RELATIONSHIP OF MEHLICH-3 ICP AND MEHLICH-3 COLORIMETRIC PHOSPHORUS DETERMINATIONS WITH THE BRAY-P1 EXTRACTANT.

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Abstract

The Bray P1 extractant has traditionally been the common extractant used for soil testing in the Midwest and Great Plains, while the Olsen P tests has been the dominant phosphorus (P) extractant used in many western states. The use of the Mehlich-3 extractant for determining soil test P in private and state operated soil test laboratories become more commonplace in recent years. The ability to extract multiple elements is a major advantage of the Mehlich-3 test. While the Mehlich-3 test is often run using the more traditional colorimetric procedure, the use of ICP in conjunction with the Mehlich-3 extractant is also becoming more commonplace as pricing declines. With changes in extractants and analytical techniques also comes the need to evaluate these new tests for agronomic and environmental stewardship purposes. As part of a larger P management project, this study utilized 367 soil samples collected from 10 locations across Kansas and western Missouri which were analyzed by Bray P1 with colorimetric determination (BP1), Mehlich-3 with colorimetric determination (M3-Col) and Mehlich-3 with ICP determination (M3-ICP). The BP1 test was highly correlated to both the M3-Col and M3-ICP procedures, especially for non-calcareous soils (r^2 = 0.91-0.93). Likewise, M3-Col and M3-ICP were highly correlated across all soils (r^2 = 0.98). However, the relationship of M3-Col to M3-ICP varies, depending on the M3-Col soil test value. Additional work to further define this relationship and the relationship of each of these tests to crop response and grain nutrient content will continue.

Introduction

Soil testing programs have long been recognized as the cornerstone of efficient, profitable P fertility programs. Additionally, as more and more attention is directed at the environmental effects of P movement to surface waters, soil testing is increasingly being viewed as an important tool for environmental protection. Unfortunately, P soil tests do not measure the actual amount of soil P available to growing crops or the amount of P subject to movement to surface waters. With proper interpretation, however, they do provide information that is useful in developing cost effective nutrient management programs that also provide for environmental stewardship.

However, there are several soil test extractants/procedures routinely used by soil testing laboratories to provide soil P status information and each of them requires individual interpretation. The extractant/procedure used often varies from state to state and sometimes from laboratory to laboratory. Before P soil tests can be interpreted, the user must know exactly what test and/or procedure is used. In the midwest, the most widely used P soil test extractant used has been the Bray P1 extractant (Bray and Kurtz, 1945). This test was developed for slightly acidic to near neutral soils and has been very reliable in areas of adaptation. However, this test has sometimes been found to be unreliable for calcareous soils (free lime) due to the rapid neutralization of the acid in the extractant by calcium carbonate (Blanchar & Caldwell, 1964; Randall & Grava, 1971). For some calcareous soils (not necessarily all) the Bray P1 soil test may consistently indicate low P supplying ability for a soil, even though responses to applied P fertilizer can not be obtained.

In much of the Great Plains and western U.S., the soils are often calcareous and the Bray P1 soil test is often relatively unreliable. Consequently, the sodium bicarbonate extractant (Olsen test) was developed (Olsen et al., 1954) and has been routinely used in these areas in years past. In parts of the country having a mixture of slightly acidic to calcareous soils, the Olsen test is often suggested for the higher pH and/or calcareous soils while the Bray P1 test was suggested for the remainder of the soils. Oftentimes, both of these tests have been used by the same laboratory and sometimes even for samples collected from the same field.

The Mehlich-3 extractant (Mehlich. 1984) was designed for use on a wide-range of soils for simultaneously extracting many crop nutrients. The ability to extract multiple elements is a major advantage of the Mehlich 3 test as it offers the potential for increasing laboratory efficiency. The Mehlich-3 test is commonly run using the more traditional colorimetric procedure, but is also measured by ICP procedure analysis. The use of ICP has become more commonplace as pricing has declined and offers the additional advantage of simultaneously measuring several nutrients from a single extract, again improving laboratory efficiency.

