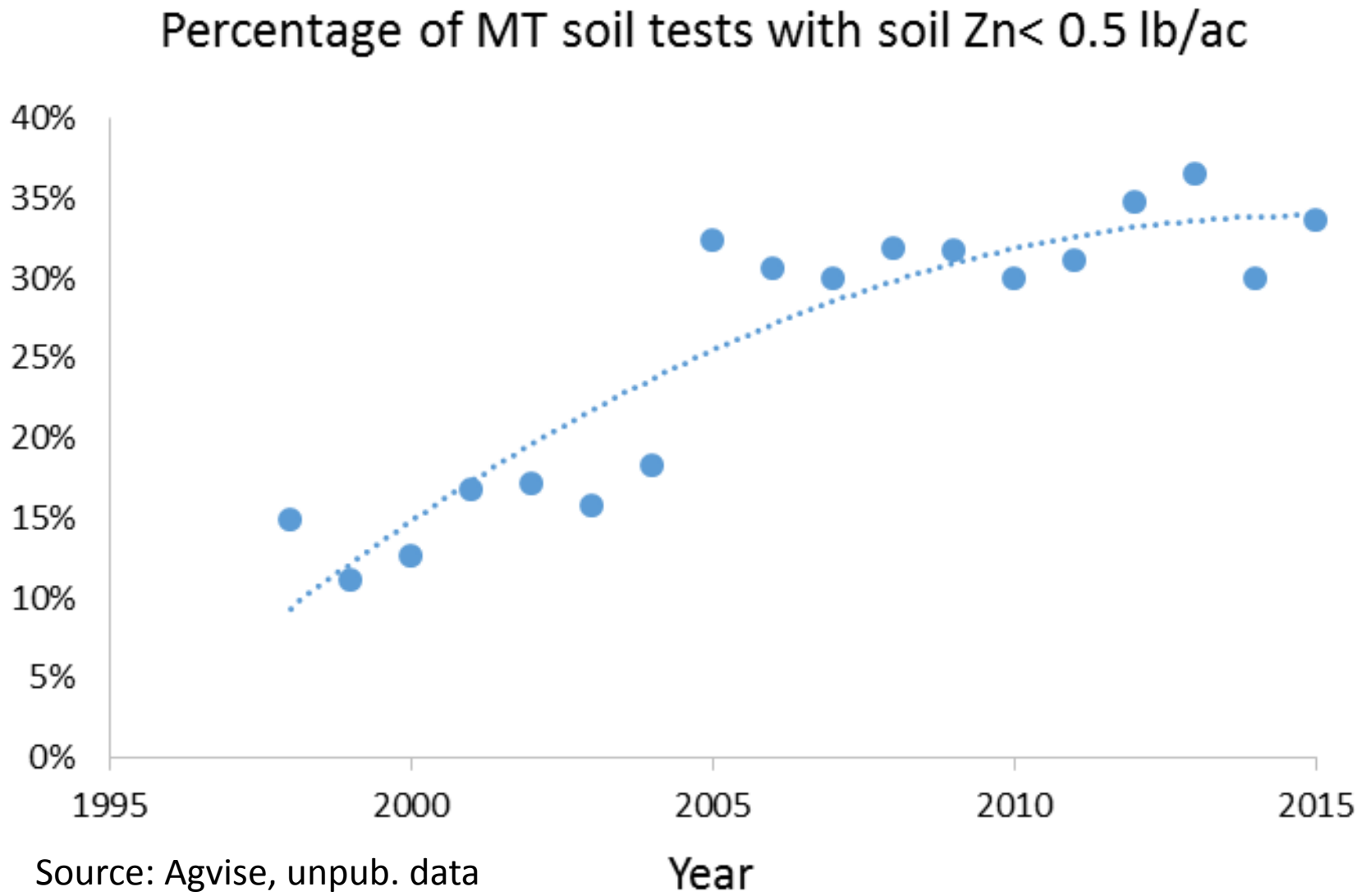
Have % of soil chloride levels below ‘critical level’ increased in last 15 years in Montana?

YES!



