Understanding the role, requirements and options for micronutrient – copper, manganese

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Better Crops, Better Environment ... through Science

Cummins & Kimba, South Australia, August 2014.
Micronutrients *(rather than trace elements)*

- Required in low amounts by plants (g/ha).
- Essential for healthy growth.
- Difficult to pick up in soil tests
- Often by association & history

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Soil Levels mg/kg</th>
<th>Wheat Grain mg/kg</th>
<th>Removal 4 t/ha</th>
<th>Canola Grain mg/kg</th>
<th>Removal 2.5 t/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>0.14%</td>
<td>23</td>
<td>94 kg</td>
<td>45</td>
<td>110 kg</td>
</tr>
<tr>
<td>Copper</td>
<td>2-400</td>
<td>5</td>
<td>20 g</td>
<td>4</td>
<td>10 g</td>
</tr>
<tr>
<td>Manganese</td>
<td>100-10,000</td>
<td>44</td>
<td>176 g</td>
<td>49</td>
<td>125 g</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>1-7</td>
<td>&lt;0.8</td>
<td>&lt;0.8</td>
<td>&lt;0.8</td>
<td></td>
</tr>
<tr>
<td>Zinc</td>
<td>20-600</td>
<td>25</td>
<td>100 g</td>
<td>34</td>
<td>85 g</td>
</tr>
</tbody>
</table>

- Copper (Cu)
- Iron (Fe)
- Manganese (Mn)
- Zinc (Zn)
- Boron (B)
- Molybdenum (Mo)
- Chloride (Cl)
- Nickel (Ni)
- Silicon (Si)
- Colbolt (Co)
- Selenium (Se)
Availability – *not amount* – is important

- Factors influencing availability of micronutrients in soils

<table>
<thead>
<tr>
<th>Condition</th>
<th>Cu</th>
<th>Fe</th>
<th>Mn</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH &gt; 7.0</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>pH &lt; 5.5</td>
<td>++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>water-logged soil</td>
<td>+</td>
<td>--</td>
<td>+</td>
</tr>
<tr>
<td>drought</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>high humus content</td>
<td>---</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>high P-content</td>
<td>-</td>
<td>---</td>
<td>-</td>
</tr>
<tr>
<td>sand</td>
<td>---</td>
<td>---</td>
<td>--</td>
</tr>
<tr>
<td>compaction</td>
<td>+</td>
<td>++</td>
<td>+</td>
</tr>
</tbody>
</table>

--- low availability high +++

It is a chemical jungle in the soil – soil/plant compete for metals
Soil Test Values – NVT surveys

<table>
<thead>
<tr>
<th>Region</th>
<th>pH (CaCl₂) (mg kg⁻¹)</th>
<th>HWS B (mg kg⁻¹)</th>
<th>DTPA Cu (mg kg⁻¹)</th>
<th>DTPA Mn (mg kg⁻¹)</th>
<th>DTPA Zn (mg kg⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower EP</td>
<td>7.1±0.1</td>
<td>5.6±0.8</td>
<td>1.9±1.0</td>
<td>14.8±54.2</td>
<td>3.9±3.8</td>
</tr>
<tr>
<td>Mid North</td>
<td>6.9±0.1</td>
<td>2.7±0.7</td>
<td>0.5±1.0</td>
<td>1.1±54.3</td>
<td>0.3±3.8</td>
</tr>
<tr>
<td>Murray Mallee</td>
<td>7.4±0.2</td>
<td>2.3±1.3</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>South East</td>
<td>7.1±0.1</td>
<td>3.1±0.6</td>
<td>0.8±0.1</td>
<td>1.7±7.0</td>
<td>0.9±0.5</td>
</tr>
<tr>
<td>Upper EP</td>
<td>7.7±0.1</td>
<td>5.1±0.8</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Yorke P</td>
<td>7.4±0.1</td>
<td>3.7±0.7</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Critical Values*</td>
<td>&lt;0.12</td>
<td>&lt;0.2-0.3</td>
<td>&lt;10</td>
<td>&lt;0.8(?)</td>
<td></td>
</tr>
<tr>
<td>All zones</td>
<td>6.3±1.3</td>
<td>3.5±13.3</td>
<td>1.1±1.0</td>
<td>24±43</td>
<td>1.0±2.9</td>
</tr>
</tbody>
</table>

