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Abstract
Soil testing is the key component for determining the need for phosphorus (P) fertilization. Also, if fertilization is required, test results guide the rate of application recommended to optimize production. Through extensive laboratory, greenhouse, and field research studies, soil tests are calibrated against the expectation of response to applied P. That is, the research determines both the relative index of P availability to the crop being grown and an indication of the probability and magnitude of yield increase one should expect when P is applied – thus providing the interpretation of test results. This research also determines which test is best at predicting available P and crop response to P application.

Disciplines
Agricultural Science | Agriculture | Agronomy and Crop Sciences

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Differentiating and Understanding the Mehlich 3, Bray, and Olsen Soil Phosphorus Tests[1]

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Soil testing is the key component for determining the need for phosphorus (P) fertilization. Also, if fertilization is required, test results guide the rate of application recommended to optimize production. Through extensive laboratory, greenhouse, and field research studies, soil tests are calibrated against the expectation of response to applied P. That is, the research determines both the relative index of P availability to the crop being grown and an indication of the probability and magnitude of yield increase one should expect when P is applied – thus providing the interpretation of test results. This research also determines which test is best at predicting available P and crop response to P application.

Soil P Test Considerations

Both the relative index of availability and interpretation of P need is specific to each soil test. Therefore it is imperative that one knows what soil test method was employed before you can adequately derive a P fertilization recommendation. This is an important consideration as there have been many methods developed to test soils for crop available P. Each can have a widely different interpretation index. For example, at a given soil test level the interpretation may be optimum for one test, but may be interpreted as low or high for another test. In Iowa for instance, at a test level of 15 ppm, the interpretation of the Bray-1 test is low, but for the Olsen test it is high (the Olsen test typically extracts less P than the Bray-1). Each test method has unique characteristics, and in the end, best application to specific soils and cropping systems.

For P this is important and somewhat complicated in geographic areas where soils vary in chemical properties across the landscape – specifically the content of free lime (calcium or magnesium carbonates in calcareous soils). This variation has been highlighted by results from intense soil sampling. Some calcareous soils can cause certain P soil tests to behave differently than in noncalcareous soils, and thus to produce erroneous results. In the Midwest, the commonly used Bray-1 test has this difficulty. The Olsen test, on the other hand, does not have this problem (was developed and calibrated to determine available P in calcareous soils).

Another important, but complicating issue is the efficiency of laboratory operations. Use of one extraction solution to provide multiple nutrient analyses can shave costs and increase through-put. Thus laboratories may be interested in employing tests that do not use traditionally recommended extractions for P. This efficiency underlies the interest in the Mehlich 3 test. Another, but sometimes non-evident issue is the analytical method utilized to measure the amount of P extracted from soil samples. Again, to increase laboratory efficiency by simultaneously determining multi-nutrient concentrations, laboratories have interest in shifting away from individual methods (in the case of P, colorimetric determination using the ascorbic acid method) to use of equipment that can make multiple element determinations on the same soil extract (specifically use of inductively coupled plasma or ICP). It is important to remember

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that the analytical result from a soil test laboratory is the culmination of the entire soil test method -- including the soil extractant and the analytical measurement method.

As a consequence of the above discussion, the following questions are key: 1) which P test should I use – the Bray-1, Olsen, or Mehlich 3; 2) should I use individual P tests for calcareous, neutral, and acidic soils; 3) can I use the Mehlich 3 for P across all soils; 4) is the Mehlich 3 calibrated in my geographic area; 5) how do I interpret results from these different soil tests; 6) can I convert results of one test to the equivalent of another; 7) should I use P test results from labs that use an ICP; and 8) does the Mehlich 3 extractant work for other nutrients like K, Ca, Mg, and Zn?

Suggested P Test Use and Interpretation for Iowa Soils

The following article is reprinted in it's entirety from the Iowa State University Integrated Crop Management Newsletter, IC-482(2), February 15, 1999, p. 11-14 – Interpreting Mehlich-3 soil test results (Mallarino and Sawyer, 1999). It discusses the relationship between the Mehlich 3, Bray 1, and Olsen P tests and current interpretations and suggested uses in Iowa. It also provides answers to the questions stated above.

For many years soil analysis laboratories in Iowa have used the Bray-P_1 (Bray 1) and Olsen (sodium bicarbonate) tests for phosphorus (P) and the ammonium acetate test for potassium (K), calcium (Ca), and magnesium (Mg). The Mehlich-3 test (M3) was developed in North Carolina for routine analysis of P, K, Ca, Mg, sodium (Na), and micronutrients. The M3 test was not recommended by universities of the North Central Region due to a lack of correlation and calibration research in this region. This year, based on several years of research, Iowa State University (ISU) is releasing soil test interpretations for analyses of P and K made with the M3 test.

The advantage of the M3 test is that it may offer the possibility of using one test for P and other nutrients across acid, neutral, and high-pH soils. The M3 extracts virtually the same amount of K as the currently used ammonium acetate test. The Bray test produces erroneously low P values in many calcareous soils. In regions having both calcareous and noncalcareous soils it is reliable on neutral or acid soils but not on calcareous soils. The Olsen test is reliable on neutral and high-pH (calcareous) soils but poor on acid soils. Also, it is not as well adapted for routine analysis as the Bray. Therefore, many soil analysis laboratories use the Bray test for all samples and the Olsen only for samples with high pH, thus reducing laboratory efficiency and increasing costs.

