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

MABA-MGEA Convention, Great Falls
Jan. 31, 2014

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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:

<table>
<thead>
<tr>
<th>Deficiency observed in MT</th>
<th>No known deficiency in MT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boron (B)</td>
<td>Molybdenum (Mo)</td>
</tr>
<tr>
<td>Chloride (Cl)</td>
<td>Nickel (Ni)</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td></td>
</tr>
<tr>
<td>Iron (Fe)</td>
<td></td>
</tr>
<tr>
<td>Manganese (Mn)</td>
<td></td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td></td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Limiting conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boron Chloride</td>
<td>Low Cl in rain (MT)</td>
</tr>
<tr>
<td></td>
<td>Very wet or very dry</td>
</tr>
<tr>
<td></td>
<td>Coarse, sandy</td>
</tr>
<tr>
<td></td>
<td>&lt;2% SOM (B)</td>
</tr>
<tr>
<td></td>
<td>pH &gt;7.5 (B)</td>
</tr>
<tr>
<td>Copper Iron</td>
<td>Cool and wet</td>
</tr>
<tr>
<td>Manganese Zinc</td>
<td>&lt;2% SOM</td>
</tr>
<tr>
<td></td>
<td>Poorly drained (Fe)</td>
</tr>
<tr>
<td></td>
<td>Coarse and dry (Cu)</td>
</tr>
<tr>
<td></td>
<td>pH &gt;7.5</td>
</tr>
</tbody>
</table>
Soil pH affects micronutrient availability

Chloride is not affected by pH

(Hoeft et al. 2000)
### Mobility and processes that affect availability

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Mobility</th>
<th>Limiting processes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boron Chloride</td>
<td>Mobile</td>
<td>Leaching Harvest</td>
</tr>
<tr>
<td>Copper Iron</td>
<td>Immobile</td>
<td>Harvest Binding to soil or forming minerals</td>
</tr>
<tr>
<td>Manganese Zinc</td>
<td>Insoluble</td>
<td></td>
</tr>
</tbody>
</table>

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)

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Fertilizer rate (lb/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; 0.25</td>
</tr>
<tr>
<td>Boron</td>
<td>2</td>
</tr>
<tr>
<td>Copper</td>
<td>2</td>
</tr>
<tr>
<td>Iron</td>
<td>4</td>
</tr>
<tr>
<td>Manganese</td>
<td>20</td>
</tr>
<tr>
<td>Zinc</td>
<td>10</td>
</tr>
<tr>
<td>Chloride</td>
<td>30 lb/acre is generally considered critical level</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>1979* (n=301)</th>
<th>2013 (n=5330)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Available</td>
</tr>
<tr>
<td>Copper</td>
<td>30</td>
<td>2.0</td>
</tr>
<tr>
<td>Iron</td>
<td>38,000</td>
<td>15.8</td>
</tr>
<tr>
<td>Zinc</td>
<td>50</td>
<td>1.2</td>
</tr>
</tbody>
</table>

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!

Percentage of MT soil tests with soil Cl< 30 lb/ac

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)

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

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

<table>
<thead>
<tr>
<th>Crop</th>
<th>Boron</th>
<th>Copper</th>
<th>Iron</th>
<th>Manganese</th>
<th>Zinc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Barley</td>
<td>Low</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Low</td>
</tr>
<tr>
<td>Sugar beet</td>
<td>Medium</td>
<td>Medium</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>High</td>
<td>High</td>
<td>N/A</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Grass</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
</tr>
</tbody>
</table>

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

MOBILE NUTRIENTS

Older or lower leaves affected

YES →

Effects mostly generalized; plants dark or light green

NO →

Effects mostly localized; chlorosis with or without spotting

NO →

Plants dark green, often developing purple or red color

YES

PHOSPHORUS (P)

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

NO

NITROGEN (N)

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

NO

MOBILE NUTRIENTS

NO →

IMMOBILE NUTRIENTS

Newer or younger leaves affected; symptoms localized

YES

Growing point (terminal bud) dies

NO →

Growing point typically remains alive

YES →

Chlorosis with interveinal chlorosis; leaves sometimes red or with dead spots

YES

CHLORIDE (Cl)

* If symptoms don’t meet any of the key descriptions, either go back through the key another time or refer to text for more specific symptom descriptions.

