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Soil phosphorus testing on

alkaline calcareous soils

Soil phosphorus testing made great strides with multiple chemical tests proposed and implemented for crop fertilizer management programs during the previous century. In the latter part of the previous century, the environmental impact of excess nonpoint phosphorus loading from the landscape (e.g., agricultural lands) to waterbodies became an issue of increased concern, and soil phosphorus testing came to the forefront of management and monitoring. This article will provide a general overview of the usage of phosphorus testing for agronomic purposes in the United States Earn 0.5 CEUs in Nutrient Management by reading this article and taking the quiz at www.certifiedcropadviser.org/education/classroom/classes/725.

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Measures of total soil phosphorus are not useful for agronomic purposes as the test must relate to the portion of phosphorus available to the plant for uptake. Thus, soil phosphorus testing for available phosphorus to plants relies on an understanding of phosphorus chemistry in the soil. Soil pH is a primary driver of phosphorus availability where both low- and high-pH soils can have substantial phosphorus fixation. In acidic soils, fixation is dominated by Fe and Al phosphates, and in alkaline soils, Ca phosphates. Of note, alkaline calcareous soils have excess calcium carbonates that can lead to substantial fixation of phosphorus.

Of the many soil phosphorus tests introduced, three tests are widely used across the Midwest (Bray-1; Bray and Kurtz, 1945), the southeastern United States (Mehlich-3; Mehlich, 1984), and the western United States (Olsen; Olsen et al., 1954). The Bray-1 test is adapted primarily for acidic soils and uses both hydrochloric acid and ammonium fluoride to extract soluble P by releasing Al- and Fe-bound phosphorus. The Olsen test uses sodium bicarbonate at pH 8.5 to extract phosphorus in neutral to alkaline soils. The extractant decreases solution Ca through

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precipitation and releases phosphorus from calcium carbonate and other surfaces. Mehlich-3 is a multinutrient extractant that uses a combination of acids, ammonium fluoride, ammonium nitrate, and EDTA. The acidic nature of the Mehlich-3 test as well as the ammonium fluoride results in extraction of phosphorus in soils. The H3A test (Haney–Haney–Hossner–Arnold; Haney et al., 2006), a component of the Soil Health Tool, has been proposed as an alternative in an attempt to extract soil phosphorus under ambient soil pH conditions. Several revisions of the H3A tests have occurred where the current version uses three organic acids (citric acid, oxalic acid, and malic acid) to extract phosphorus.

Historically, correlation and calibration studies were conducted to determine the effectiveness of extractants and to determine fertilizer application rates for crop production. In general, the correlation phase entails determining the relationship between soil phosphorus measured by different tests to crop response (e.g., plant uptake, yield), and the calibration phase determines expected response from fertilizer applications in relation to the soil levels of the test determined to be most appropriate in the correlation phase.

Know the soil test used on your samples

From a production standpoint, growers should understand what soil test was conducted on the sample they sent in. Crop response studies and extension fertilizer recommendations are typically based on a single extractant that was tested and determined to be appropriate for the region. Using a different soil phosphorus test than was developed for fertilizer recommendations in the region will likely result in inaccurate and faulty fertilizer recommendations. This is due to the fact that different soil phosphorus tests will extract different amounts of soil P based on the chemical makeup of the extractant, and thus, if those soil phosphorus values are used to make fertilizer recommendations, fertilizer may either be over- or under-applied. This issue often comes up when samples are sent to laboratories well outside the region in which they were collected where testing protocols (e.g., appropriate sample depth) as well as the appropriate soil phosphorus test may not be used. This may impact farm economy from a production standpoint as yields and quality may be negatively impacted if under- or over-fertilization occurs.

Recent interest in soil health testing has resulted in an increase in samples being submitted to geographically distant laboratories. Often the soil test may not be specified when submitted, and the soil depth used may vary between the laboratory and the recommendations that are found in the state where the samples were submitted. The interest to compare across regions, and the interest in multi-nutrient extractants, has led researchers to investigate the relationships between soil phosphorus tests.

