Soil Testing for Effective Nutrient Management

Maryland Nutrient Management Program
2015 Winter Webinar Series

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Soil fertility testing

Measure the ability of a soil to supply essential nutrients

Predict the probability of a profitable response to fertilizer and lime
Fundamentals of soil fertility testing:

1) Sampling
2) Analysis
3) Interpretation
4) Recommendations
Soil sampling

Validity of results and recommendations are a function of sample quality

Generally the most limiting factor – most significant source of error in soil test results

Important to take the necessary steps to obtain a representative sample

- 2.5 g of soil in the lab may represent as much as 20,000,000 lbs of soil in a 10 acre parcel
Soil sampling

Need to recognize that soil is variable

- **Macro-variation** (yards) associated with soil type, landscape position, previous management, etc.

- **Meso-variation** (feet) associated with fertilizer application patterns, crop rows, etc.

- **Micro-variation** (inches), depth stratification, crop residues, soil heterogeneity
**Soil sampling**

Determine area to be represented by sample

- Soil texture, color, slope, drainage, and past management should be similar throughout sampling area
- Sample unusual or trouble spots separately

Create a map, keep good records

Collect representative samples by forming a composite of 15 to 20 soil cores (*subsamples*)
Soil sampling

Precision approach

*Grid point sampling*

- Field is broken into subunits based on a specified grid pattern; grid size a function of soil variability (~1 to 2.5 ac)
- Composite sample collect in an 8 to 10 ft radius around georeferenced points
- Results & recommendations extrapolated b/t points for variable rate application
Recommended K$_2$O, ¼ acre grid
<table>
<thead>
<tr>
<th>Map Unit</th>
<th>Series</th>
<th>Slope</th>
<th>Acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>HaA</td>
<td>Hagerstown</td>
<td>0 to 3</td>
<td>1.5</td>
</tr>
<tr>
<td>HaB</td>
<td>Hagerstown</td>
<td>3 to 8</td>
<td>3.6</td>
</tr>
<tr>
<td>HaC</td>
<td>Hagerstown</td>
<td>8 to 15</td>
<td>3.0</td>
</tr>
<tr>
<td>No</td>
<td>Nolin</td>
<td>0 to 3</td>
<td>3.0</td>
</tr>
<tr>
<td>OhC</td>
<td>Opequon-Hagerstown</td>
<td>8 to 15</td>
<td>2.5</td>
</tr>
</tbody>
</table>
Bulk soil electrical conductivity, 0 to 12 inches

Penn State Extension
Soil sampling

With very few exceptions, sampling depth for routine analysis should be the *furrow slice* (the depth of tillage, 0 to 8”).

Soil properties tend to be stratified (e.g., no-till vs. plow)

If samples are collected too shallow or too deep, results will be skewed

- Interpretation & recommendations calibrated for the *furrow slice*
Stratification of soil test K after 10 years of no-till production

Murrell, 2009
Soil sampling

Frequency:

For routine soil analysis, once every ~3 years generally sufficient.

More intensive sampling may be warranted:

1) to diagnose problems (e.g., diagnose suspected nutrient deficiencies)
2) for certain non-routine tests (e.g., nitrate)
3) prior to making major management changes
Soil sampling

When is the best time to sample?

Where no current soil test is available, the best time to test is now.

Lime and fertilizer shouldn't be applied without current soil test.
Soil sampling

When is the best time to sample?

For routine analysis, fall is generally the best time of year.

Manager can use winter months to order materials and/or address major fertility problems.
Soil sampling

When is the best time to sample?

Soil test values vary over the season...

Best way to manage is to be consistent

- Avoid sampling recently fertilized soils

Murrell, 2009
Soil sampling

The most effective tool for obtaining a uniform subsample is a soil probe; soil augers also work well, especially in stony soils.

Many professionals use ATV mounted hydraulic samplers.

All soil cores combined in a clean container (e.g., 5-gal bucket), mixed well to form a composite, and subsampled for submission to lab (~1 cup).
Soil analysis

Routine soil analysis in the Mid-Atlantic region generally includes:

- pH and exchangeable acidity (lime req.)
- extractable P, K, Ca, and Mg
- estimated CEC and BS

- may also include extractable micronutrients and organic matter
**Nutrients in soil**

Plants absorb nutrients dissolved in soil solution.

Our focus is often on the total amount or ‘quantity’ of nutrients present in soil, but the ability of a soil to supply nutrients is determined by the release of those nutrients into the soil solution, ‘intensity’

Land Institute, Salina Kansas.
Nutrients in soil

Quantity–intensity relationship describes the ability of a soil to store and supply a given nutrient.