• DTPA is common extractant used
  - Cu critical values very low & unreliable 4/10
  - Mn values values very variable & unreliable 0/10

• Grain nutrient concentrations
  - SA LEP Cu 4.4±0.3; Mn 25±3; Zn 19±2 Cu 1.5; Mn 10; Zn 15
  - SA UEP Cu 4.9±0.2; Mn 49±2; Zn 26±1 Cu & Mn 3/10; Zn 5/10
Diagnosis of micronutrient deficiency

• Situations (soil & season & crop) – probably most reliable
  – LEP long history of Mn, Cu and Zn responses.
  – Different reasons on different soils – fixed (pH) or low parent or washed out.

• Soil tests – for the reasons above soil tests tend to be unreliable
  – Use DTPA (chelating agent) and then assayed
    • eg DTPA Zn, critical value crop dependant (around 0.5 mg/kg)
  – No soil test for Fe or Mo.
  – Use an ASPAC lab & Fertcare advisors

• Plant tissue tests

• Visual symptoms
Which is the copper deficiency?

1. Chloride
2. Zinc
3. Copper
4. Manganese
Too easy?

FROST
(J Hunt, CSIRO.

DROUGHT
Copper deficiency

- High OM soils & sandy alkaline soils, acidic
- Rolling/curling YEB
- Chlorophyll & pollen (timing)
- Wheat most likely.
- No confirmed Cu deficiency for canola reported
- Interaction with N.
• Classic on carbonate soils
• Washed out acid sands
• Coincident with Zn and Cu
• Mild wilting to water soaked patches – streaks or grey spots at leaf base
• Split seed in lupin
• Canola more tolerant
Risk & Reality

- Risk of Cu and Mn deficiency high
- Low soil mobility (distribution/response)
- Contribution factors to getting a response to added Cu or Mn
  - Paddock history
    - Cu supplemented basal fertilizer has a long residual life (>5 y)
    - Mn almost no residual activity
  - Carbonate - >60% lime almost certain Mn
  - Wet compacted soils, lower risk of Mn

<table>
<thead>
<tr>
<th>Micronutrient</th>
<th>Susceptible Crops</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>Oats, Sunflower, Lucerne &amp; canola more tolerant.</td>
</tr>
<tr>
<td>Manganese</td>
<td>Oats, Legumes, Lupins &amp; canola more tolerant than cereals.</td>
</tr>
<tr>
<td></td>
<td>Variety differences.</td>
</tr>
</tbody>
</table>
Diagnosing trace element deficiencies

confirm using tissue testing

• Nutrient mobility in the plant
• Determines if seen in older or younger leaves
• Symptoms in older leaves occur with mobile nutrients (eg Nitrogen)
• Symptoms in younger leaves occur with less mobile nutrients (eg Sulphur).
• 100 random YEB/YML

<table>
<thead>
<tr>
<th></th>
<th>Cu</th>
<th>Mn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat (YEB)</td>
<td>&lt;1.5 mg/kg</td>
<td>&lt;12 mg/kg</td>
</tr>
<tr>
<td>Lupin/Lentil (YMG)</td>
<td>&lt;1.5 mg/kg</td>
<td>&lt;20 mg/kg</td>
</tr>
<tr>
<td>Canola (YML)</td>
<td>2-3 mg/kg</td>
<td>&lt;25 mg/kg</td>
</tr>
</tbody>
</table>
Delivering micronutrients

- Seed supplemented – late Cu, Zn to increase seed reserves. Maybe not enough added for Mn
- Seed dressing – Cu, Zn added (a range of formulations). Not able to load up enough to meet all Mn demands
- Dry blended – Co-granulated (ie in the MAP melt)
  - Copper sulfate and/or copper oxysulfate – 2-10 kg/ha
  - Manganese sulfate (soluble) or oxysulfate – 10-20 kg/ha.
  - Acidification around granule – enhanced uptake
  - Residual response.
- Fluid applied in-furrow
  - Foliar
Co-granulation of TE with NPK(S) is beneficial

MAP+S+Zn blend

MAP+S+Zn co-granulated

M. McLaughin, CSIRO
Delivering micronutrients

• What is the right source?