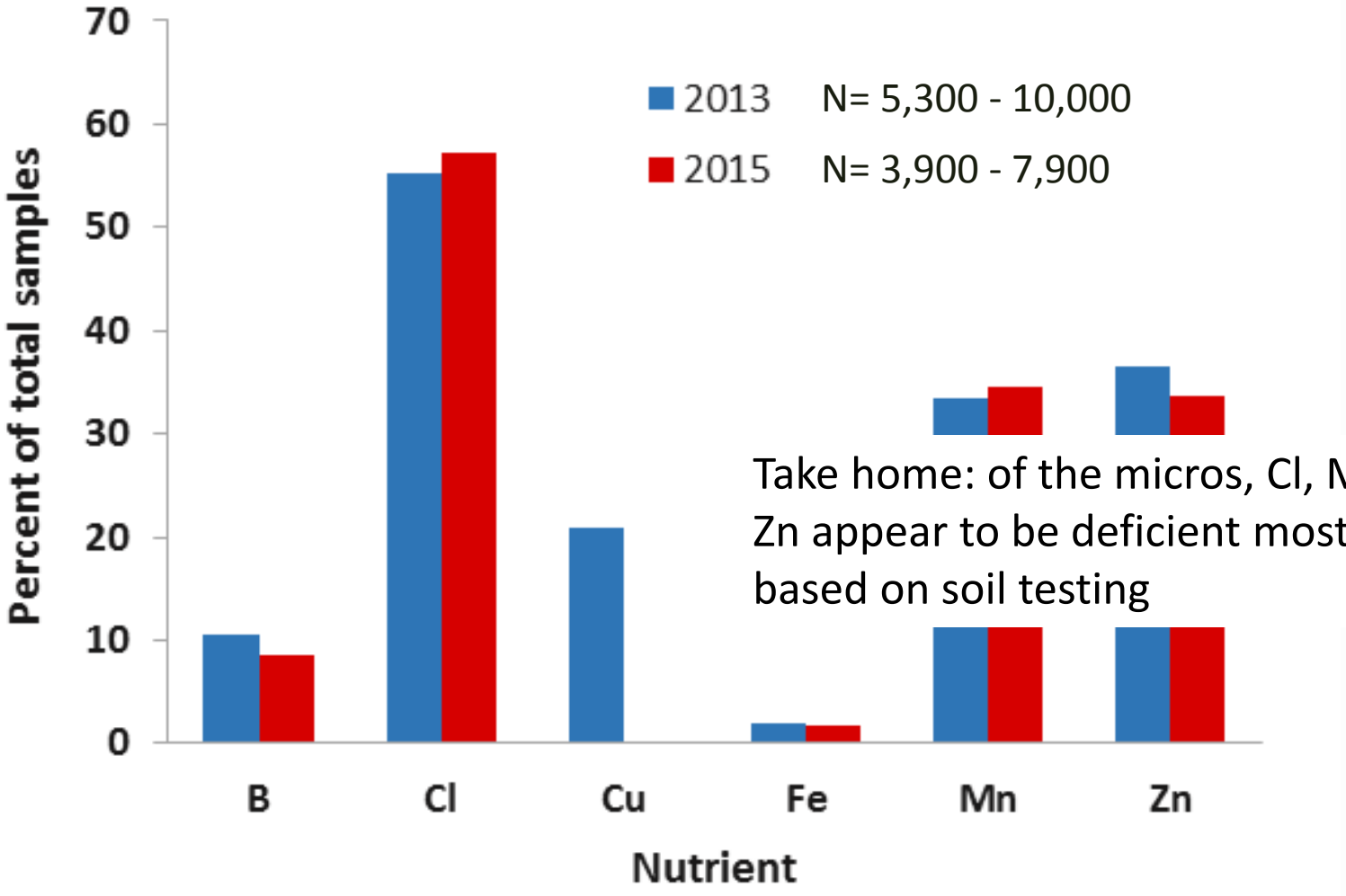
Source: Agvise, unpub. data

% of soil zinc levels below ‘critical level’ over last 15 years in Montana



Source: Agvise, unpub. data

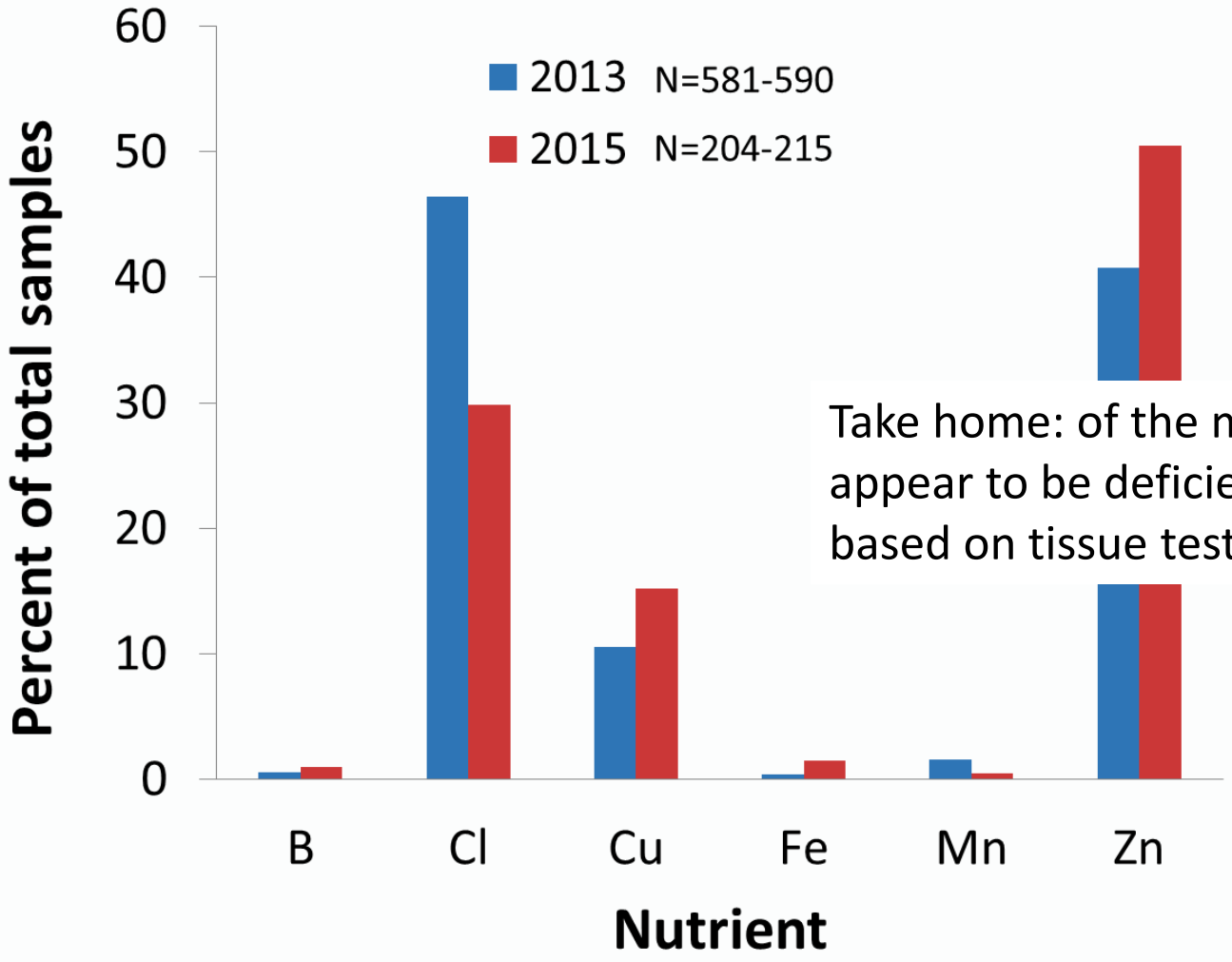
MT soils with low micronutrient concentrations (source: Agvise)



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