Soil minerals

Organic matter

Exchangeable ions adsorbed on soil colloids

Soil solution

Stored nutrients (quantity)

Available nutrients (intensity)
Nutrients in soil

An ideal soil test would provide a measure of nutrients in soil solution (intensity), in stored pools (quantity), and buffering capacity (change in intensity with respect to quantity).

Soil minerals

Organic matter

Exchangeable ions adsorbed on soil colloids

Soil solution

Stored nutrients (quantity)

Available nutrients (intensity)
Nutrients in soil

Number of factors influence the quantity-intensity relationship

- pH/soil acidity
- soil texture & mineralogy
- soil organic matter
- temperature/moisture regime
**Nutrients in soil**

Q/I curve describes the ability of the soil to maintain nutrients in solution, available to plants.

Not feasible to determine Q/I relationship in every case where a nutrient recommendations are desired.

However, an appreciation of Q/I relationships does inform routine soil analysis and interpretation.

Conceptual quantity-intensity curves for phosphorus in a coarse vs. fine textured soil
A discrete fraction of *available* soil nutrients does not exist, ...

...

rather, nutrient *availability* is more a continuum in soil based on specific conditions affecting solubility of different nutrient *pools*.
Soil nutrient analysis

Extraction solutions designed to remove immediately available nutrients plus a portion of that expected to become available (labile pools).

Developed for specific conditions present within a given region.

<table>
<thead>
<tr>
<th>Common soil test P extractants</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Extractant</strong></td>
</tr>
<tr>
<td>Bray-P</td>
</tr>
<tr>
<td>Mehlich 1*</td>
</tr>
<tr>
<td>Mehlich 3*</td>
</tr>
<tr>
<td>Morgan*</td>
</tr>
<tr>
<td>Modified Morgan*</td>
</tr>
<tr>
<td>Olsen</td>
</tr>
</tbody>
</table>

*Universal extracts – used for simultaneous extraction of both macro- & micro-nutrients
Soil nutrient analysis

Soil tests do not provide a quantitative measure of available nutrients, rather they provide an index of soil nutrient supply.

Interpretation of soil test results is based on the empirical relationship between extractable nutrient levels and crop response to applied nutrient.

Interpretation

Research, under local conditions, with representative soils ranging from deficient to adequate for given nutrient necessary to obtain meaningful soil test correlation and calibration.
**Interpretation**

Define *critical soil test level* in order to identify responsive vs. non-responsive sites.
Interpretation

Soil test level
vs.
Relative yield \( \left( \frac{\text{yield without } P_2O_5}{\text{yield with } P_2O_5} \right) \)

Define critical soil test level in order to identify responsive vs. non-responsive sites.

## Interpretation

Optimum pH and Mehlich 3 extractable nutrient levels for agronomic crops in Pennsylvania

<table>
<thead>
<tr>
<th>Soil test</th>
<th>Optimum range</th>
<th>Crops</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>6.0-6.5 ppm</td>
<td>Most agronomic crops</td>
</tr>
<tr>
<td></td>
<td>6.5-7.0 ppm</td>
<td>Alfalfa and barley</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>30-50 ppm</td>
<td>All agronomic crops</td>
</tr>
<tr>
<td>Potassium</td>
<td>100-150 ppm</td>
<td>Grain crops</td>
</tr>
<tr>
<td></td>
<td>100-200 ppm</td>
<td>Forage crops</td>
</tr>
<tr>
<td>Magnesium</td>
<td>120-180 ppm</td>
<td>Grass forage crops</td>
</tr>
<tr>
<td></td>
<td>60-120 ppm</td>
<td>Other agronomic crops</td>
</tr>
</tbody>
</table>
Interpretation

Optimum test ranges vary across different regions. Therefore, even when the same methods are used, the results may have a different meaning.

<table>
<thead>
<tr>
<th>State</th>
<th>Mehlich-3 P, ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pennsylvania</td>
<td>30 to 50</td>
</tr>
<tr>
<td>Ohio, Indiana, Michigan</td>
<td>25 to 60</td>
</tr>
<tr>
<td>Iowa</td>
<td>25 to 35</td>
</tr>
<tr>
<td>Nebraska</td>
<td>10 to 20</td>
</tr>
</tbody>
</table>

*determined by ICP-AES*
**Interpretation**

*Units*

Extractable nutrient levels can be expressed in different units.

Most labs report in ppm, but some use alternative units.

Some states (e.g., OK, MD, DE, NC) report results using a unit-less index system.

