Nutrient Management for Vegetable Crops
Plant Nutrients and Fertilizer Sources

Wenjing Guan, Liz Maynard and Petrus Langenhoven
January 11, 2017
Goals of Plant Nutrient Management Plan

- Ensure supply of essential nutrients does not limit crop growth
- Optimizing the economic returns from fertilizers
- Minimize the negative impact of nutrients on the environment
Essential Nutrients

Macronutrients:
- Nitrogen (N)
- Phosphorus (P)
- Potassium (K)
- Calcium (Ca)
- Magnesium (Mg)
- Sulfur (S)

Micronutrients:
- Boron (B)
- Chlorine (Cl)
- Copper (Cu)
- Iron (Fe)
- Manganese (Mn)
- Molybdenum (Mo)
- Zinc (Zn)

Which nutrient is the most important one?

A crop’s yield is restricted by the lack of a single element, even though there may be sufficient quantities of all other essential nutrients.
Essential Nutrients

Macronutrients:
- Nitrogen (N)
- Phosphorus (P)
- Potassium (K)
- Calcium (Ca)
- Magnesium (Mg)
- Sulfur (S)

Micronutrients:
- Boron (B)
- Copper (Cu)
- Manganese (Mn)
- Zinc (Zn)
- Chlorine (Cl)
- Iron (Fe)
- Molybdenum (Mo)
Nitrogen

- Nitrate ($\text{NO}_3^-$) and Ammonium ($\text{NH}_4^+$)
  - Plants take up N in both forms. Excess ammonium can cause ammonium toxicity
  - Fertilizers can provide N in both forms. Nitrate is the main source of nitrogen under soil temperature above 55 °F and aerated conditions regardless of fertilizer use

- Nitrogen lost
  - Ammonium, volatilization if not incorporated
  - Nitrate: leach, denitrification
Nitrogen Fertilizers

- Anhydrous ammonia (82% N) ammonium-N
- Urea (46% N) ammonium-N
- Nitrogen solutions (UAN, 28-32% N)
  Ammonium : nitrate = 3:1
- Ammonium sulfate (21% N), ammonium, recommended to lower soil pH
- Ammonium phosphate (10-21% N), ammonium, supply P, also contribute N
- Calcium nitrate (15.5% N), nitrate
- Potassium nitrate (14% N), nitrate
<table>
<thead>
<tr>
<th>Fertilizer forms</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrate-N fertilizers</td>
<td>- Ready source of N when soil temperature is low, and soil nitrate is low</td>
<td>- More expensive</td>
</tr>
<tr>
<td></td>
<td>- Supply important cations: K, Ca</td>
<td>- Subject to leach</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Increase soil pH</td>
</tr>
<tr>
<td>Ammonium-N fertilizers</td>
<td>- More economic source of N fertilizers</td>
<td>- Subject to volatilization</td>
</tr>
<tr>
<td></td>
<td>- Less leach concerns</td>
<td>- Under suboptimal growing conditions (low soil temperature, saturated, low soil pH) and excess application, plant uptake excessive ammonium may lead to ammonium toxicity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Excess uptake of ammonium may reduce uptake of K, Ca and Mg.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Soil acidification</td>
</tr>
</tbody>
</table>

*Nitrate form of nitrogen is considered when immediate source of nitrogen is needed while soil is cool (less than 55°F) and has low pH, or after water-logged soil has drained*
Phosphorus

Most soil P is not available
- Soil pH management
- Mobility of phosphorus is very limited.

*Mycorrhizal fungi* increase phosphorus uptake

http://www.soillifeforyoursoilandcrop.com/about-mycorrhizal-fungi.html

✓ Apply P fertilizers

- P is mostly applied in preplant fertilizer
  - Difficult to recover from phosphorus deficiency
  - Young seedlings are the most sensitive
  - Leaching is less a concern

- Band or broadcast
  - Soil with high phosphorus, broadcast is adequate
Phosphorus fertilizers

- Monoammonium phosphate (MAP) (11% N, 48% P₂O₅)
- Diammonium phosphate (DAP) (18% N, 46% P₂O₅)
- Ammonium polyphosphate (APP) (10% N, 34% P₂O₅)

*Phosphorus is more readily available when applied with nitrogen*

- Superphosphate (20% P₂O₅)
- Rock Phosphate
Potassium

- Potassium is between N and P in mobility
- Leached in sandy soil, split application
- Recommendations takes into account Cation Exchange Capacity
Potassium fertilizers

- Potash, potassium chloride (60-62 % K₂O)
  High salt index, avoided if salinity is a problem
  split apply if high rate is required
- Potassium sulfate (52% K₂O, 18% S)
- Sulfate of potash-Magnesia (K-Mag) (22% K₂O, 11% Mg, 22% S)
- Potassium nitrate (44% K₂O, 13% N)
Calcium and Magnesium

- Mg deficiency likely to occur in acid sandy soil with low CEC
- Most soil contain sufficient available calcium, soil moisture play a major role for plant to take up of calcium

http://www.smart-fertilizer.com/articles/Cation-Exchange-Capacity
Antagonistic effects of K, Ca and Mg

- Excessive Ca may induce Mg deficiency
- A very high soil K can cause Ca and Mg deficiency
- High Mg and Ca may result in K deficiency

Base saturation: Ca at least 60%, Mg 10-15%, K 1-5%

Source: MSU E2934
Calcium and Magnesium fertilizer sources

- Calcitic and dolomitic limes (3-12% Mg)
- *If pH is adequate*, apply Calcium sulfate (gypsum), and Magnesium sulfate (Epsom salt)
- Calcium nitrate (15.5% N, 19% Ca)
- Calcium chloride (36% Ca)
- Potassium magnesium sulfate (22% K₂O, 11% Mg, 22% S)
Sulfur

- Primary source: soil organic matter, atmospheric deposition
- Sandy soil low in organic matter may show sulfur deficiency

Sulfur fertilizer sources

- Potassium sulfate
- Gypsum
- Magnesium sulfate (Epsom salt)
- Element sulfur
- Ammonium sulfate
Micronutrients

✓ Boron

Table 1: Potential for a crop response to boron when applied to boron deficient soils.