* MOLYBDENUM (Mo)

* COPPER (Cu)

* ZINC (Zn)

NOTE: Since nickel (Ni) was only recently added as an essential nutrient, specific Ni deficiency symptoms are not well defined. Common symptoms include chlorosis and interveinal chlorosis in younger leaves.
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

Critical level = 0.4%?
**Typical minimum sufficient micronutrient levels in plant tissue**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Sample</th>
<th>B (ppm)</th>
<th>Cu (ppm)</th>
<th>Fe (ppm)</th>
<th>Mn (ppm)</th>
<th>Zn (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>Upper 6” of leaves at bloom</td>
<td>30</td>
<td>8</td>
<td>30</td>
<td>25</td>
<td>20</td>
</tr>
<tr>
<td>Small grains</td>
<td>Whole plant prior to grain filling</td>
<td>5</td>
<td>3.7 (barley)</td>
<td>20</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Canola</td>
<td>Leaves at flowering</td>
<td>30</td>
<td>2.7</td>
<td>20</td>
<td>15</td>
<td>15</td>
</tr>
</tbody>
</table>

McKenzie 2001
## Common micronutrient sources

<table>
<thead>
<tr>
<th>Micronutrient</th>
<th>Fertilizer name</th>
<th>Fertilizer Formula</th>
<th>Solubility*</th>
<th>Micronutrient content (%) **</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boron</td>
<td>Borax</td>
<td>Na$_2$B$_4$O$_7$·10H$_2$O</td>
<td>Low</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Boric acid</td>
<td>H$_3$BO$_3$</td>
<td>Medium</td>
<td>10</td>
</tr>
<tr>
<td>Chloride</td>
<td>Potassium Chloride</td>
<td>KCl</td>
<td>High</td>
<td>47</td>
</tr>
<tr>
<td>Copper</td>
<td>Copper sulfate</td>
<td>CuSO$_4$·5H$_2$O</td>
<td>Medium</td>
<td>25</td>
</tr>
<tr>
<td>Iron</td>
<td>Ferrous sulfate</td>
<td>FeSO$_4$·7H$_2$O</td>
<td>Medium</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Iron oxalate</td>
<td>Fe$_2$(C$_2$O$_4$)$_3$</td>
<td>High</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Iron EDTA</td>
<td>Varies</td>
<td>Varies</td>
<td>5-14</td>
</tr>
<tr>
<td>Manganese</td>
<td>Manganeseous sulfate</td>
<td>MnSO$_4$·4H$_2$O</td>
<td>High</td>
<td>25</td>
</tr>
<tr>
<td>Zinc</td>
<td>Zinc sulfate</td>
<td>ZnSO$_4$·H$_2$O</td>
<td>Medium</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>Zinc EDTA</td>
<td>Varies</td>
<td>Varies</td>
<td>6-14</td>
</tr>
</tbody>
</table>

* 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).
### Common micronutrient forms

<table>
<thead>
<tr>
<th>Form</th>
<th>Availability</th>
<th>Nutrients</th>
<th>Application surface</th>
<th>Residual &gt; 1 year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulfate (salts)</td>
<td>Water soluble, plant available</td>
<td>Cu, Fe, Mn, Zn B (borate)</td>
<td>Soil or Foliage</td>
<td>Yes</td>
</tr>
<tr>
<td>Oxysulfate</td>
<td>Oxide portion not very available, sulfide portion is, should be &gt; 50% water soluble</td>
<td>Cu, Fe, Mn, Zn</td>
<td>Soil</td>
<td>Yes</td>
</tr>
<tr>
<td>Oxide</td>
<td>Bound with O₂, not soluble, needs to be converted</td>
<td>Cu, Fe, Mn, Zn</td>
<td>Soil</td>
<td>Yes, but is not plant available</td>
</tr>
<tr>
<td>Chelate</td>
<td>Plant available form</td>
<td>Cu, Fe, Mn, Zn</td>
<td>Soil or Foliage</td>
<td>No</td>
</tr>
<tr>
<td>Manure</td>
<td>Bound in OM</td>
<td>Cu, Zn</td>
<td>Soil</td>
<td>Yes</td>
</tr>
</tbody>
</table>
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, tan spot
- 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

<table>
<thead>
<tr>
<th>Fertilizer Cl (lb/ac)</th>
<th>Flag Leaf Spot Severity (%)</th>
<th>Yield (lb/ac)</th>
<th>Shoot Cl (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>87</td>
<td>2954</td>
<td>540</td>
</tr>
<tr>
<td>40</td>
<td>6</td>
<td>3615</td>
<td>5520</td>
</tr>
</tbody>
</table>

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

Low rates and lack of dispersion in soil limit Cu availability

Grain Yield (bu/acre)

- 0 lb
- 0.22 lb seed-row
- 0.89 lb @ 4-leaf
- 0.22 lb @ flag-leaf

Cu rate/method/timing

Foliar
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?
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