Previous work in the Midwest compared the Bray-1 and Mehlich-3 tests to the Olsen test and determined that the Bray-1 test had many samples below the detection limit when pH is alkaline. Inorganic carbon (e.g., calcium carbonate) content is also needed to establish when Bray-1 samples would fall below the detection limit. One reason for reduction in detection is that the calcium

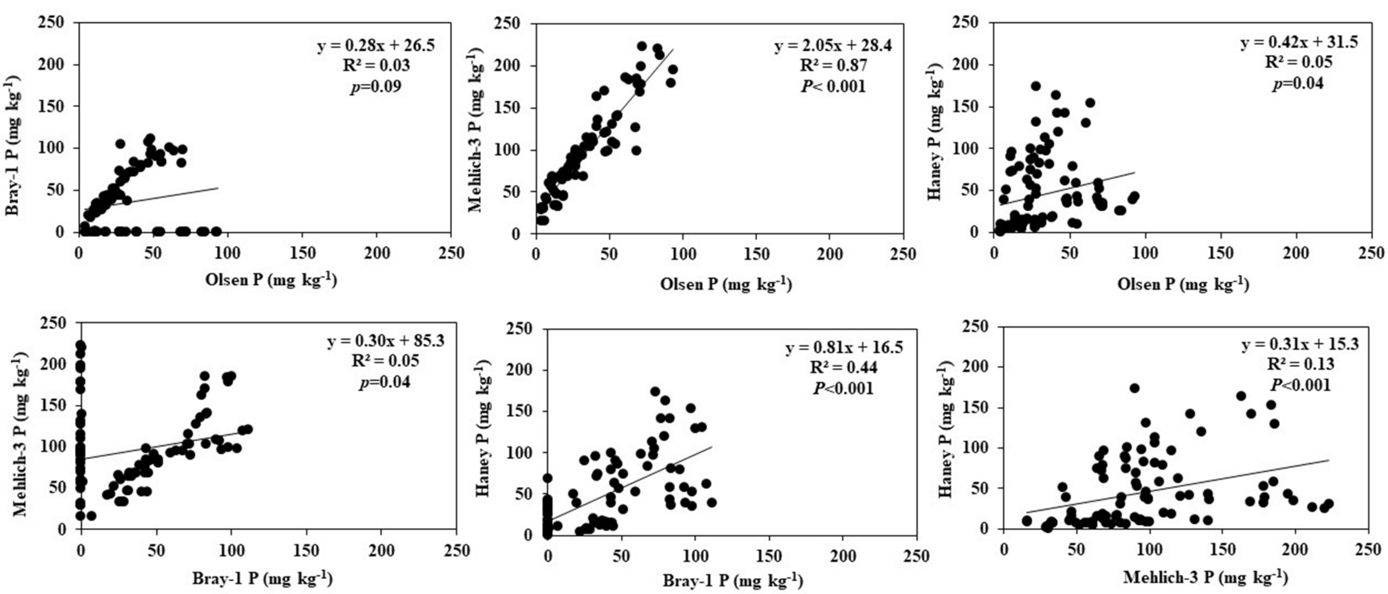

Fig. 1. Relationship among various laboratory soil-phosphorus (P) tests [Olsen, Bray-1, Mehlich-3 and Haney (H3A)] for soil samples collected at a depth of 0- to 30-cm from agricultural fields in Idaho in 2015. (Dari et al., 2019).

carbonate neutralizes the extractants, reducing its extracting capability. Mehlich-3 samples have resulted in greater values of phosphorus from extractions compared with Bray-1 or Olsen.

In the western United States, the Olsen test is predominately used where alkaline soils are common. Recent work by Dari et al. (2019) reported results comparing Bray-1, Mehlich-3, Olsen, and the newly developed H3A on predominately alkaline soils. As in the Midwestern studies, Bray-1 had appreciable issues in selected samples (Fig. 1). Regression analysis indicated a strong correlation between Olsen and Mehlich-3 ($R^2 = 0.87$) with lower R^2 values when the other tests were compared with Olsen. While a strong relationship was established, the Mehlich-3 test extracted greater amounts of soil test phosphorus as compared with the Olsen test (Fig. 1). This clearly shows the potential pitfalls (e.g., a reduced phosphorus recommendation) that can occur if the extractant used to test a soil does not match those used for the recommendation.

