Differentiating and Understanding the Mehlich 3, Bray, and Olsen Soil Phosphorus Tests

Dr. John E. Sawyer
Soil Fertility Extension Specialist
Iowa State University
The Four Components of Soil Testing

- Field Sampling
- Extraction and Chemical Analysis
- Interpreting the Analytical Results
- Making the Fertilizer Recommendation
What are the Laboratory Components in a Soil Test Method

- Soil preparation and sampling
- Extractant
- Extraction procedure
- Chemical analysis method (measurement)
- (Result interpretation)
Soil Test Interpretation
Index of Availability and Crop Response

Soil Test
Relative Yield, %
0
20
40
60
80
100

Likely
Marginal
Economic Optimum
Unlikely

VL L Opt H VH

Iowa State University
Laboratory Method for Phosphorus

- Grind soil
- Measure 2 g soil into 50 ml flask (125 ml for Olsen)
- Add 20 ml extraction solution (40 ml for Olsen)
- Shake for 5 minutes (30 min for Olsen)
- Filter through filter paper
- Determine P concentration by colorimetric procedure -- Ascorbic Acid Method

NCR 221 (Rev.)
Phosphorus Test Extractants

- **Bray 1-P Extractant** (Bray & Kurtz, 1945)
  - 0.025 M HCl; 0.03 M NH₄F

- **Mehlich-3 Extractant** (Mehlich, 1984)
  - 0.2 N acetic acid; 0.25 N NH₄NO₃; 0.015 NH₄F; 0.013 N HNO₃; 0.001 M EDTA

- **Olsen Extractant** (Olsen et al., 1954)
  - 0.5 M NaHCO₃
P Extraction with Dilute Acid Fluoride (Bray)

- **Acid soils**
  - Fluoride ion promotes P desorption by decreasing aluminum activity by forming aluminum-fluoride complexes

- **Highly calcareous soils**
  - Acid neutralized by calcium carbonate and CaF$_2$ is formed
  - This is when Bray results in false low values
P Extraction with Dilute Acids and Fluoride (Mehlich)

- Acid soils
  - Similar to Bray
- Highly calcareous soils
  - ? Variety and stronger acids than Bray
  - ? More buffered solution
P Extraction with Buffered Alkaline Solution (Olsen)

- NaHCO₃ solution decreases concentration and activity of Ca²⁺ and Al³⁺ and increases P solubility
Phosphorus Soil Test Reproducibility

- **Bray 1-P**
  - ± 10% (dry soil basis)
  - 1 ppm detection limit

- **Mehlich 3**
  - ± 10% (dry soil basis)
  - 1 ppm detection limit

- **Olsen**
  - ± 12% (dry soil basis)
  - 2 ppm detection limit
SOILS OF pH 7.3 OR LOWER

SOILS OF pH 7.4 OR HIGHER
240 FARMERS' SAMPLES

**pH < 7.05**

\[ Y = 3.5 + 0.42X \]

\[ r = 0.77 \]

**pH 7.05-7.45**

\[ Y = 3.1 + 0.45X \]

\[ r = 0.62 \]

**pH 7.45-8.2**

Iowa State University
240 FARMERS' SAMPLES

Olsen P (ppm)

pH < 7.05

\[ Y = 2.1 + 0.47X \]
\[ r = 0.79 \]

pH 7.05-7.45

\[ Y = 0.7 + 0.47X \]
\[ r = 0.67 \]

pH 7.45-8.2

\[ Y = 1.8 + 0.45X \]
\[ r = 0.81 \]

Mehlich-3 P (ppm)
17 GRID-SAMPLED FIELDS, 2925 SAMPLES

- pH<6.5: $Y=1.2+0.93X$, $r=0.96$
- pH 6.5-7.3: $Y=2.7+0.98X$, $r=0.95$
- pH 7.4-8.2: 

Iowa State University
544 SAMPLES OF pH 7.4 TO 8.2

Bray-1 P (ppm) vs. Olsen P (ppm)

