Soil fertility testing

Measure of the ability of a soil to supply nutrients required for healthy plant growth.

*Predict the probability of a profitable response to nutrient addition*
**Soil fertility testing**

Routine soil fertility tests are empirically related to plant response.

Soil test methods are developed for specific soil and climate conditions present within a given region.

By design, they are rapid and inexpensive, so that they are practical.
Soil fertility testing

Standardized methods

Recommended Soil Testing Procedures for the Northeastern United States

Prepared by: NEC-1012
Northeast Coordinating Committee for Soil Testing

Available on-line
Soil fertility testing

Four key components:

1) Sampling
2) Extraction & analysis
3) Interpretation of results
4) Recommendations
**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 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.
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).
Conceptual illustration of phosphorus pools
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 recommendation is desired.

However, an appreciation of this relationship does inform routine soil analysis and interpretation.
Soil analysis

A discrete fraction of available nutrients does not exist,…

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

Penn State Extension
Soil analysis

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

Developed for specific conditions present within a given region.

The solution(s) used to extract nutrients in one region are often not appropriate for soils found in other regions.
Soil analysis

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<table>
<thead>
<tr>
<th>Extractant</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bray-P</td>
<td>0.03 M NH₄F + 0.025 M HCl</td>
</tr>
<tr>
<td>Mehlich 1</td>
<td>0.05 M HCl + 0.0125 M H₂SO₄</td>
</tr>
<tr>
<td>Mehlich 3</td>
<td>0.015 M NH₄F + 0.2 M CH₃COOH + 0.25 M NH₄NO₃ + 0.013 M HNO₃ + 0.001 M EDTA</td>
</tr>
<tr>
<td>Morgan</td>
<td>0.72 M NaOAc + 0.52 M CH₃COOH at pH 4.8</td>
</tr>
<tr>
<td>Modified Morgan</td>
<td>0.62 M NH₄OAc + 1.25 M CH₃COOH at pH 4.8</td>
</tr>
<tr>
<td>Olsen</td>
<td>0.5 M NaHCO₃ at pH 8.5</td>
</tr>
</tbody>
</table>
**Soil analysis**

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

Developed for specific conditions present within a given region.

The solution(s) used to extract nutrients in one region are often not appropriate for soils found in other regions.

Soil analysis

*Not* a quantitative measure of available nutrients; rather an *index* of soil nutrient supply.

Interpretation of results 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**

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

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

Generalized relationship between soil test level and crop response to nutrient applied.
Interpretation

Soil test level

vs.

Relative yield \( \left( \frac{\text{yield without } P_2O_5}{\text{yield with } P_2O_5} \right) \)

Define \textit{critical soil test level} in order to identify responsive vs. non-responsive sites.

Interpretation

Optimum 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>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>26 to 35</td>
</tr>
<tr>
<td>Nebraska</td>
<td>10 to 20</td>
</tr>
</tbody>
</table>

* determined by ICP-AES
Interpretation

Most New England LGU soil test recs are based field calibration of (modified) Morgan.

Work by Magdoff (UVM) showed that Modified Morgan was far better correlated with crop (alfalfa) response to $P_2O_5$ than either Mehlich 3 or Bray-Kurtz.

Other studies have found similar results for New England soils.
Interpretation
Optimum Modified Morgan extractable nutrient levels for all crops in Massachusetts

<table>
<thead>
<tr>
<th>Soil test</th>
<th>Optimum range</th>
<th>Excessive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phosphorus†</td>
<td>4-14 ppm</td>
<td>&gt;40‡</td>
</tr>
<tr>
<td>Potassium</td>
<td>100-160 ppm</td>
<td>-</td>
</tr>
<tr>
<td>Calcium</td>
<td>1000-1500 ppm</td>
<td>-</td>
</tr>
<tr>
<td>Magnesium</td>
<td>50-120 ppm</td>
<td>-</td>
</tr>
</tbody>
</table>

† Interpretation and recommendations for forage and grain crops based on extractable P and Al (Jokela et al., 1998).
‡ Has been shown to correspond to a \( P_{\text{sat}} \) of approximately 20% (Knight et al., 2012), the value proposed by the USEPA as a cutoff for manure and fertilizer applications in the Chesapeake Bay Watershed (USEPA, 2010)
Can we use Mehlich 3 extractable P to estimate (modified) Morgan P?

