Soil Testing & Plant Analysis

Carrie Laboski
Dept. of Soil Science
UW-Madison
4 Steps in the soil testing-nutrient recommendation system

1. Collect soil samples

2. Determine the nutrient availability of the soil represented by the samples (soil test)

3. Interpret the soil test results (soil test calibration)

4. Estimate the quantity of nutrient required by the crop (nutrient recommendation)
Soil Sampling
Minimum Requirements

- Follow recommendations in UWEX A2100

- How will the data be used?
  - One recommendation per field – whole field
  - Variable rate application – grid
### Whole Field – Sampling Intensity

<table>
<thead>
<tr>
<th>Field characteristics</th>
<th>Field size (acres)</th>
<th>Suggested number of samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fields tested &gt; 4 years ago; or Fields testing in responsive range</td>
<td>All fields</td>
<td>1 sample/ 5 acres</td>
</tr>
<tr>
<td>Non-responsive fields tested ≤ 4 years ago</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 – 10</td>
<td></td>
<td>2 samples/ field</td>
</tr>
<tr>
<td>11 – 25</td>
<td></td>
<td>3 samples/ field</td>
</tr>
<tr>
<td>26 – 40</td>
<td></td>
<td>4 samples/ field</td>
</tr>
<tr>
<td>41 – 60</td>
<td></td>
<td>5 samples/ field</td>
</tr>
<tr>
<td>61 – 80</td>
<td></td>
<td>6 samples/ field</td>
</tr>
<tr>
<td>81 - 100</td>
<td></td>
<td>7 samples/ field</td>
</tr>
</tbody>
</table>

- Responsive range is where *either* soil test P or K are in the high (H) category or lower
- Non-responsive range is where *both* soil test P & K are in the very high (VH) or excessively high (EH) category
Whole Field – Specific sampling details in A2100

- Proper tools
- Depth
- Pattern / location
- Frequency
- Special situations
  - Tillage
  - Contour strips

- Sampling pattern for 15 acre field with past soil tests in responsive range

- Each sample should be composed of at least 10 cores
Unaligned systematic grid point method

- 300’ (2.1 acre) grid – if both P & K are in non-responsive categories (VH & EH)

- 200’ (0.92 acre) grid – if either P or K are in responsive categories (below H)
- Sample locations have GPS coordinates
- Sample consists of at least 10 cores composited within a 10’ radius of grid point
Soil Testing
What is a soil test?

- A chemical method for estimating the nutrient supplying capacity of a soil
  - Measures a portion of a nutrient from a “pool” that is used by plants
    - An index of nutrient availability
  - *Does not measure the total amount of a nutrient in the soil*
  - Needs to be calibrated in field/greenhouse rate studies to then use in nutrient (fertilizer) recommendations

- Can determine soil’s nutrient status before a crop (field, vegetable, ornamental) is planted
Objectives of Soil Tests

1. Provide an index of nutrient availability (or supply) in a given soil
   - A soil test measures a portion of a nutrient from a “pool” that is used by plants
   - Calibration

- Sorbed P
  Clays, Fe, Al oxides

- Secondary P Minerals
  Ca, Fe, Al phosphates

- Soil Solution P

- Partial P Cycle

- Organic P

- Fertilizer
Objectives of Soil Tests

2. Predict the probability of obtaining a profitable response to lime and fertilizer
   - On low testing soils, a response to applied nutrients may not always be obtained because of other limiting factors (moisture, pH, other nutrients)
   - **BUT** the probability of a response to nutrient additions on low testing soils is greater than high testing soils
   - Correlation
Objectives of Soil Tests

3. Provide a basis for recommendations on the amount of lime and fertilizer to apply
   - Relationships obtained through laboratory, greenhouse, and field studies
Overriding Goal of Soil Testing

- To obtain a value that will help to predict the amount of nutrients (fertilizer) needed to supplement the nutrient supplying capacity of the soil such that maximum economic yield is achieved
  - Now, and more so in the future, we will need to balance environmental degradation with economics
Nutrient Recommendation
Philosophies

- Build and Maintain
- Sufficiency Level
- Cation Ratio/Balance

For immobile nutrients
  - Primarily P & K, not N
Build and Maintain

- Goal: Apply nutrients such that soil tests are built up to a certain level and then maintained within a range

- Feed the soil theory
- Provides a margin of safety to compensate for differential crop response
Sufficiency Level

- Soil test levels established & identified by likelihood of a crop response
  - Low soil test = crop response assured
  - Medium soil test = crop response possible
  - High soil test = crop response marginal
  - Very high soil test = crop response unlikely

- Nutrient recommended only for low through high soil tests

- Fertilize the crop theory
### Soil Test Interpretation Categories

<table>
<thead>
<tr>
<th>Soil Test Level</th>
<th>Relative Supply of Nutrients From Soil and Fertilizer</th>
<th>Probability of Yield Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very High</td>
<td>Soil</td>
<td>&lt;5%</td>
</tr>
<tr>
<td>High</td>
<td>Soil + Fert.*</td>
<td>5-30%</td>
</tr>
<tr>
<td>Optimum</td>
<td>Soil + Fertilizer</td>
<td>30-60%</td>
</tr>
<tr>
<td>Low</td>
<td>Soil + Fertilizer</td>
<td>60-90%</td>
</tr>
<tr>
<td>Very Low</td>
<td>Soil + Fertilizer</td>
<td>&gt;90%</td>
</tr>
</tbody>
</table>