Follow-up analysis determined that appreciable inorganic carbon (i.e., calcium carbonate) only occurred in soil samples above pH 7.5, and detection limit issues with Bray-1 phosphorus were predominant above an inorganic carbon content of 6.7 g/kg. Removal of sites with high inorganic carbon content resulted in much improved relationships between Bray-1 and the other tests. The H3A test exhibited relatively similar issues as the Bray-1 test though samples were still detectable. Reduced extraction of phosphorus at high pH has previously been noted for the H3A test, and in our study, inorganic carbon exceeding 5.1 g/kg resulted in reduced extraction of soil phosphorus for the H3A test.

The results form Dari et al. (2019) provide evidence that the Olsen and Mehlich-3 phosphorus tests are strongly correlated to one another on alkaline calcareous soils. However, Bray-1 and H3A had notable issues and poorer correlation on these soils. Thus, Mehlich-3 can be suggested as a suitable soil phosphorus test for calcareous soils as a part of multi-nutrient extraction where fertilizer response studies would provide an understanding of the test as related to crop production. The H3A phosphorus test had notable issues on calcareous soils, and thus, its use alone or as part of soil health testing may be problematic for these particular soils commonly found in the western United States. C&S

The References are omitted here due to space constraints but can be viewed on p. 31.

Self-study CEU quiz

Soil phosphorus testing on alkaline calcareous soils

Earn 0.5 CEUs in Nutrient Management by taking the quiz for the article on pages 36–38 at www.certifiedcropadviser.org/education/classroom/classes/725. For convenience, the quiz is printed below. Cost: $25.

1. Which soil test often shows soil samples as below the phosphorus detection limit when soil pH is alkaline?

a. Olsen.
b. Mehlich-3.
c. H3A.
d. Bray-1.

2. Which test is often used in the Western U.S. where alkaline soils are common?

a. Olsen.
b. Mehlich-3.
c. H3A.
d. Bray-1.

3. Which two soil tests are strongly correlated to one another on alkaline calcareous soils?

a. Mehlich-3 and Bray-1.
b. Olsen and H3A.
c. Mehlich-3 and Olsen.
d. H3A and Bray-1.

4. Phosphorus fixation in acidic soil is dominated by which two phosphates?

a. Fe and Ca.
b. Fe and Al.
c. Al and Mg.
d. Ca and Al.

5. Which phase of a study aims to determine the relationship between crop response and soil phosphorus measured by different tests?

a. Extraction
b. Calibration
c. Detection
d. Correlation

Self-study CEU quiz

Cover crops for improved soil health in silage corn cropping systems in Idaho

Earn 1 CEU in Soil & Water Management by taking the quiz for the article on pages 20–24 at www.certifiedcropadviser.org/education/classroom/classes/723. For convenience, the quiz is printed below. Cost: $35.

1. Unlike many cool-season grass species, corn silage does not accumulate

a. nitrogen c. calcium
b. potassium d. phosphorus

2. Digestibility of whole-plant silage corn tends to _________ as the crop reaches the early dent stage.

a. increase
b. decrease
c stay the same
d. become much more difficult to measure

3. Corn acreage has been __________in the Pacific Northwest and the state of Idaho in the recent years.

a. declining c. increasing
b. static d. variable

4. The current typical corn silage yields are _________ tons per acre.

a. 3 c. 30
b. 50 d. 130

5. Soil health is defined as the continued capacity of ________to function as a vital living ecosystem that sustains plants, animals, and humans.

a. weather c. health
b. organic matter d. soil

6. The Solvita test aims to measure of the _________ activity in the soil and may be indirectly related to soil fertility.

a. respiration c. microbial
b. organic d. mineral

7. The soil health index is determined with a combination of five independent measurements of soil's ___________________ properties.

a. biological and chemical c. physical and chemical
b. mineral and organic d. mineral and microbial

8. Treatments 1 and 2 had no cover crop seeded, so the GreenSeeker sensor has been measuring only the _______________biomass present within these plots.

a. microbial c. corn
b. organic d. green

9. Treatment 1 (no cover crop) had higher ____but substantially lower ___ available after corn harvest.

a. soil moisture/N
b. available P_2O_5 and K_2O/N
c. organic matter/ P_2O_5 and K_2O
d. S/Mn.

10. It is important to note that the soil health score is not directly related to soil

a. fertility. c. development.
b. health. d. productivity.

Soil phosphorus testing [continued from p. 38]

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