In this data set of 51 soils collected from the Northeast, Mehlich 3 extracted 2 to 90 times more P than modified-Morgan.

The two methods are not well correlated.

Can we use Mehlich 3 extractable P to estimate (modified) Morgan P?

Ketterings et al. compared Morgan vs Mehlich 3 extractable P of 235 soil samples from NY.

They also found very poor correlation.

Fig. 2. Morgan and Mehlich-III extractable P for 235 New York State soil samples.

Can we use Mehlich 3 extractable P to estimate (modified) Morgan P?

Did find that Morgan P could be predicted using Mehlich 3 Al, Ca, and pH.

Important to recognize that conversion equations always add uncertainty.

\[
\text{Morgan STP} = 1.62 + 0.56 \times \text{M3P} - 0.0018 \times \text{M3Ca} - 12.97 \times \text{pH} + 0.058 \times \text{M3Al} - 0.000027 \times \text{M3Al}^2 + 1.28 \times \text{pH}^2 + 0.000044 \times \text{M3P} \times \text{M3Ca} - 0.00092 \times \text{M3P} \times \text{M3Al} + 0.00000038 \times \text{M3P} \times \text{M3Al}^2 \quad (r^2=0.88) \quad [8]
\]

**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., DE, MD, OK, NC) report results using a unit-less index system.

<table>
<thead>
<tr>
<th>Soil test unit</th>
<th>To convert to ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P$, lbs/A</td>
<td>$\frac{P, lbs/\text{ac}}{2}$</td>
</tr>
<tr>
<td>$P_2O_5$, ppm</td>
<td>$\frac{P_2O_5, \text{ ppm}}{2.3}$</td>
</tr>
<tr>
<td>$P_2O_5$, lbs/A</td>
<td>$\frac{P_2O_5, \text{ lbs/ac}}{4.6}$</td>
</tr>
</tbody>
</table>
Recommendations

Two basic philosophies:

Sufficiency approach (feed the crop)

When soil test level is below optimum, apply only enough nutrients to meet crop needs

Buildup and maintenance approach (feed the soil)

Build soil test levels to optimum range over several years then replace nutrients removed by crop
Recommendations

Example of PSU
*Build & Maintain*
soil test recs for
$P_2O_5$

- Corn (grain),
  expected yield
  of 200 bu/A
Recommendations

University of Vermont, University of Massachusetts, and University of Connecticut recommendations consider both extractable P and soil P buffering capacity.

$P_2O_5$ recommendations are a function of Modified Morgan extractable P and Al, to account for P buffering capacity.
Take-home message

We need to use relevant soil test methods and base our interpretation of results on local/regional field calibration in order to make sound nutrient management decisions.
Organic residuals testing

Key measurements for nutrient management

• Total solids (and volatile solids for compost)
• Ammonium-N
• Total N (and C for compost)
• **Total P & K** (plus other essential elements)
• **Water extractable P** (WEP)
Organic residuals testing

Reference Methods

Biosolids

Standard Methods for the Examination of Water and Wastewater

Compost
Test Methods for the Examination of Composting and Compost

Manure
Recommended Methods of Manure Analysis
Organic residuals testing

Reference Methods

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Total Phosphorus

Several established reference methods give equivalent results

Generally subsample digested using conc. strong acid to bring P into solution which is analyzed by ICP-OES.

Includes soluble and insoluble organic and inorganic phosphorus.

Generally assumed to be 80 to 90% fertilizer equivalent, but this depends on nature of the material and the soil it is applied to…
**Organic residuals testing**

**Water extractable P**

Operationally defined. Extensive work done by members of SERA-17 to develop standard method

_Briefly_, subsample of as-received residual extracted using 1:100 ratio of solids:water, 60 min. equilibration time.

Measure of soluble inorganic, organic, and colloidal P.

Significantly influenced by characteristics of the residual (e.g., Fe, Al, Ca content)

Used to help predict risk of runoff P from recently amended soils – P source coefficient

Kleinman et al., 2007. JEQ 36:1357-1367
Organic residuals testing

Units

Phosphorus expressed many ways
Generally expressed as $P_2O_5$ in units that are ready to use

- $\text{lbs } P_2O_5/\text{cu yd (compost)}$
- $\text{lbs } P_2O_5/\text{ton}$
- $\text{lbs } P_2O_5/1000 \text{ gal}$

Reported on an as-received and/or dry weight basis where appropriate.
Questions or Comments?

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