• Chlorides – high solubility (foliar damage)
• Oxysulfates – suitable only for dry blending
• Sulfates (esp. Cu)– generally moderate solubility - corrosive
• Oxides– low to very low solubility
• Chelates – protected

• Low solubility not all bad, high solubility not all good.
• Match products on cost and active delivered
Source comparisons

- Soil applied MnO vs MnSO$_4$ mixed through the soil
- Range of rates, 2 soils
- Compare the shape of the curve – rate to reach maximum yield.
- Oxide 40% as effective as sulphate form.
Fighting the chemical battle

- Chelating agents form bonds with metallic ions (ligands)
  - Synthetic eg EDTA, Humic and fulvic acids, Organic acids eg citric acid (divalent cations), Amino acids
  - New chemistry coming for trace element chelates
    - Rhamnolipids, Polyethyleneimine

- Prevent interaction with soil
- Protect micronutrient in spray tank
- Reduce canopy damage

M. McLaughin, CSIRO
As a foliar?

- Little or no residual value
- For Cu and Mn, recovery from early deficiency is OK.
- Generally need more at seeding than as a foliar – residual Cu response
- Cost per kg nutrient
- Product Efficacy comparisons
- Supplements, adjuvants, magic potions.
  - Need proper data on the efficacy – field trials.
- Key selection criterion is the potential for immobilization in soil

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Ignorance more frequently begets confidence than does knowledge.

– Charles Darwin

<table>
<thead>
<tr>
<th>Species</th>
<th>Foliar Uncertain</th>
<th>Soil &gt;5 kg Zn/ha</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>2-29</td>
<td>22</td>
<td>Duncan, 1967a</td>
</tr>
<tr>
<td>Wheat</td>
<td>16</td>
<td>39</td>
<td>Takkar 1989</td>
</tr>
</tbody>
</table>

% response over control
Copper Sources

- Foliar application products compared.
- WA a long time ago.
- Relative effectiveness
  - Sulfate = 1 (250 g/ha)
  - Chelate = 1.72-2.24 (150 g/ha)
  - Oxychloride = 0.47 – 0.63 (520 g/ha)
  - RATE VERSUS FORMULATION

- Timing
  - Most effective was the chelate applied early (2-3 leaf).

Brennan, 1990, AJEA.