Iowa research shows that the M3 P results are similar to the Bray in acid and neutral soils, but are much better in many high-pH soils. Similar conclusions apply to many soils of nearby states, although the M3 does underestimate P in many soils of western states that have higher (and perhaps a different type of) calcium carbonate. Figure 1 shows an example of the relationship between amounts of P extracted by three tests for Iowa soils varying in soil pH. Only the amount of P extracted by the Bray was strongly influenced by soil pH and it extracted less P than the M3 in many calcareous soils (look for data points with Bray values near zero but higher M3 values). Correlations involving the Bray are high only when calcareous soils are excluded. The Olsen and M3 tests are well correlated across all soils. The Olsen, as expected, extracts less P than the other tests. This difference is accounted for when interpreting the results for fertilizer recommendations.

Results from dozens of field response trials with corn and soybean across Iowa confirm that the relationship between crop response to fertilization and soil-test P is similar for the Bray and M3 tests on neutral and acid soils. On calcareous soils, however, the M3 improved the predictability of the yield response to P especially in soils with pH 7.4 or higher. Thus, the capacity of the M3 test to measure available P across soils of varying pH is much better than for the Bray. Another important result is that the Olsen test also works well across all Iowa soils as long as soil pH is above 5.0, but few Iowa soils are so acidic.

Table 1 shows the soil test interpretation classes for P by the Bray, M3, and Olsen tests and for K by the ammonium acetate and M3 tests recommended by ISU. Given the results discussed previously, interpretations for the M3 are exactly the same as those currently in use for P with the Bray and for K with the ammonium acetate test (see ISU Extension publication Pm-1688 – which may be viewed at: http://extension.agron.iastate.edu/fert/ or downloaded at: http://www.extension.iastate.edu/Publications/PM1688.pdf). These interpretations will be adjusted in the future if necessary.

The interpretations for P must be used with one very important consideration. They apply only when a colorimetric method is used to measure P solubilized by the extractant. A soil test is composed of two parts: the extraction of available P from the soil, which defines the soil test method, and the determination of P solubilized by the extractant. The colorimetric method most widely used in soil testing is similar for all P tests, and measures a blue color that develops with different intensity depending on the P concentration in the extracted solution. The North Central Regional Committee for Soil Testing and Plant Analysis (NCR 13) and ISU do not recommend the determination of P with the ICP (inductively coupled plasma) method for any P soil test, including the M3. This recommendation is proposed because variations in the P concentrations measured by ICP compared with the standard colorimetric method (the ICP sometimes measures up to 40 percent more P) are not well understood. A simple correction factor does not appear effective to correct this difference.

How reliable is the M3 test for measuring Ca, Mg, or micronutrients and estimating cation exchange capacity (CEC)? The amounts of Ca and Mg extracted with the M3 from soils of acid or neutral pH is similar to amounts extracted by the commonly used ammonium acetate test. The amount of Ca and Mg extracted (especially Ca) does not seem the same, however, in calcareous soils. Thus, until more data are gathered, the NCR 13 committee only recommends the use of the M3 test for Ca and Mg and to estimate CEC (in conjunction with SMP buffer pH) for acid or neutral soils. The committee does not recommend its use for Ca, Mg, or CEC in calcareous soils or for micronutrients in any soil. Actually, the problem of estimating CEC in calcareous soils also applies to the ammonium acetate test.

ISU does not support soil-test interpretations for sufficiency of Ca, Mg, or micronutrients other than zinc. This decision, made years ago, is based on the lack of reliable information on deficiencies of these nutrients for the major Iowa crops or soils and lack of reliable field response data that could support a recommendation. This policy does not contradict the fact that measurements of Ca, Mg, or CEC, for example, allow for useful inferences about other soil properties that may influence crop yields. Current interpretations for zinc are based on the DTPA test, and for lime requirements on the SMP buffer test.

The Bottom Line

Use soil test procedures that are calibrated for the soils and cropping systems of your geographic region. This means recognition of both the laboratory extraction and chemical analysis method. Conversion of test results from one method to another should not be done – rather use the interpretation guides for each test. Choice of the Bray-1, Mehlich-3, or Olsen test for P should be made in consultation with the soil test lab, and should be chosen to provide the best results for the soils being tested. In Iowa there is great flexibility in choosing the test of preference because calibration studies have documented performance of each test. Of greatest concern (potentially poorest or erratic results) is use of the Bray-1 test on soils with pH > 7.4, use of the Olsen test on highly acidic soils (pH < 5.0), and use of ICP for determination of P in soil test extracts. Otherwise, performance should be similar, but only when interpreted using the specific calibration guidelines for each P test method.

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Figure 1. Relationship between P extracted by three tests for Iowa soils varying in soil pH.