There may be bias because more samples may be submitted when deficiency symptoms are suspected than when not

Small grains with low and deficient tissue micronutrient concentrations in MT (source: Agvise)



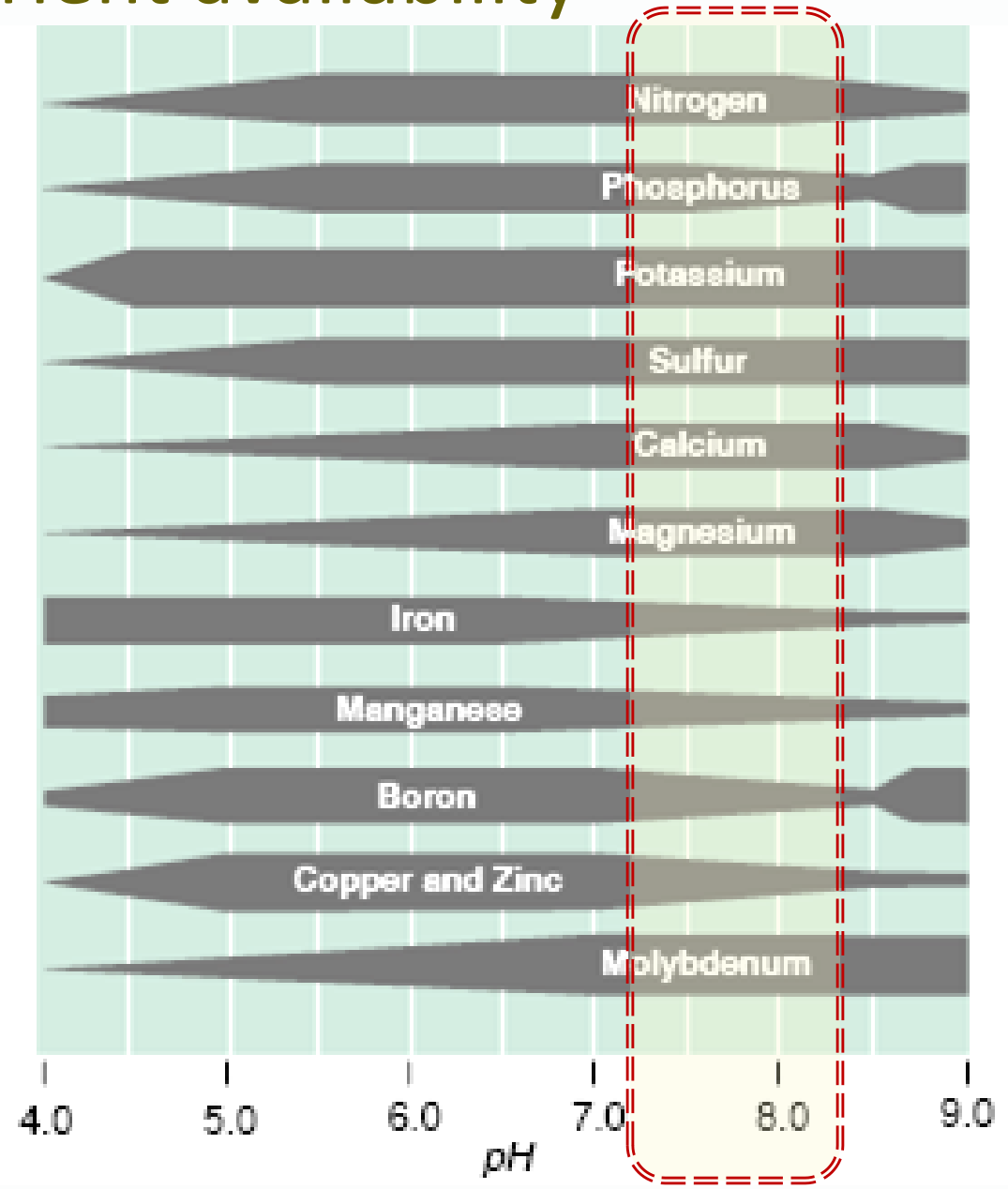
Take home: of the micros, Cl and Zn appear to be deficient most often, based on tissue testing