<table>
<thead>
<tr>
<th>RESPONSE TO BORON</th>
<th>LARGE</th>
<th>MODERATE</th>
<th>SMALL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa, apple,</td>
<td>Cabbage, carrot,</td>
<td>Asparagus, barley,</td>
<td></td>
</tr>
<tr>
<td>broccoli, canola,</td>
<td>clover, grape,</td>
<td>blueberries, field</td>
<td></td>
</tr>
<tr>
<td>cauliflower,</td>
<td>lettuce, onion,</td>
<td>corn, cucumber,</td>
<td></td>
</tr>
<tr>
<td>celery, red beet,</td>
<td>radish, spinach,</td>
<td>oats, pasture</td>
<td></td>
</tr>
<tr>
<td>sugar beet,</td>
<td>strawberry, and</td>
<td>grasses, pea,</td>
<td></td>
</tr>
<tr>
<td>sunflower, turnip</td>
<td>tomato</td>
<td>pepper, potato,</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>raspberry, rye,</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>soybean, sweet</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>corn, and wheat</td>
<td></td>
</tr>
</tbody>
</table>

- Recommendations based on crops.
- Boron should be broadcast with other fertilizers
- Foliar application

✓ Boron fertilizer sources
- Borax
- Sodium tetraborate
- Boric acid
- Solubor
- Sodium pentaborate
Some fungicide application supply Mn, Zn, Cu
Manganese deficiency is likely on higher pH soils with higher levels of organic matter
Zinc deficiency likely on higher pH soils with high P

<table>
<thead>
<tr>
<th>Element</th>
<th>Source</th>
<th>Highly responsive crops</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mn</td>
<td>Mn sulfate</td>
<td>Bean, cuke, garlic, greens, lettuce, onion, pea, potato, pumpkin, radish, spinach, squash, sweet corn</td>
</tr>
<tr>
<td>Zn</td>
<td>Zn sulfate</td>
<td>Bean, onion, spinach, sweet corn</td>
</tr>
</tbody>
</table>

Source: Purdue AY-276-W

Source: MSU, e2934
- pH influence plant nutrient availability
  - Optimal range pH 6.0-6.8
  - Lime increase soil pH
    - Reduce Ca, Mg deficiency,
    - Reduce Mn toxicity
  - Add element S or ammonium fertilizers reduce soil pH
    - Increase availability of Fe, Zn, Mn

Foliar fertilization

- Can be a viable way to supply a micronutrient if it is in unavailable form in the soil or soil application is not practical
- Not a practical approach for routinely supplying macronutrients
  Possibly an option for overcoming temporary macronutrient deficiencies when soil conditions prevent root uptake (e.g. flooded soils)
Fertilizer solubility

- When dissolve a fertilizer, not exceed its solubility

<table>
<thead>
<tr>
<th>Fertilizer /Temperature (°F)</th>
<th>41</th>
<th>50</th>
<th>68</th>
<th>77</th>
<th>86</th>
<th>104</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potassium nitrate</td>
<td>133</td>
<td>170</td>
<td>209</td>
<td>316</td>
<td>370</td>
<td>458</td>
</tr>
<tr>
<td>Calcium nitrate</td>
<td>1020</td>
<td>1130</td>
<td>1290</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mono ammonium phosphate</td>
<td>250</td>
<td>295</td>
<td>374</td>
<td>410</td>
<td>464</td>
<td>567</td>
</tr>
</tbody>
</table>

Fertilizer compatibility

Fertilizers contain calcium are incompatible with
fertilizers contain phosphate and sulfate in a fertilizer concentrate

- Calcium nitrate × Epsom salt
- Calcium nitrate × Ammonium Sulfate
- Calcium nitrate × Ammonium phosphate

Jar Test

[Jar Test Image](http://www.smart-fertilizer.com/articles/fertilizer-solubility)
Plant nutrient management in organic systems

- Organic fertilizers
- Organic matter
- Soluble nutrients
- Microbial release
- Plant uptake
✓ Manure and compost
  ▪ Availability in current season:
    • 80% availability for $P_2O_5$
    • 90% availability for $K_2O$
    • Soluble Nitrogen plus 10-50% of N in organic form
  ▪ Manure should be applied at least 4 month prior to harvest
  ▪ Caution of building up P,
  
  Compost: 1-3%N, 1-2%P, 1-2%K

✓ Cover crops
Other fertilizer sources used in organic production

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>P</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Feather meal</td>
<td>Bone meal</td>
<td>Greensand</td>
</tr>
<tr>
<td></td>
<td>Blood meal</td>
<td>Rock phosphate</td>
<td>Kelp meal</td>
</tr>
<tr>
<td></td>
<td>Fish product</td>
<td>Bat Guano</td>
<td>Potassium sulfate</td>
</tr>
<tr>
<td></td>
<td>Amino acid</td>
<td></td>
<td>Potassium magnesium sulfate</td>
</tr>
</tbody>
</table>

http://www.omri.org/
Questions & Comments

Wenjing Guan
812-886-0198
guan40@purdue.edu