Mehlich-3 P (ppm) vs. Bray-1 P (ppm)

Mehlich-3 P (ppm) vs. Olsen P (ppm)
17 GRID-SAMPLED FIELDS, 2925 SAMPLES

- pH < 6.5
  \[ Y = 15 + 0.82x \]
  \[ r = 0.88 \]

- pH 6.5-7.3
  \[ Y = 14 + 0.83x \]
  \[ r = 0.91 \]

- pH 7.4-8.2
  \[ Y = 21 + 0.73x \]
  \[ r = 0.84 \]

Iowa State University
CORRELATION WITH YIELD RESPONSE - ALL SOILS

RELATIVE CORN YIELD (%)

BRAY-1

- pH < 7.0
- pH 7.0-7.4
- pH > 7.4

MEHLICH-3

- pH < 7.0
- pH 7.0-7.4
- pH > 7.4

Iowa State University
Iowa State University
COMPARISON OF ICP AND COLORIMETRIC P DETERMINATION

ICP - COLORIMETRIC P

M3 COLORIMETRIC P (ppm)

ICP / COLORIMETRIC RATIO

M3-COLORIMETRIC P (ppm)
Soil Test Interpretation
Index of Availability and Crop Response

For High Subsoil P Soils

Relative Yield, %

VL  L  Opt  H  VH

Likely  Marginal  Unlikely

Bray:  0  6  11  16  21+
Mehlich 3:  0  6  11  16  21+
Olsen:  0  4  8  12  16+

Iowa State University
Soil Test Interpretation
Index of Availability and Crop Response

For Low Subsoil P Soils

<table>
<thead>
<tr>
<th></th>
<th>VL</th>
<th>L</th>
<th>Opt</th>
<th>H</th>
<th>VH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bray:</td>
<td>0</td>
<td>9</td>
<td>16</td>
<td>21</td>
<td>31+</td>
</tr>
<tr>
<td>Mehlich 3:</td>
<td>0</td>
<td>9</td>
<td>16</td>
<td>21</td>
<td>31+</td>
</tr>
<tr>
<td>Olsen:</td>
<td>0</td>
<td>6</td>
<td>11</td>
<td>15</td>
<td>21+</td>
</tr>
</tbody>
</table>

Iowa State University
# Iowa State University
Interpretations for P Soil Tests

**Bray P<sub>1</sub> and Mehlich-3: Phosphorus (P)**

<table>
<thead>
<tr>
<th>Relative Level</th>
<th>Wheat (ppm)</th>
<th>All crops except wheat and alfalfa (ppm)</th>
<th>Subsoil P (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Low (VL)</td>
<td>0 – 15</td>
<td>0 – 8</td>
<td>0 – 5</td>
</tr>
<tr>
<td>Low (L)</td>
<td>16 – 20</td>
<td>9 – 15</td>
<td>6 – 10</td>
</tr>
<tr>
<td>High (H)</td>
<td>26 – 30</td>
<td>21 – 30</td>
<td>16 – 20</td>
</tr>
<tr>
<td>Very High (VH)</td>
<td>31 +</td>
<td>31 +</td>
<td>21 +</td>
</tr>
</tbody>
</table>

Pm-1688 General Guide for Crop Nutrient Recommendations in Iowa
## Iowa State University
### Interpretations for P Soil Tests

<table>
<thead>
<tr>
<th>Relative Level</th>
<th>Wheat (ppm)</th>
<th>Alfalfa (ppm)</th>
<th>All crops except wheat and alfalfa (ppm)</th>
<th>Subsoil P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Low (VL)</td>
<td>0 – 10</td>
<td></td>
<td>0 – 5</td>
<td>0 – 3</td>
</tr>
<tr>
<td>Low (L)</td>
<td>11 – 14</td>
<td></td>
<td>6 – 10</td>
<td>4 – 7</td>
</tr>
<tr>
<td>Optimum (Opt)</td>
<td>15 – 17</td>
<td></td>
<td>11 – 14</td>
<td>8 – 11</td>
</tr>
<tr>
<td>High (H)</td>
<td>18 – 20</td>
<td></td>
<td>15 – 20</td>
<td>12 – 15</td>
</tr>
<tr>
<td>Very High (VH)</td>
<td>21 +</td>
<td>21 +</td>
<td>16 +</td>
<td></td>
</tr>
</tbody>
</table>