But improved laboratory efficiency by itself is not sufficient grounds to adopt a new soil test procedure. The usefulness and credibility of a soil-testing program is determined by the correlation and calibration data that supports the interpretation of the analytical results (Beegle & Oravec, 1990). There are questions about the relationship between the Bray P1 extractant and Mehlich-3 extractant across geographies and soils. Additionally, Mehlich-3 values typically vary depending on whether colorimetric or ICP determinations are utilized. It has been suggested that one reason M3-ICP values are higher that M3-Col values is that organic P, in addition in addition to inorganic P, is measured with ICP (Hylander et al., 1995; Eckert & Watson, 1996; Eliason et al., 2001; Nathan et al., 2002).

Current research at Kansas State University includes collection of additional P correlation/ calibration data, grain nutrient removals and soil test data for corn and grain sorghum from locations across the state. Initial soil P test results for 2003 from ten of these locations were used to evaluate the relationship among Mehlich-3 colorimetric (M3-Col), Mehlich-3 ICP (M3-ICP) and the colorimetric Bray P1 (BP1) procedures. While these results only address at the relationship among the soil test numbers, each method will eventually be correlated to crop response as well. 2003 was only the first of a three year project and these results will be followed for two more years.

Materials and Methods

A total of 367 soil samples were collected from individual plots at nine locations throughout Kansas and one from western Missouri. Selected soil properties for each location are presented in Table 1. Fifteen soil cores were collected from the 0-15 cm depth for each sample location at each site. Each sample was then air dried and ground to pass a 2-mm sieve.

The samples were analyzed for Bray-P1 soil test P (Bray and Kurtz, 1945), soil pH determined on a 1:1 soil:water mixture and free lime estimates made using a 1 M HCl acid visual neutralization method at the Kansas State University soil test laboratory. Mehlich-3 colorimetric and ICP determinations (Mehlich, 1978; Soltanpour & Schwab, 1977; Eik & Hanway, 1986) and soil organic matter were run by Servi-Tech soil test laboratory. All soil test determinations were made using the same dried and ground sample. Linear coefficients of determination between the three soil test procedures (BP1, M3-Col and M3-ICP) were made for each site.

Results and Discussion

M3-Col and M3-ICP vs. Bray P1. In general, the relationship between the M3-Col and BP1 procedure and the M3-ICP and BP1 procedures were well correlated at individual locations. The main exceptions were the Brown and the Dekalb sites (Table 2). At both these locations, coefficients of determination were less than about 0.50 for each comparison. It is unknown why these locations were so different from the rest of the sites. Interestingly, the Dekalb location was previously in pasture, with the sod being worked up in late winter 2003 and also had very low Bray P1 soil test values.

At Ellis county, 12 of the 90 samples collected contained appreciable amounts of free lime (calcareous soils). While the relationship of both the M3-Col and M3-ICP procedures to the BP1 extractant were very good. many of these 12 samples appeared as outliers (Figure 1). These outliers resulted in lower than expected BP1 values relative to either Mehlich-3 determination. While the r^2 value of the M3-ICP to BP1 comparison was not improved by removal of these soils (0.84 vs. 0.84), the relationship of the M3-Col to BP1 was improved (0.79 to 0.85).

Both the M3-Col and M3-ICP methods were highly correlated to BP1 when all locations were combined for analysis (Figure 2). Calcareous samples were excluded for this analysis. Overall, the M3-Col method extracted about 12% more P than the BP1 extractant. The M3-ICP extracted more P than either the M3-ICP or BP1 procedures.