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

Conditions that affect availability to plant

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

pH affects soil nutrient availability

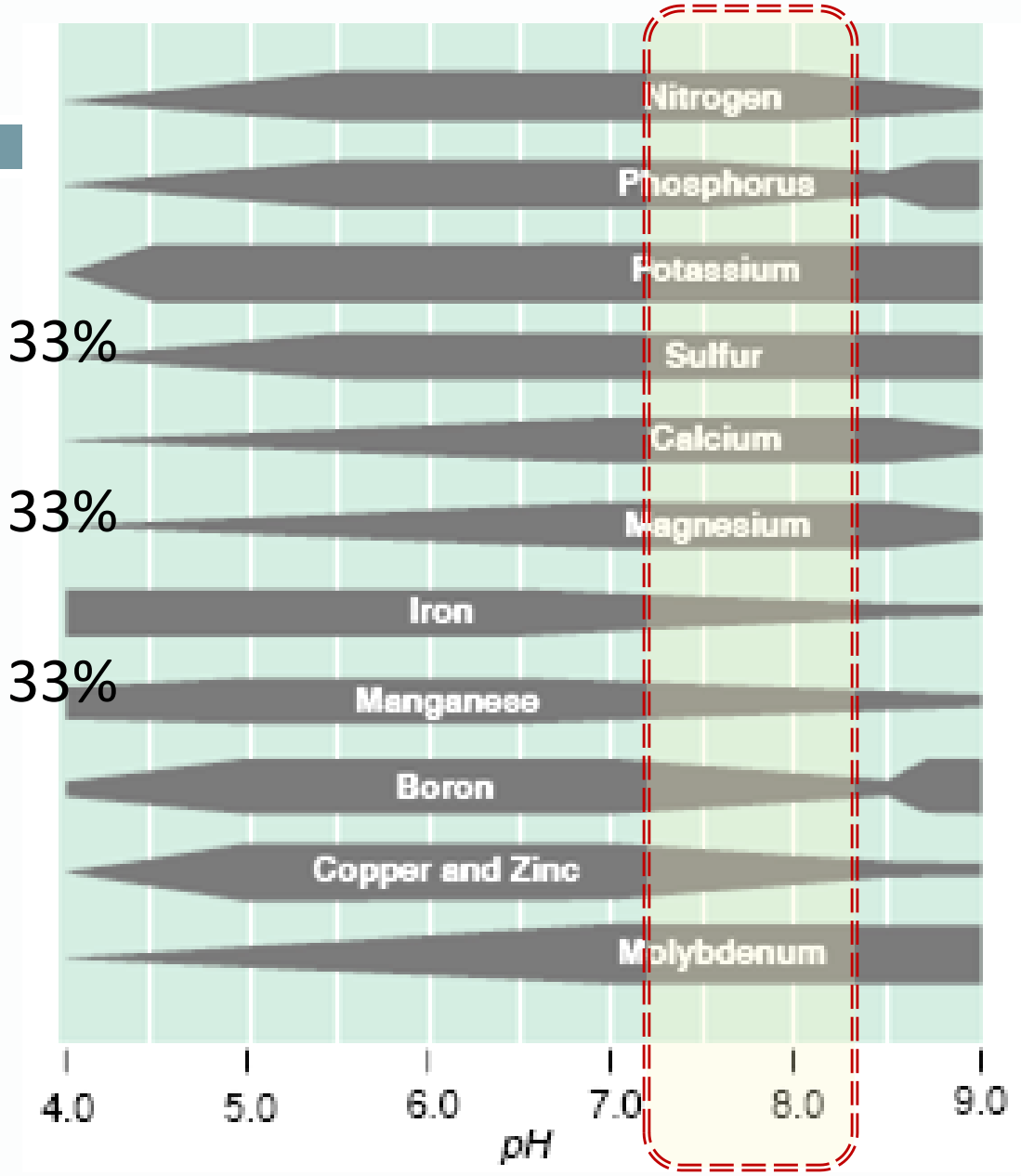


Most Montana soils are:

