Soil Fertility
Whitehall Gardener Club

May 1, 2019

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Hands-on is the best way to learn, but we’ll use clickers because....

1. I just had my nails done

2. Clicker training isn’t just for dogs

3. There isn’t enough dirt on the floor to get a good soil sample
Today’s topics

- Present what a soil test tells you
  - Soil nutrients
  - Soil properties
- Provide fertilizer guidelines for gardens
- Compare fertilizer sources
- Present plant symptoms of nutrient deficiencies
- Explain limitations, to know which soil properties you can influence
Why should home gardeners know something about soil nutrition?

• To grow healthy plants and tasty vegetables

• To protect the environment

• For efficient use of resources (water and $)
Six questions to ask yourself before you add fertilizer

1. Which elements do I need (N, P, K, S, etc.)? Soil test
2. How much do I apply?
3. What type of material do I use?
4. Which application method is best?
5. When is the best time to apply it?
6. Will I get a return ($ or environmental) on my investment?
Soil tests help to

• Identify nutrient deficiency or imbalance
• Calculate fertilizer rates
• Increase yield and/or save on fertilizer costs, and decrease environmental risks

Soil tests are

• Best done in early spring, but not when soil is wet
• Perhaps best done in late fall in our climate

See publications listed at end for details on ‘how-to’
## Soil laboratory vs home test kits

<table>
<thead>
<tr>
<th>Test</th>
<th>Kit cost</th>
<th>Cost/sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test kit</td>
<td>N, P, K, pH</td>
<td>$15 - $750</td>
</tr>
<tr>
<td>Lab</td>
<td>N, P, K, pH, salts</td>
<td>$17 per sample + shipping</td>
</tr>
</tbody>
</table>

- Sample treatment: Labs dry, grind, sieve, most home test kits do not.
- Test method used: e.g. Olsen P vs Mehlich-2 is pH dependent
- Format of results: Values (e.g. ppm) vs rating (low/med/high or deficient/adequate/surplus)
- Of 4 home kits tested, only 1 provided results similar to laboratory analysis, the others were moderately to far off in results (Sharma and Chatterjee, Crops & Soils Mar. 2019). Accurate one was most expensive.
- Before trusting a soil test kit’s results, calibrate results against standard soil test methods.
**How much fertilizer do I need to apply?**

- Estimate the amount of fertilizer needed based on soil test results, crop needs and area to receive fertilizer
- Sometimes provided on soil test results

<table>
<thead>
<tr>
<th>CROP:</th>
<th>VEGETABLES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dolomites (70 score)</td>
<td>Lime (70 score)</td>
</tr>
<tr>
<td>25</td>
<td>2.6</td>
</tr>
</tbody>
</table>

- Most fertilizer recommendations are in pounds per 1,000 square feet, or pounds per acre
- MSU publications listed at end provide guidelines and example calculations
For gardens, in top 6”, see *The Soil Scoop* or MT200705AG

<table>
<thead>
<tr>
<th>Soil Test</th>
<th>Organic Matter (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrate - N</td>
<td>&lt; 1.5</td>
</tr>
<tr>
<td>lbs /acre</td>
<td></td>
</tr>
<tr>
<td>&lt;20</td>
<td>4</td>
</tr>
<tr>
<td>20-40</td>
<td>2</td>
</tr>
<tr>
<td>40-80</td>
<td>1</td>
</tr>
<tr>
<td>&gt;80</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Olsen P (ppm)</th>
<th>&lt; 4</th>
<th>4 – 8</th>
<th>8 – 12</th>
<th>12 – 16</th>
<th>&gt; 16</th>
</tr>
</thead>
<tbody>
<tr>
<td>lb P$_2$O$_5$/1000 sq. ft.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>K (ppm)</th>
<th>&lt; 75</th>
<th>75 – 150</th>
<th>150 – 250</th>
<th>&gt;250</th>
</tr>
</thead>
<tbody>
<tr>
<td>lb K$_2$O/1000 sq. ft.</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>
To determine N rate you need:
1. Soil sample depth to convert ppm to lb N/acre (ppm x 2 x actual depth in inches / 6)

P rate: MSU guidelines are based on Olsen P. Bray works in pH < 7.3, Olsen works pH > 6.

Which P test should be used in this soil?
Questions?

*On to conventional vs organic materials*
Feed the plant or feed the soil that feeds the plant

Conventional/chemical
- No carbon
- Easy to store
- Higher nutrient concentration
- Custom formulated
- Easy to use
- Liquid or solid available
- Usually provide quickly available nutrients

Compost/manure
- Bulkier
- Nutrient content low but diverse
- Nutrient content difficult to quantify
- Supplies organic matter
- Takes time to ‘release’ nutrients
50%  A. True
50%  B. False

- Compost can create excess N, P and K.
- N can contaminate groundwater, P can contaminate surface water and excess P and K can limit uptake of other nutrients
Approximately how much total N, P, and K does 1” of manure compost supply?