<table>
<thead>
<tr>
<th>Cu source</th>
<th>A (t/ha)</th>
<th>$A_0$ (t/ha)</th>
<th>$C$ ($10^2 \times C$)</th>
<th>REA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Experiment 1a</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chelate</td>
<td>2.27 ± 0.02</td>
<td>1.56 ± 0.09</td>
<td>2.581</td>
<td>1.77</td>
</tr>
<tr>
<td>Sulphate</td>
<td>2.25 ± 0.03</td>
<td>1.56 ± 0.08</td>
<td>1.457</td>
<td>1.0</td>
</tr>
<tr>
<td><strong>Experiment 1b</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chelate</td>
<td>2.14 ± 0.02</td>
<td>1.56 ± 0.06</td>
<td>2.248</td>
<td>1.97</td>
</tr>
<tr>
<td>Sulphate</td>
<td>2.14 ± 0.01</td>
<td>1.56 ± 0.04</td>
<td>1.140</td>
<td>1.0</td>
</tr>
<tr>
<td><strong>Experiment 2a</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxychloride</td>
<td>2.59 ± 0.05</td>
<td>0.66 ± 0.02</td>
<td>0.705</td>
<td>0.49</td>
</tr>
<tr>
<td>Chelate</td>
<td>2.53 ± 0.01</td>
<td>0.63 ± 0.01</td>
<td>2.476</td>
<td>1.72</td>
</tr>
<tr>
<td>Sulphate</td>
<td>2.53 ± 0.02</td>
<td>0.64 ± 0.01</td>
<td>1.442</td>
<td>1.0</td>
</tr>
<tr>
<td><strong>Experiment 2b</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxychloride</td>
<td>2.32 ± 0.05</td>
<td>0.61 ± 0.02</td>
<td>0.610</td>
<td>0.49</td>
</tr>
<tr>
<td>Chelate</td>
<td>2.27 ± 0.02</td>
<td>0.60 ± 0.01</td>
<td>2.265</td>
<td>1.81</td>
</tr>
<tr>
<td>Sulphate</td>
<td>2.28 ± 0.04</td>
<td>0.63 ± 0.02</td>
<td>1.252</td>
<td>1.0</td>
</tr>
<tr>
<td><strong>Experiment 3</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxychloride</td>
<td>1.93 ± 0.02</td>
<td>0.35 ± 0.05</td>
<td>0.934</td>
<td>0.63</td>
</tr>
<tr>
<td>Chelate</td>
<td>1.94 ± 0.07</td>
<td>0.32 ± 0.02</td>
<td>3.015</td>
<td>2.02</td>
</tr>
<tr>
<td>Sulphate</td>
<td>1.94 ± 0.04</td>
<td>0.33 ± 0.01</td>
<td>1.490</td>
<td>1.0</td>
</tr>
<tr>
<td><strong>Experiment 4</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxychloride</td>
<td>2.15 ± 0.09</td>
<td>0.33 ± 0.02</td>
<td>0.407</td>
<td>0.47</td>
</tr>
<tr>
<td>Chelate</td>
<td>2.05 ± 0.04</td>
<td>0.35 ± 0.01</td>
<td>1.925</td>
<td>2.24</td>
</tr>
<tr>
<td>Sulphate</td>
<td>2.08 ± 0.03</td>
<td>0.35 ± 0.01</td>
<td>0.860</td>
<td>1.0</td>
</tr>
</tbody>
</table>

$C_X/C_S$ is the RE where $C_X$ is the curvature coefficient for any of the three Cu sources while $C_S$ is the curvature coefficient for CuSO$_4$. 

Brennan, 1990, AJEA.
Is there a magic formula for success?

Copper
- At-sowing – more residual, formulation, delivery 1-5 Cu kg/ha.
- Copper as foliar – do the sums on sulfate/chelate $, 50-100 g Cu/ha, foliar damage
- Apply earlier rather than later.

Manganese
- As foliar as symptoms appear
- ~200-500 g Mn/ha
- May need two applications.

COMPATIBILITY

YIELD RESPONSE
Mn product comparison

- Streaky Bay - Mn foliar source on wheat
  - Mn sulphate; Mn EDTA chelate; Mn Lignosulphate chelate; Mn Amino acid chelate (all label rates), as well as at 150 g Mn/ha

- One of a series of experiments on deployment of micronutrients
  - Large emphasis on fluid-in-furrow rate comparisons against foliar and granular.
  - Residual values of Cu/Mn/Zn products on SA soil types.
  - Building on the great work of Holloway et al. using fluid micronutrients (mixtures) and deep placement.
Summary and take home

• There are areas where micronutrients will give benefits.
  – Sometimes it is obvious

• The tools for identifying specific risks are not so good.
  – Tissue testing (timing)

• Products on the market vary in efficiency and price.
  – Very little efficacy data in the public domain.
  – Demand that information from the supplier – from proper trials.
  – At sowing requires more product but is usually cheaper
  – Foliar is generally more expensive per kg supplied, but more efficient.

  – $ for $ - do the sums
  • At sowing 5 kg @ $5/kg = $25
  • Foliar 2 kg @ $12/kg = $24