A. Generally alkaline (pH > 7.0)

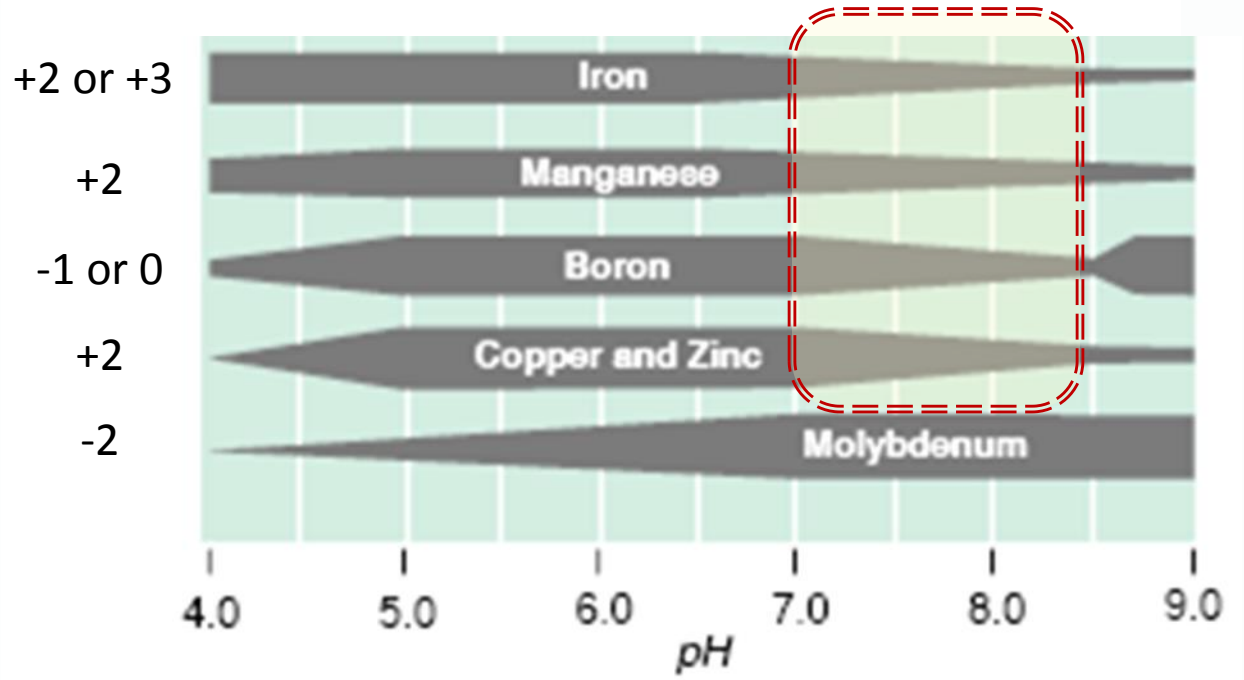
B. Generally acidic (pH < 7.0)

C. "Gumbo" = too difficult to sample



pH affects soil nutrient availability

These are relatively small ions when in soluble form – strong charge density (small balloon sticks to wall easier)