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>P$_2$O$_5$</th>
<th>K$_2$O</th>
</tr>
</thead>
<tbody>
<tr>
<td>lbs/1000 sq. ft.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Removed annually$^1$</td>
<td>2.3</td>
<td>0.5</td>
<td>2.7</td>
</tr>
<tr>
<td>Added by 1” manure</td>
<td>40</td>
<td>15</td>
<td>40</td>
</tr>
<tr>
<td>Added by 1” manure</td>
<td>6</td>
<td>1</td>
<td>6</td>
</tr>
</tbody>
</table>

$^1$ Univ. Mass, Michigan State, Oregon State, Morris et al., 2007

To add 5 lb N/1000 sq. ft. takes approx. 500 lb manure compost or 11 ton/acre
Of 67 Midwest gardens 92% had excess P and 88% excess K after just 1 to 6 years of ‘uninformed’ fertilization with composted dairy manure (Hansen unpub data, Ohio State Univ)
Adding organic material is good, but...

How can you increase soil organic matter without adding too much P and K?

• Add organic matter high in C (dry leaves, wood shavings, straw, peat), but remember, high C ties up N

• Add organic matter based on plant’s P needs and add N with chemical fertilizer, organic fertilizer such as blood meal, or plant legumes
Which of the following has a similar N:P as removed by vegetable harvest?

20%  A. Manure compost
20%  B. Yard compost
20%  C. Green/food compost
20%  D. Dry leaves
20%  E. Green pine needles
N, P, K added by 4000 lbs ≈ 1” material/1000 sq. ft.

<table>
<thead>
<tr>
<th>Material</th>
<th>N</th>
<th>P\textsubscript{2}O\textsubscript{5}</th>
<th>K\textsubscript{2}O</th>
<th>N:P\textsubscript{2}O\textsubscript{5}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual veg harvest\textsuperscript{1}</td>
<td>2.3</td>
<td>0.5</td>
<td>2.7</td>
<td>5:1</td>
</tr>
<tr>
<td>Manure compost\textsuperscript{2}</td>
<td>40</td>
<td>15</td>
<td>40</td>
<td>3:1</td>
</tr>
<tr>
<td>Yard compost\textsuperscript{3}</td>
<td>58</td>
<td>8</td>
<td>12</td>
<td>7:1</td>
</tr>
<tr>
<td>Green/food compost\textsuperscript{4}</td>
<td>15</td>
<td>9</td>
<td>30</td>
<td>1.6:1</td>
</tr>
<tr>
<td>Dry leaves\textsuperscript{5}</td>
<td>40</td>
<td>9</td>
<td>18</td>
<td>5:1</td>
</tr>
<tr>
<td>Green pine needles\textsuperscript{6}</td>
<td>57</td>
<td>12</td>
<td>25</td>
<td>5:1</td>
</tr>
</tbody>
</table>

1 Univ. Mass, Michigan State, Oregon State, Morris et al., 2007
2 MSU
3 Maryland Urban compost LeafGro and SmartLeaf
4 Waste Resources Action Programme of Wales
5 Heckman and Kluchinski 1996
6 Pietrzykowski et al., 2018
Additional considerations when fertilizing with manure

• Consider the salt content
• Herbicide residual; SOM has huge CEC, CEC holds onto herbicides - know your source!
• Can be full of weed seeds & pathogens
• Prevent water contamination from runoff and leaching
Questions?

On to other factors that influence soil nutrient management
What to else look for on a soil test report?
Factors affecting plant health and production

<table>
<thead>
<tr>
<th>Factor</th>
<th>Value</th>
<th>Impact/consider</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil organic matter</td>
<td>≤ 1 (%)</td>
<td>Minimize bare soil, increase N, add legumes</td>
</tr>
<tr>
<td></td>
<td>&gt; 3 (%)</td>
<td>Extra N for heavy feeders (e.g. tomatoes, squash)</td>
</tr>
<tr>
<td>Soil pH</td>
<td>&lt; 5</td>
<td>Poor seedling establishment</td>
</tr>
<tr>
<td></td>
<td>&lt; 6</td>
<td>Poor legume nodulation</td>
</tr>
<tr>
<td></td>
<td>&gt; 8.3</td>
<td>Nutrients tied up, possibly high Na</td>
</tr>
<tr>
<td>Soluble salts (EC)</td>
<td>&gt; 4 (mmhos/cm)</td>
<td>Too saline, water stress, nutrient imbalance</td>
</tr>
<tr>
<td>Soil texture and CEC</td>
<td></td>
<td>Water and nutrient holding capacity</td>
</tr>
</tbody>
</table>
Gallatin Valley garden soil test report – info provided