Pm-1688 General Guide for Crop Nutrient Recommendations in Iowa

---

Iowa State University
Iowa State University
Subsoil P and K Determination

- **P -- Bray P-1 test**
  - 30 to 42 inch depth
    - Low ≤ 8 ppm
    - High ≤ 9 ppm

- **K -- Ammonium acetate test**
  - 12 to 24 inch depth
    - Low ≤ 50 ppm
    - High ≤ 51 ppm
Iowa State P Interpretations and Recommendations for Corn Grain

<table>
<thead>
<tr>
<th>Soil Test Category:</th>
<th>Very Low</th>
<th>Low</th>
<th>Optimum*</th>
<th>High</th>
<th>Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bray P₁ and Mehlich-3 P:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low Subsoil P</td>
<td>0-8</td>
<td>9-15</td>
<td>16-20</td>
<td>21-30</td>
<td>31+</td>
</tr>
<tr>
<td>High Subsoil P</td>
<td>0-5</td>
<td>6-10</td>
<td>11-15</td>
<td>16-20</td>
<td>21+</td>
</tr>
<tr>
<td><strong>Olsen P:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low Subsoil P</td>
<td>0-5</td>
<td>6-10</td>
<td>11-14</td>
<td>15-20</td>
<td>21+</td>
</tr>
<tr>
<td>High Subsoil P</td>
<td>0-3</td>
<td>4-7</td>
<td>8-11</td>
<td>12-15</td>
<td>16+</td>
</tr>
<tr>
<td><strong>Mehlich-3 ICP:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low Subsoil P</td>
<td>0-15</td>
<td>16-25</td>
<td>26-35</td>
<td>36-45</td>
<td>46+</td>
</tr>
<tr>
<td>High Subsoil P</td>
<td>0-10</td>
<td>11-20</td>
<td>21-30</td>
<td>31-40</td>
<td>41+</td>
</tr>
</tbody>
</table>

P₂O₅ to apply (lb/acre)

100  75  55  0  0

PM-1688 General Guide for Crop Nutrient and Limestone Recommendations in Iowa

Iowa State University
### Iowa State K Interprettations and Recommendations for Corn Grain

<table>
<thead>
<tr>
<th>Potassium Soil Test (ppm)</th>
<th>Very Low</th>
<th>Low</th>
<th>Optimum*</th>
<th>High</th>
<th>Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Test Category:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ammonium Acetate and Mehlitch-3 Extractable K:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low Subsoil K</td>
<td>0-90</td>
<td>91-130</td>
<td>131-170</td>
<td>171-200</td>
<td>201+</td>
</tr>
<tr>
<td>High Subsoil K</td>
<td>0-70</td>
<td>71-110</td>
<td>111-150</td>
<td>151-180</td>
<td>181+</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>K₂O to apply (lb/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fine Textured</td>
</tr>
<tr>
<td>Sandy Textured</td>
</tr>
</tbody>
</table>

PM-1688 General Guide for Crop Nutrient and Limestone Recommendations in Iowa
Suggestions on Use of P Soil Tests

- Bray 1-P
  - If soil pH is less than 7.4
- Olsen
  - If soil pH is above 7.4
  - If soil pH is above 5.0
- Mehlich 3
  - Any soil
Mehlich 3 Extraction of Ca, Mg, K and Estimation of CEC

- In acid and neutral soils
  - Similar to ammonium acetate extraction
- In calcareous soils
  - Not the same, especially for Ca
  - Same problem with CEC estimation as with ammonium acetate extraction
Mehlich 3 Extraction of Zn or Other Elements

- Not recommended by NCR 13 committee
- Not recommended for use in Iowa
  - In Iowa -- still use DTPA extraction for Zn