Nutrients available from soil | Nutrients required

*Fertilizers used at high soil test levels are for starter or maintenance purposes*
### Relationship Between Soil Test and Fertilizer Recommendations in WI

<table>
<thead>
<tr>
<th>Soil Test Category</th>
<th>Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Low, Low</td>
<td>Crop removal +</td>
</tr>
<tr>
<td>Optimum</td>
<td>Crop removal</td>
</tr>
<tr>
<td>High</td>
<td>½ Crop removal</td>
</tr>
<tr>
<td>Very High</td>
<td>¼ Crop removal</td>
</tr>
<tr>
<td>Excessively High</td>
<td>None</td>
</tr>
</tbody>
</table>
Basic Cation Saturation Ratios (BCSR)

- Concept that there is an ideal ratio or range of ratios that maximizes crop production
  - Eg. 65-85% Ca, 6-12% Mg, 2-5% K

- Research in WI does not support this theory

- Relying on cation ratios has several drawbacks:
  - OK ratio, but nutrient supply not sufficient
  - Not OK ratio, but nutrient supply sufficient
  - No economic analysis goes into recommendations that use the cation ratio approach
Quotes from BCSR Researchers

1. “Basic cation ratios per se seem unimportant to the well-being of the crop. Indeed, it appears that instead we should concentrate on sufficiency levels of each basic cation.”
   E.O. McLean, 1982

2. Emphasis should be placed on providing sufficient, but non-excessive levels of each basic cation rather than attempting to adjust to a favorable BCSR which evidently does not exist.
   McLean et al., 1983
# Soil Test Report

**Soil Name:** Lorenzo  
**Field Name:** White

## Nutrient Recommendations

<table>
<thead>
<tr>
<th>Cropping Sequence</th>
<th>Yield Goal</th>
<th>Crop Nutrient Need</th>
<th>Fertilizer Credit</th>
<th>Nutrients to Apply</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>N</td>
<td>P2O5</td>
<td>K2O</td>
</tr>
<tr>
<td>Red Clover</td>
<td>1.5-2.5 tons</td>
<td>0</td>
<td>0</td>
<td>50</td>
</tr>
<tr>
<td>Red Clover</td>
<td>2.6-3.5 tons</td>
<td>0</td>
<td>0</td>
<td>75</td>
</tr>
<tr>
<td>Corn, grain (no crop)</td>
<td>131-150 bu</td>
<td>120</td>
<td>0</td>
<td>20</td>
</tr>
</tbody>
</table>

The lime required for this rotation to reach pH 6.3 is 4 T/a of 60-69 lime or 3 T/a of 80-89 lime.

## Additional Information

- If lime has been applied in the last two years, more lime may not be needed due to incomplete reaction.
- Year 3: If corn harvested for silage instead of grain apply extra 90 lbs K2O per acre to next crop.
- Starter fertilizer (e.g. 10+20+20 lbs N+P2O5+K2O/a) is advisable for row crops on soils slow to warm in the spring.
- A soil nitrate test may better estimate actual corn needs.
- If conservation tillage leaves more than 50% residue cover when corn follows after corn, add an additional 30 N lbs/a.

## Soil Test Interpretation

<table>
<thead>
<tr>
<th>Cropping Sequence</th>
<th>Very Low</th>
<th>Low</th>
<th>Optimum</th>
<th>High</th>
<th>Very High</th>
<th>Excessive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red Clover</td>
<td></td>
<td></td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Red Clover</td>
<td></td>
<td></td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Corn, grain (no crop)</td>
<td></td>
<td></td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Rotation pH</td>
<td></td>
<td></td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

## Laboratory Analysis

| Sample Identification | Soil pH | O.M. % | Phosphorus ppm | Potassium ppm | Calcium ppm | Magnesium ppm | Estimated CEC | Boron ppm | Manganese ppm | Zinc ppm | Sulfate-Sulfate ppm | Sulfur Available Index | Texture Code | Sample Density | Buffer Code |
|-----------------------|---------|--------|----------------|---------------|-------------|---------------|---------------|------------|----------------|----------|---------------------|-----------------------|--------------|----------------|------------|------------|
| 4                     | 5.8     | 3.3    | 35             | 110           |             |               |               |            |                |          |                    |                       |              |                |            |            |
| 5                     | 5.7     | 3.4    | 39             | 135           |             |               |               |            |                |          |                    |                       |              |                |            |            |
| 6                     | 5.9     | 3.4    | 45             | 114           |             |               |               |            |                |          |                    |                       |              |                |            |            |
| 7                     | 5.8     | 3.4    | 48             | 149           |             |               |               |            |                |          |                    |                       |              |                |            |            |
| Adjusted Averages     | 5.8     | 3.4    | 40             | 120           |             |               |               |            |                |          |                    |                       |              |                |            |            |
Plant Analysis Uses