<table>
<thead>
<tr>
<th>Soil test unit</th>
<th>To convert to ppm</th>
</tr>
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<tbody>
<tr>
<td>P, lbs/A</td>
<td>( \frac{P, lbs/\text{ac}}{2} )</td>
</tr>
<tr>
<td>P(_2)O(_5), ppm</td>
<td>( \frac{P(_2)O(_5), ppm}{2.3} )</td>
</tr>
<tr>
<td>P(_2)O(_5), lbs/A</td>
<td>( \frac{P(_2)O(_5), lbs/\text{ac}}{4.6} )</td>
</tr>
<tr>
<td>K, lbs/A</td>
<td>( \frac{K, lbs/\text{ac}}{2} )</td>
</tr>
<tr>
<td>K(_2)O, ppm</td>
<td>( \frac{K(_2)O, ppm}{1.2} )</td>
</tr>
<tr>
<td>K(_2)O, lbs/A</td>
<td>( \frac{K(_2)O, lbs/\text{ac}}{2.4} )</td>
</tr>
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</table>
**Interpretation**

**MD Fertility Index Values (FIV)**

Alternative method for expressing the relative level of nutrients measured by soil testing

<table>
<thead>
<tr>
<th>Interpretive category</th>
<th>FIV range</th>
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<tr>
<td>Low</td>
<td>0 to 25</td>
</tr>
<tr>
<td>Medium</td>
<td>26 to 50</td>
</tr>
<tr>
<td>Optimum</td>
<td>51 to 100</td>
</tr>
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<td>Excessive</td>
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Soil test results from different laboratories, using appropriate methods, may easily be converted to FIV units.
**Interpretation**

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Soil test results from different laboratories, using appropriate methods, may easily be converted to FIV units.
Recommendations

Three basic philosophies:

1. Sufficiency approach (feed the crop)
   When soil test level is below optimum, apply only enough nutrients to meet crop needs

2. Buildup and maintenance approach (feed the soil)
   Build soil test levels to optimum range over several years then replace nutrients removed by crop

3. Cation saturation approach
   Based on belief that there is an ideal base cation saturation ratio (60-70% Ca, 12-14% Mg, 3-5% K).
   - the Cation saturation approach is not well supported by observational evidence.
Recommendations

Example of PSU

*Build & Maintain*

soil test recs for

$P_2O_5$

- Corn (grain) with
  an expected
  yield of 200 bu/A

![Graph showing fertilizer P$_2$O$_5$ vs. Mehlich 3 extractable P, ppm]
What about micronutrients?

Micronutrient deficiencies are rare in Pennsylvania, and throughout the Northeastern US

- As a result, good soil test calibrations do not exist.
- Without responsive sites, there is no way to identify critical soil test levels

Does soil testing have any value for micronutrient management in our region?
What about micronutrients?

While rare in the NE, micronutrient deficiencies are sometimes observed under very specific conditions:

Increased likelihood of response:

- Excessive levels of P (from $P_2O_5$ fertilizer)
- Low OM, coarse texture soils
- High pH

![Zinc deficient corn in Centre county, Pennsylvania. D. Beegle](image-url)
**Soil acidity and nutrient availability**

Solubility of most of the essential macronutrients limited in acidic soils while micronutrients limited in alkaline soils

- Judicious management of soil acidity is critical
Predicting need

Are conditions right for deficiency to occur? High pH, excessive P, low organic matter, etc.?

Extractable Zn and S

How do observed values compare with **normal** range

| Normal ranges of Zn, Cu, and S in PA soils (Mehlich 3) |
|-----------------|-----------------|-----------------|
| Zn              | Cu              | S               |
| 1.1-9.4         | 1.2-5.5         | 10-25           |

- Confirm with plant tissue analysis
Predicting need

Plant tissue analysis is the most definitive measure of micronutrient status.

As a diagnostic tool, used to verify suspected micronutrient deficiency.

For routine monitoring, plant tissue analysis can also be used to identify *hidden hunger* and to help fine-tune fertility management.
Helpful resources

Penn State Agricultural Analytical Services Laboratory
http://agsci.psu.edu/aasl

Penn State Agronomy Guide
http://extension.psu.edu/agronomy-guide

Agronomic crop nutrient recommendations based on soil tests and yield goals in Maryland – SFM 1
http://extension.umd.edu/sites/default/files/_images/programs/anmp/SFM-1.pdf

Converting among soil test analyses frequently used in Maryland – SFM 4

2014 Commercial vegetable production recommendations for Maryland
https://extension.umd.edu/mdvegetables/2014-commercial-vegetable-production-recommendations