Phosphorus Soil Tests For Nutrient Recommendations

Comparisons of Routine And Soil Health Testing Methods

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Basis of P soil tests for recommendations

Fertilization

Water quality

Adapted from Jones (2021)
Soil P tests – how do they work?

• Mehlich-3 (Mehlich, 1984)
  • HNO₃ - Ca-P forms
  • NH₄F – Al and Fe-P forms
  • CH₃COOH buffers to pH 2.5
  • EDTA prevents CaF₂ precipitation

• Bray-P1 (Bray and Kurtz, 1945)
  • Not recommended for calcareous soils
  • F⁻ (NH₄F) replaces P anions after solubilization by Al³⁺ activity in solution (HCl)

• Olsen (Olsen et al., 1954)
  • HCO₃⁻ replaces adsorbed P
  • OH⁻ bond with Al and Fe
  • Na⁺ reduces Ca²⁺ activity

• Dissolve secondary minerals
• Focus on calcium, aluminum, and iron
• Displacement from anion exchange capacity (AEC)
• Keep P as orthophosphate in solution
Soil health P tests – weak organic acids

• Component of one Soil Health Assessment Tool; others use routine tests
  • Developed to apply similar composition of root exudates to soil testing
  • Measures extracted P with colorimetric methods
  • Measures extracted P with ICP (measures mainly soluble organic P)

• Three weak organic acids
  • 0.003 $M$ Citric acid (C$_6$H$_8$O$_7$)
  • 0.004 $M$ Malic acid (C$_4$H$_6$O$_5$)
  • 0.003 $M$ Oxalic acid (C$_2$H$_2$O$_4$)

• “H3A” extracting solution (Haney et al., 2006, 2010, 2016)
1. Do soil health P tests measure similar amounts of P to routine test?
2. Will soil health P tests correlate to crop yield response to P?
Summary of Iowa study

• 183 site-years (2000-2017)
• Corn and soybean
• No-tillage and chisel-plow
• 6-in depth samples
• Varying soil P levels.
• Loam, clay loam, silt clay loam
• Organic matter 3.5 to 5.1%
• pH 5.0 to 7.9
Relationships between routine P tests

• Bray-1 and Mehlich-3 closely related
• Olsen extracts ~ ½ of acidic tests

Y = 0.19 + 1.06x
\( r^2 = 0.97 \)
\( P < 0.0001 \)

Y = 0.95 + 0.49x
\( r^2 = 0.91 \)
\( P < 0.0001 \)

Y = 0.92 + 0.46x
\( r^2 = 0.92 \)
\( P < 0.0001 \)

Colorimetric determination
mg P kg\(^{-1}\) = ppm P

Jones and Mallarino, 2021
Relationships between routine P tests

- H3A ~ \( \frac{1}{2} \) strong acid (BP & M3P) tests
- Similar to Olsen test (in acidic to neutral soil)

Colorimetric determination
mg P kg\(^{-1}\) = ppm P

\[
Y = 1.03 + 0.49x \quad r^2 = 0.88 \quad P < 0.0001
\]

\[
Y = 0.95 + 0.46x \quad r^2 = 0.92 \quad P < 0.0001
\]

\[
Y = 0.71 + 0.94x \quad r^2 = 0.86 \quad P < 0.0001
\]

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Jones and Mallarino, 2021
Soil-test P and crop yield

- Field correlation step of investigating soil test
- Required for an applicable soil test method
- Relative yield: treatment not receiving fertilizer for full crop year divided by statistically highest treatment (expressed as %)

Jones and Mallarino, 2021
Soil-test P and crop yield

Critical Concentration Range:
- Bray-1 P: 14 to 18 ppm P
  - Soybean: 54% below & 46% above
  - Corn: 59% below & 41% above
- H3A P: 9 to 12 ppm P
  - Soybean: 54% below & 46% above
  - Corn: 59% below & 41% above

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Biological activity & P mineralization

• Soil health brought attention to soil biology, and oriented tests focus on this.
• Proxy for biological activity [CO$_2$ respiration, permanganate oxidizable C (POXC), microbial active C)
• Increases in soil solution P mechanistically very different than N
• Estimated of mineralization using CO$_2$ respiration being used

Dijkstra et al. (2013)
Relationships between P tests

(Solvita burst)

(Solvita burst, water-extractable C:N)

(Sum of H3A and P min)

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Routine vs alternative tests

Including a mineralization factor based on CO\textsubscript{2} respiration could not improve the performance

Critical Concentration Range:
- Soybean: 14 to 18 ppm P
- Corn: 9 to 12 ppm P

Both crops

27% below & 73% above

Jones and Mallarino, (2019)
Soil test P trends

- 2020 NA Soil Test Summary ~ 7.4M samples
- Mehlich-3 test determined with inductively-coupled plasma spectroscopy (ICP) (56%)
- Bray-P1 (24%)
- Olsen (9%)
- Mehlich-1 (6%)
- Mehlich-3 determined colorimetrically (4%).
- For potassium, 86% were either Mehlich-3 or ammonium acetate.
What does a soil-test value represent?

1. Laboratory value represents one point in time
2. Crop yield (or response to P) represents an entire growing season of P utilization.
3. Effective soil P tests must relate to an entire growing season uptake, utilization, and resulting yield response

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General thoughts & summary

- Large effort to field correlate H3A, and provide a framework for at least a critical soil-test P concentration range level for corn and soybean.
- “yes vs no” decision could be made
- Poorer relationship between H3A and crop yield response to P than routine test
- Not there yet on estimating P mineralization
- If trying alternative P tests, run routine as well
Thank you!

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