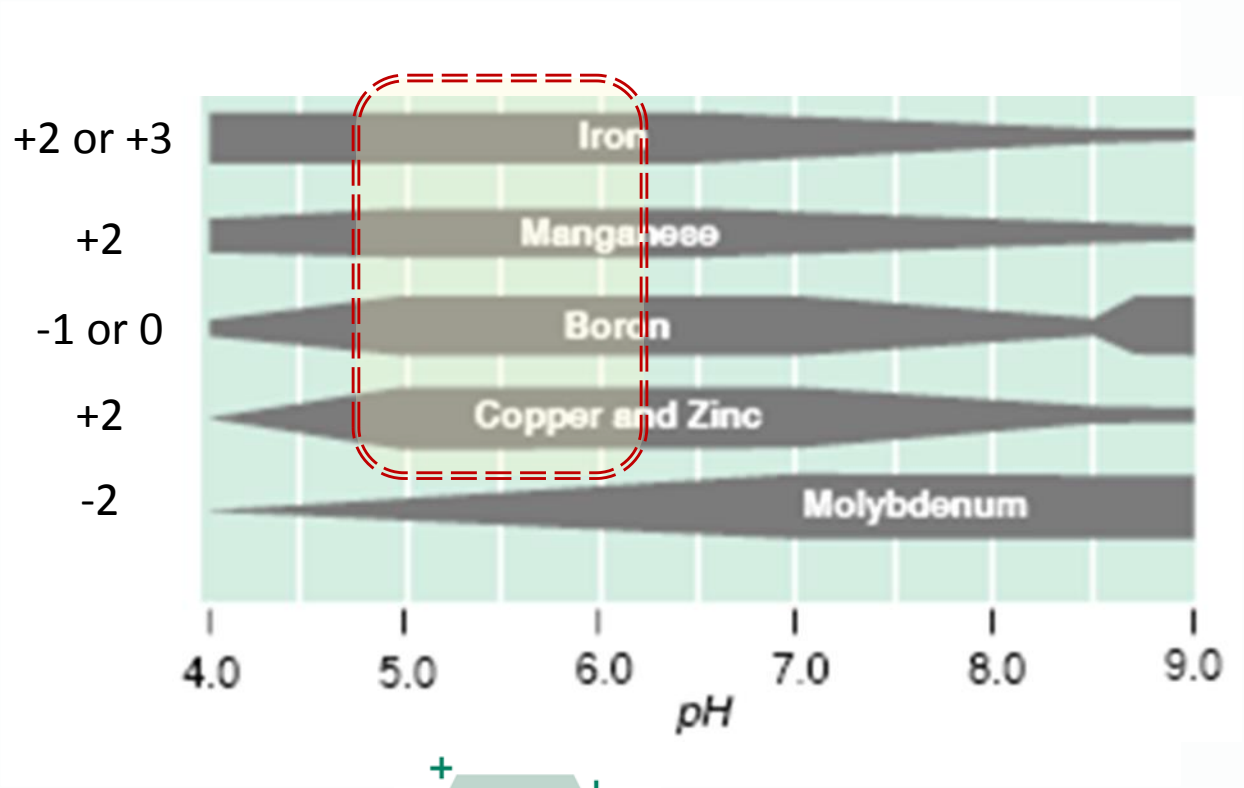


How tightly are they bound to soil in high pH?

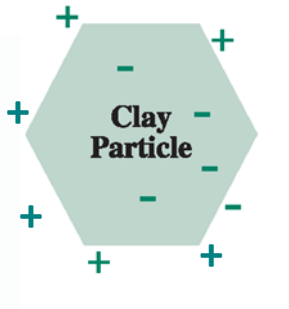
So strong they are not very plant available.

pH affects soil nutrient availability

What happens when they are in a lower pH?



The bonds weaken, they become more available



Chloride is not affected by pH

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

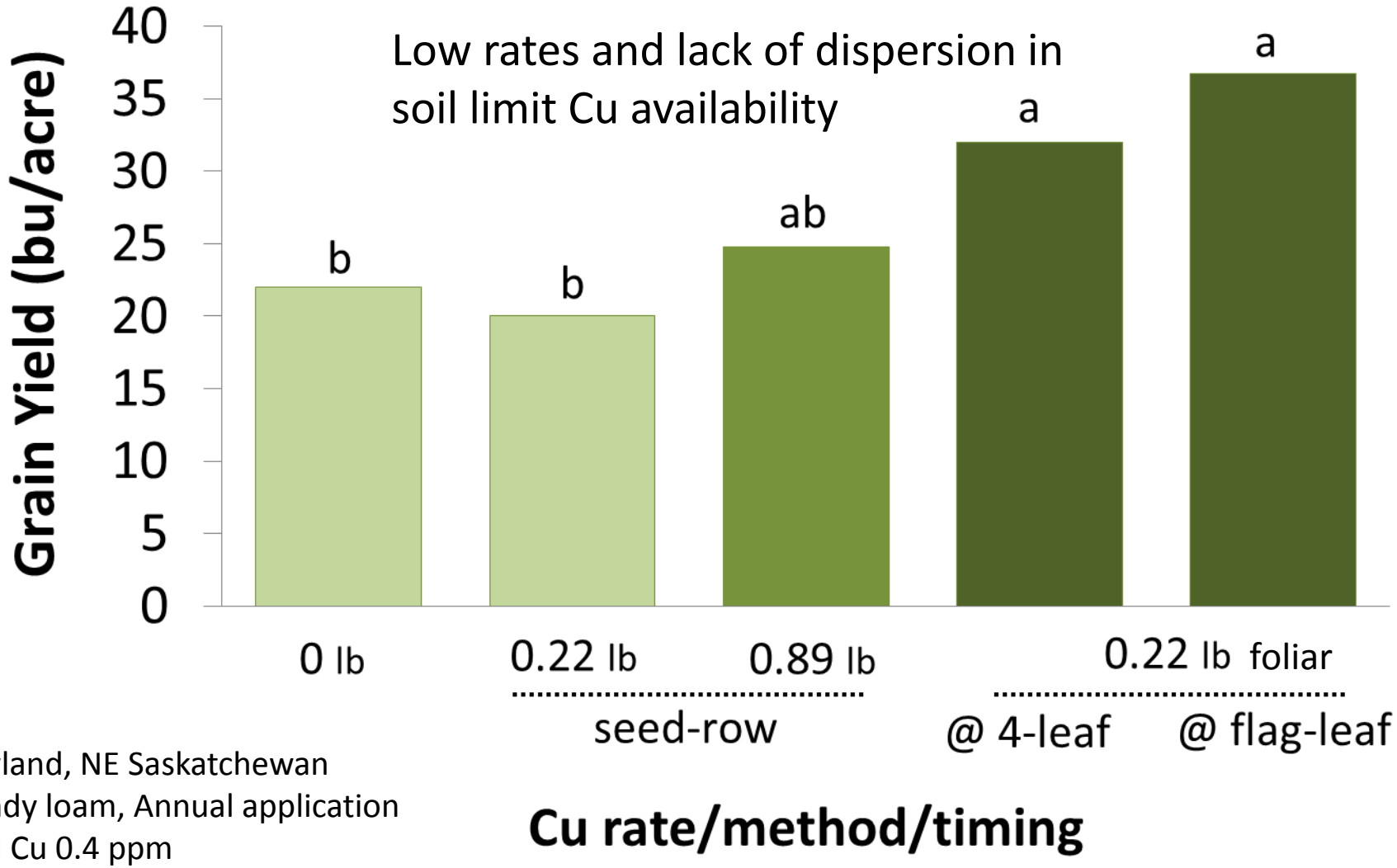
Where are the immobile micros (Cu, Fe, Mn, and Zn) best placed? Select all that apply.