- Identify deficiency symptoms
  - Determine nutrient shortages before they appear as symptoms
- Aid in determining nutrient supplying capacity of the soil
  - Need soil test and field history
- Aid in determining effect of nutrient addition on the nutrient supply in the plant
- Study the relationship between nutrient status of plant and crop performance
Types of Plant Analysis

- **Cell sap tests**
  - Usually in-field, quick tests, semiquantitative

- **Total analysis**
  - Lab tests on whole plant or specific part
    - Sampled part may be dependent on growth stage
  - Provides an indicator of plant nutritional status
  - Assumes nutritional status is related to soil nutrient availability
Tissue Sampling

- What to sample
- When to sample
- Sample handling
  - Refrigerated (kept cold)
  - Removal of contaminants (soil, dust, fertilizer)
- Interpretation
### Table 12-13. Proper plant sampling for diagnostic plant analysis

<table>
<thead>
<tr>
<th>Crop</th>
<th>Stage of growth</th>
<th>Plant part</th>
<th>Number of plants to sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa, bird's foot trefoil, clover</td>
<td>Prior to flowering</td>
<td>Top 6 inches</td>
<td>35</td>
</tr>
<tr>
<td>Asparagus, onion</td>
<td>Boot</td>
<td>Top 6 inches</td>
<td>20</td>
</tr>
<tr>
<td>Bean, pea</td>
<td>Prior to or at initial flowering</td>
<td>Newest fully developed leaf</td>
<td>25</td>
</tr>
<tr>
<td>Beets, broccoli, brussel sprouts, cabbage,</td>
<td>Midseason</td>
<td>Upper mature leaves</td>
<td>20</td>
</tr>
<tr>
<td>carrot, cauliflower, celery, lettuce, radish,</td>
<td>a) Seedling to 20 inches high</td>
<td>Whole plant above ground</td>
<td>20</td>
</tr>
<tr>
<td>spinach, tobacco</td>
<td>b) 20 inches high to flag leaf</td>
<td>Newest fully developed leaf</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>c) Tasseling to silking</td>
<td>Earleaf or opposite &amp; below</td>
<td>15</td>
</tr>
<tr>
<td>Corn</td>
<td>Prior to or at initial flowering</td>
<td>Newest fully developed leaf</td>
<td>25</td>
</tr>
<tr>
<td>Cucumber, melon, pumpkin, squash</td>
<td>Prior to heading</td>
<td>Newest fully developed leaf</td>
<td>50</td>
</tr>
<tr>
<td>Forage (grasses, grains)</td>
<td>Prior to heading</td>
<td>Newest fully developed leaf</td>
<td></td>
</tr>
<tr>
<td>Mint</td>
<td>Boot</td>
<td>Whole plant</td>
<td>20</td>
</tr>
<tr>
<td>Pepper, potato, tomato</td>
<td>Prior to or at initial flowering</td>
<td>Newest petiole and leaflet</td>
<td>40</td>
</tr>
<tr>
<td>Sorghum (grain, sudan)</td>
<td>Prior to heading</td>
<td>Second fully developed leaf</td>
<td>20</td>
</tr>
<tr>
<td>Apple, cherry, pear, plum</td>
<td>Current season's shoots taken July 1-15</td>
<td>Fully developed leaf at midpoint of new shoots</td>
<td>4 leaves from each of 10 trees</td>
</tr>
<tr>
<td>Grape</td>
<td>Bearing primary shoots</td>
<td>Petioles from newest leaves</td>
<td>5 petioles from each of 10 vines</td>
</tr>
<tr>
<td>Strawberry</td>
<td>Current season's shoots</td>
<td>New petioles and leaves</td>
<td>5 parts from each of 10 plants</td>
</tr>
</tbody>
</table>

Table 12-13 in Management of WI Soils (A3588)
Relationship between nutrient concentration in leaves over the growing season

Redrawn from Havlin et al., 2005
Critical Nutrient Range (no symptoms)

Visual Symptoms

Concentration of Nutrient in Tissue (dry basis)

Critical Concentration

10% Reduction in Growth

Luxury Consumption

Toxicity

Redrawn from Havlin et al., 1999
Tissue Test Interpretation

- Critical nutrient concentration ranges (sufficiency ranges)
  - Using Plant Analysis as a Diagnostic Tool
    see New Horizons in Soil Science 2000
    http://www.soils.wisc.edu/extension/publications/horizons/index.htm

- DRIS (Diagnostic & Recommendation Integrated System)

- PASS (Plant Analysis with Standardized Scores)
Correction of deficiencies identified with tissues tests may not be feasible because:

- Deficiency may have already caused yield loss
- Crop may not respond at the growth stage tested
- Crop may be too large for nutrient application
- Weather may be unfavorable for fertilization and/or for crop to benefit

From Havlin et al., 2005
Using plant analysis to help diagnose a field problem

- **Not a clear cut tool**

- Need to collect all the evidence:
  - Nutrient deficiency symptoms
  - Root growth patterns
  - Weather
  - Current field conditions
  - Field history
  - Tissue analysis
  - Soil analysis
Don’t Guess
Soil Test!