- SOM
- CEC
- pH
- Texture is missing

See link below for Mason jar texture test

**Soil texture**

**Sand:** large pore space, low surface area = low water or nutrient holding capacity

**Clay:** small pore space, large surface area, often negative charge on surface = holds water and nutrients tight

Ideal is loam to clay loam approx. equal parts of sand, silt, clay
### Texture Effects on Soil Properties

<table>
<thead>
<tr>
<th></th>
<th>Drainage</th>
<th>Water holding capacity</th>
<th>Aeration</th>
<th>CEC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>excellent</td>
<td>poor</td>
<td>excellent</td>
<td>low</td>
</tr>
<tr>
<td>Silt</td>
<td>good</td>
<td>good</td>
<td>good</td>
<td>medium</td>
</tr>
<tr>
<td>Clay</td>
<td>poor</td>
<td>excellent</td>
<td>poor</td>
<td>high</td>
</tr>
</tbody>
</table>

Soils with large surface areas, such as clay and organic matter, have more cation exchange capacity and surface area and therefore are generally more fertile.
Texture effect on soil properties

Water holding capacity would seem a benefit. But, what are problems in clay soils?

- Surface pooling and runoff
- Compaction
- Drowned roots
Questions?

On to pH and Cation Exchange Capacity (CEC)
1. Vegetables vary in their preferred soil pH
2. Legumes prefer pH > 6 to fix N
pH affects soil nutrient availability

**Low pH, acidic soils** – may limit N, Ca, Mg, Mo because they don’t stick tight and can leach away (Fe) or form minerals (P)

**High pH, alkaline calcareous soils** – may limit P, Fe, Mn, B, Cu, Zn because they stick tight to the soil, plant can’t get them
What is the best option to lower pH in highly calcareous soils?

17%  A. Add elemental sulfur (S)
17%  B. Add gypsum (CaSO₄)
17%  C. Add pine needles
17%  D. No reasonable option to lower significantly and QUICKLY on LARGE scale
17%  E. Use ammonia based N fertilizers (e.g., urea)
17%  F. Plant legumes
Adding elemental sulfur

Soil pH

Sulfur Added (lb/1000 sq. ft.)

April 5 months later

Consequences? Costs?

0 23 230

10,000 lb/acre

AgVise Laboratories
What might happen if you add 230 lbs S/1000 sq. ft.?

- Soil S levels may become toxic
- Soil salt levels may become toxic
- You spend $366/1000 sq ft

Select plants suitable to your soil’s pH

The Mission and Flathead Valleys grow blueberries, the Gallatin Valley grows sweet peas!
Cation Exchange Capacity (CEC) – the parking spaces for nutrients in the soil

- CEC is the total negative charge on a soil.
- A high CEC soil (> 15) has the capacity to attract and hold nutrients with positive charges, e.g., K⁺, Zn⁺², NH₄⁺.
- Soils with large surface areas, such as clay and SOM, have more CEC and therefore are generally more fertile.
- What else might high CEC soils hold onto? Herbicides.
Management influenced by CEC and texture

• Water
  • low CEC soils – short frequent irrigation (daily) – to avoid leaching nutrients
  • high CEC soils – tend to be clay, slow irrigation less often (e.g., low flow emitters, every 3-4 days)

• Nutrients
  • low CEC soil, a little at a time to avoid leaching loss
  • High CEC, incorporate them – to avoid runoff and get to plant roots
Low soil organic matter is rarely an issue in gardens

Questions?

On to visual assessment
Visual assessment

- May identify what has been lacking to this point, likely can correct in time in garden environments.
- Sulfur soil tests are not reliable. Use visual symptoms (yellow or light green upper leaves)

Examples posted at

http://landresources.montana.edu/soilfertility/nutrientdeficiencies.html
Visual assessment of tissue

Other issues can cause symptoms that look like nutrient deficiency symptoms

- Insects
- Salinity
- Moisture stress
- Disease
- Herbicides
Summary

• Understanding soils leads to wise nutrient use and promotes maximum plant health and yields

• Soil testing is an important tool to help prevent or correct plant growth problems, and protect the environment from over-fertilization

• The foundation of a healthy garden is a healthy soil

• Observe and adjust to your specific conditions
Questions?

For additional information:

Home garden soil testing and fertilization guidelines
http://landresources.montana.edu/soilfertility/home-gardening.html

Nutrient deficiency symptoms
http://landresources.montana.edu/soilfertility/nutrientdeficiencies.html

The Soil Scoop
http://landresources.montana.edu/soilfertility/soilscoop.html

MSU Extension catalog
http://store.msueextension.org

- Using Manure as Fertilizer (EB0184)
- Home Composting (MT199203AG)
- Manure Composting (MT201206AG)