A.	Foliar	25%
B.	In a gel cap	25%
C.	In the root zone	25%
D.	Soil surface broadcast	25%

Response Counter

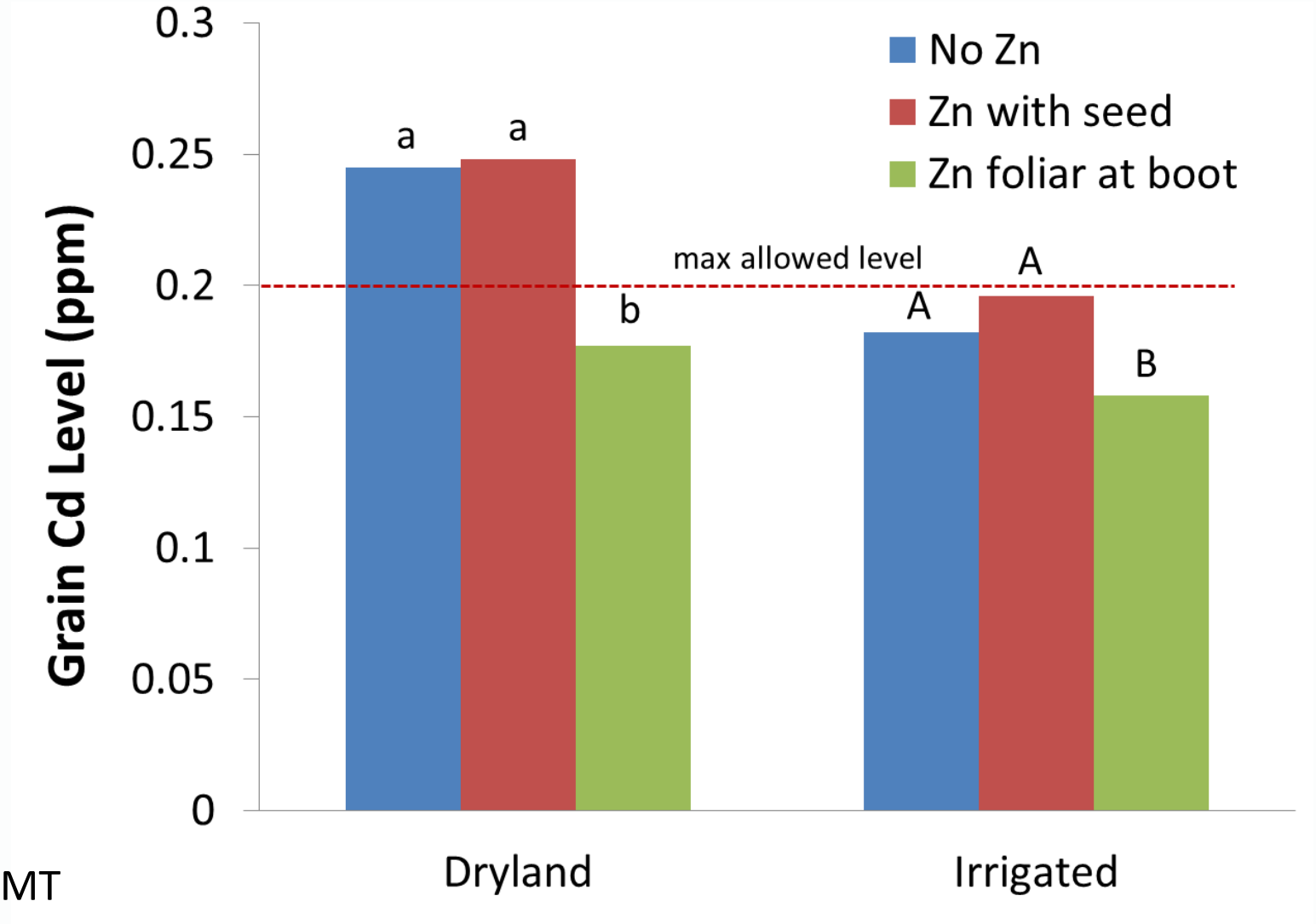
Questions?