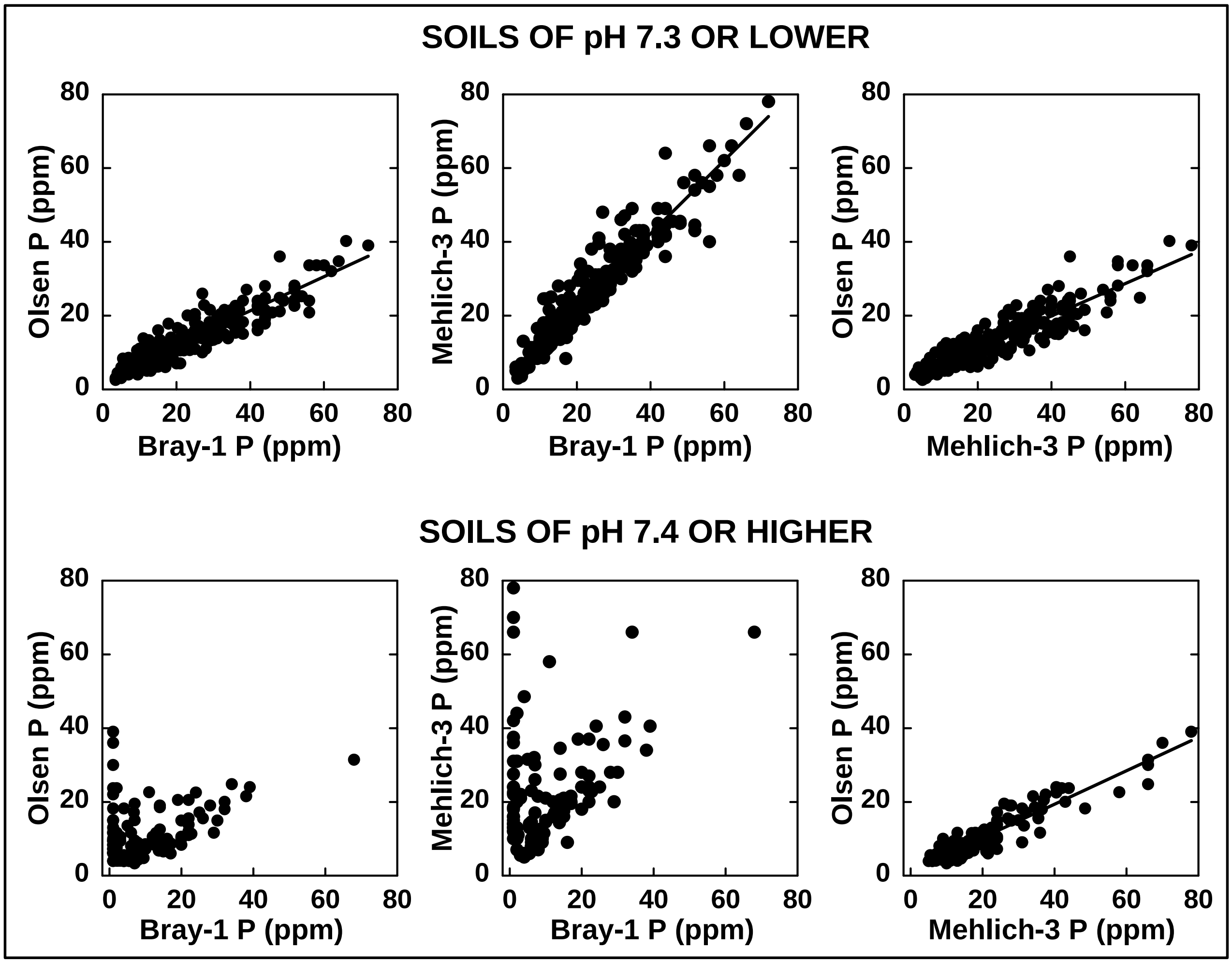

Table 1. Interpretation of soil test values for phosphorus (P) determined by Bray P_1, Mehlich-3, or Olsen extractant and potassium (K) determined by ammonium acetate or Mehlich-3 extractant for surface soil samples (6- to 7- inch deep cores).

	Bray P_1, Mehlich-3: Phosphorus (P)			Ammonium acetate or Mehlich-3: Potassium (K)	
	Wheat, alfalfa	All crops except wheat, alfalfa		All Crops	
		Subsoil P		Subsoil K	
Relative Level *		Low	High	Low	High
	ppm				
Very low (VL)	0-15	0-8	0-5	0-60	0-40
Low (L)	16-20	9-15	6-10	61-90	41-80
Optimum (Opt)	21-25	16-20	11-15	91-130	81-120
High (H)	26-30	21-30	16-20	131-170	121-160
Very High (VH)	31+	31+	21+	171+	161+
	Olsen: Phosphorus (P)				
Very Low (VL)	0-10	0-5	0-3		
Low (L)	11-14	6-10	4-7		
Optimum (Opt)	15-17	11-14	8-11		
High (H)	18-20	15-20	12-15		
Very High (VH)	21+	21+	16+		

* The optimum soil test category is the most profitable to maintain.
The very high soil test category indicates that the nutrient concentration exceeds crop needs, and further additions of that nutrient very seldom produce a profitable yield response.