Basic Concepts of Soil Fertility

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Basic Concepts of Soil Fertility:

1. 17 essential elements
   • function
   • form taken up
   • mobility in plant

2. Nutrient uptake
   • mechanisms
   • effect of soil characteristics

3. Cation exchange
   • factors affecting
   • relative magnitude
Essential nutrients

• Structural
  – Carbon
  – Hydrogen
  – Oxygen
Essential nutrients

• Primary
  – Nitrogen
  – Phosphorus
  – Potassium
Essential nutrients

• Secondary
  – Calcium
  – Magnesium
  – Sulfur
Essential nutrients

- Micronutrients
  - Iron
  - Manganese
  - Copper
  - Zinc
  - Boron
  - Molybdenum
  - Chlorine
  - Nickel
Essential nutrients

• Beneficial or Enhancing
  – Sodium
  – Silicon
  – Cobalt
  – Selenium
  – Aluminum
Sources of nutrients to plants

1. Soil solution
   - ionic form
   - low concentration
   - highly buffered

2. Contributors to the soil solution
   - exchange sites on clay and organic matter
   - organic matter and microorganisms
   - soil rocks and minerals
   - atmosphere and precipitation
   - fertilizer and other additions
Movement of ions from soils to roots

- Root interception
- Mass flow
- Diffusion
Mass flow – dissolved nutrients move to the root in soil water that is flowing towards the roots.
**Diffusion** – nutrients move from higher concentration in the bulk soil solution to lower concentration at the root; -In the time it takes $\text{NO}_3^-$ to diffuse 1 cm, $\text{K}^+$ diffuses 0.2 cm, and $\text{H}_2\text{PO}_4^-$ diffuses 0.02 cm
**Root interception** – roots obtain nutrients by physically contacting nutrients in soil solution or on soil surfaces;
- roots contact ~1% of soil volume;
- mycorrhizal infection of root increase root-soil contact
### Principal ways in which ions move from soil to the roots of corn

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Amount of Nutrient Required for 150 bu/a of Corn (lb/a)</th>
<th>Percentage Supplied by</th>
<th>Root Interception</th>
<th>Mass Flow</th>
<th>Diffusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>170</td>
<td>1</td>
<td>99</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>35</td>
<td>3</td>
<td>6</td>
<td>94</td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>175</td>
<td>2</td>
<td>20</td>
<td>78</td>
<td></td>
</tr>
<tr>
<td>Ca</td>
<td>35</td>
<td>171</td>
<td>429</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Mg</td>
<td>40</td>
<td>38</td>
<td>250</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>20</td>
<td>5</td>
<td>95</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Cu</td>
<td>0.1</td>
<td>10</td>
<td>400</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Zn</td>
<td>0.3</td>
<td>33</td>
<td>33</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>0.2</td>
<td>10</td>
<td>350</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Fe</td>
<td>1.9</td>
<td>11</td>
<td>53</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>Mn</td>
<td>0.3</td>
<td>33</td>
<td>133</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Mo</td>
<td>0.01</td>
<td>10</td>
<td>200</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Ion absorption by plants:

1. Passive uptake
   - diffusion
   - ion exchange

2. Active ion uptake
   - ion carriers
   - selective / competitive
Cation Exchange Capacity (CEC)

• Cations – positively charged ions eg. K⁺
• CEC – soil property
  – Ability of soil to hold cations
    • Nutrients or other chemicals (herbicides)

\[\text{Al}^{3+} > \text{H}^+ > \text{Ca}^{2+} > \text{Mg}^{2+} > \text{K}^+ = \text{NH}_4^+ > \text{Na}^+\]

– Units are meq/100 g or cmol_c/kg
  • Number is the same regardless of units
Importance of CEC

- Nutrient retention
- Nutrient availability
- Act as buffer
- Control levels of waste disposal
- Control levels of herbicide
Soil properties that affect CEC

- Amount of clay
- Amount of organic matter
- pH
- Type of clay

Estimated by summing exch. Ca + Mg + K

\[ \text{Est. CEC} = \frac{\text{ppm Ca}}{200} \times \frac{\text{ppm Mg}}{122} \times \frac{\text{ppm K}}{391} \times \frac{5 \text{ g wt. of soil}}{5 \text{ g scoop}} \]
## CEC range for various soil textures

<table>
<thead>
<tr>
<th>Texture</th>
<th>CEC (meq/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sands (light colored)</td>
<td>3 – 5</td>
</tr>
<tr>
<td>Sands (dark colored)</td>
<td>10 – 20</td>
</tr>
<tr>
<td>Loams</td>
<td>10 – 15</td>
</tr>
<tr>
<td>Silt loams</td>
<td>15 – 25</td>
</tr>
<tr>
<td>Clays and clay loams</td>
<td>20 – 50</td>
</tr>
<tr>
<td>Organic soils</td>
<td>50 – 100</td>
</tr>
</tbody>
</table>

From Havlin et al., 2005
Determining nutrient need:

- Visual symptoms
- Plant analysis
- In-field plant tests
- In-field soil “quickkit” tests
- Soil tests
Describe how the following soil characteristics affect nutrient availability:

- Texture
- Structure
- Drainage/aeration
- Soil moisture
- Organic matter
- CEC