Copper Rate, Method and Timing Effects SW Grain Yield



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

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

Cl affects 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

All differences are significant with 95% confidence.
Initial soil Cl was 0.6 to 0.7 ppm in upper 3 ft.

Poplar, MT, Engel et al. 2001

Questions?

Summary

- Micronutrients are used in tiny amounts but are critical
- 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.
- A combination of deficiency symptoms, soil testing, and tissue testing may be best approach at identifying deficiencies

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?

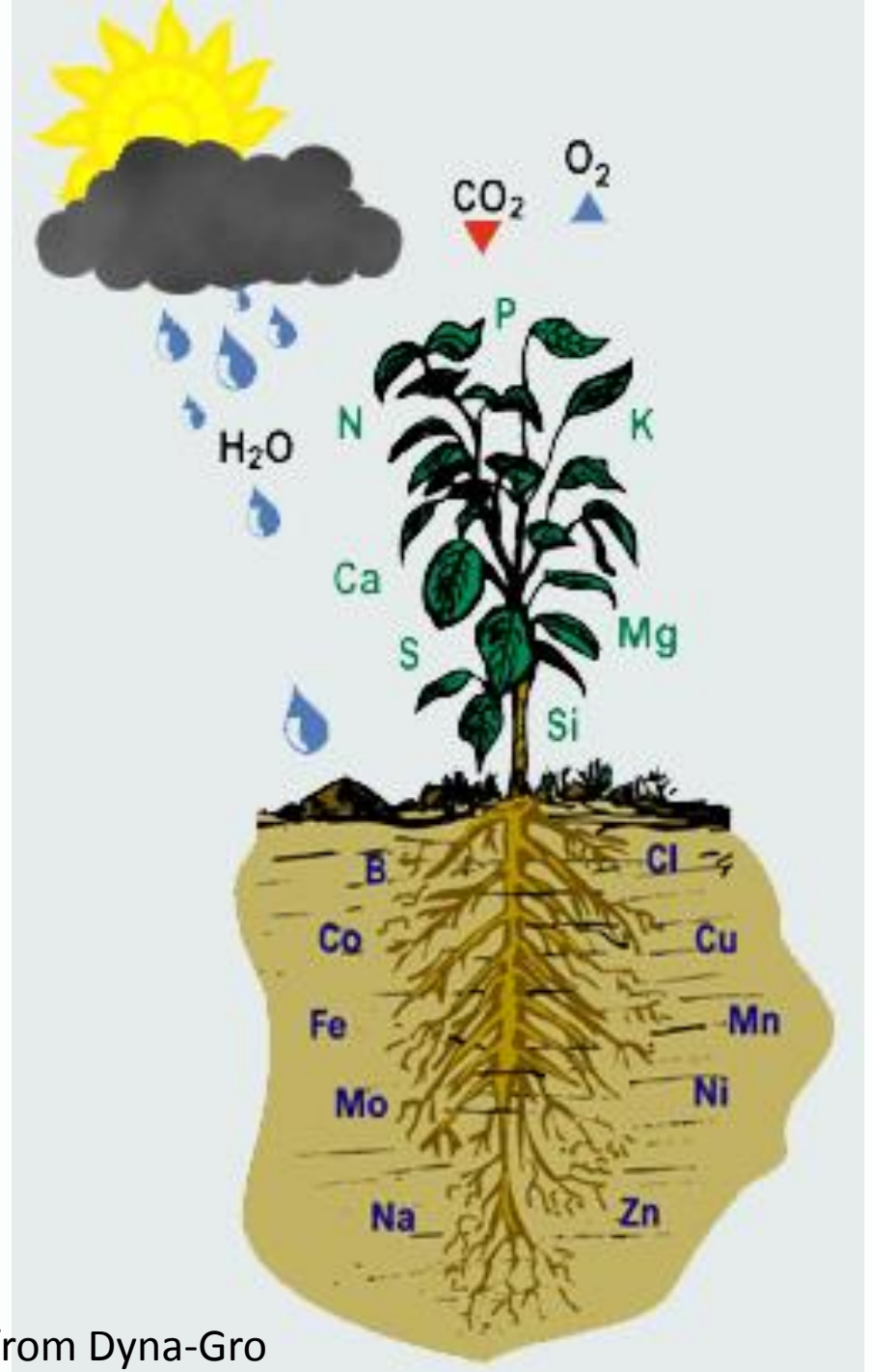


Image from Dyna-Gro