M3-Col and M3-ICP. The relationship between the M3-Col and M3-ICP determinations were very highly correlated with r^2 values exceeding 0.70 at all locations except for the Dekalb county site (r^2 = 0.35). If fact. the r^2 values were greater than 0.96 at seven of ten locations. While it is unknown at this time why the Dekalb location provided such results, the differences at Dekalb County were striking. The average soil test values at this location were 3.6, 3.2 and 9.8 ppm for the BP1. M3-Col and M3-ICP determinations, respectively. It is possible that the only recently disturbed pasture residues resulted in greater amounts of organic P being measured the M3-ICP procedure as compared to either the BP1 or M3-Col procedure.

When the samples from all locations are combined (Fig. 3), including the calcareous soils, the M3-Col and M3-ICP determinations were very highly correlated (r^2 = 0.98). However, at low soil test values, the M3-ICP procedure extracted relatively more P than the M3-Col procedure. Figure 3 presents the ratio of the M3-Col determination divided by the M3-ICP determination. Clearly, the data suggests that the relationship between M3-Col and M3-ICP varies depending on the relative P soil test levels. Mallarino reported similar results from Iowa soils. A possible explanation for this is that the relative importance of organic P is greater with low P soil tests, while the relative importance of inorganic P is greater at higher P soil test values. We intend to explore this in the near future. Hopefully, this relationship will become clearer as additional years of data are included.

Summary

More state university and commercial laboratories are switching to the Mehlich 3 extractant and away from the Bray P1 extractant since it allows multiple nutrient analyses on a single extract. Additionally, there continues to be a trend to laboratories utilizing ICP analysis since it allows for simultaneous analyses of multiple nutrients with the same extract. High correlations exist among the three P soil test methods examined (BP1, M3-Col and M3-ICP), although the BP1 test provided lower than expected values on calcareous samples. Both the M3-Col and M3-ICP tests worked well on both calcareous and non-calcareous soils and both were highly correlated with each other.

However, additional work will be conducted to examine the relationship between M3-Col and M3-ICP at soil test levels in the crop response range (less than 30 ppm) since it seems that at low P soil test levels the M3-ICP extracts relatively more P than the M3-Col method. Also, additional work relating P soil test values for each of these three soil test methods to crop response and grain nutrient content will continue.

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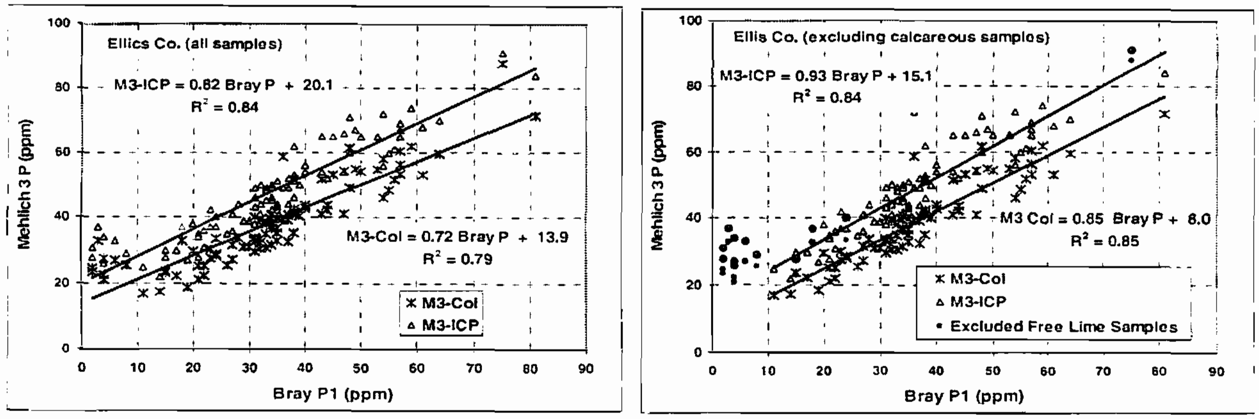

Figure 1. Relationship of M3-Col and M3-ICP with Bray P1 Soil Tests Values on Calcareous and Non-calcareous Soils (Ellis county Kansas, 2003).

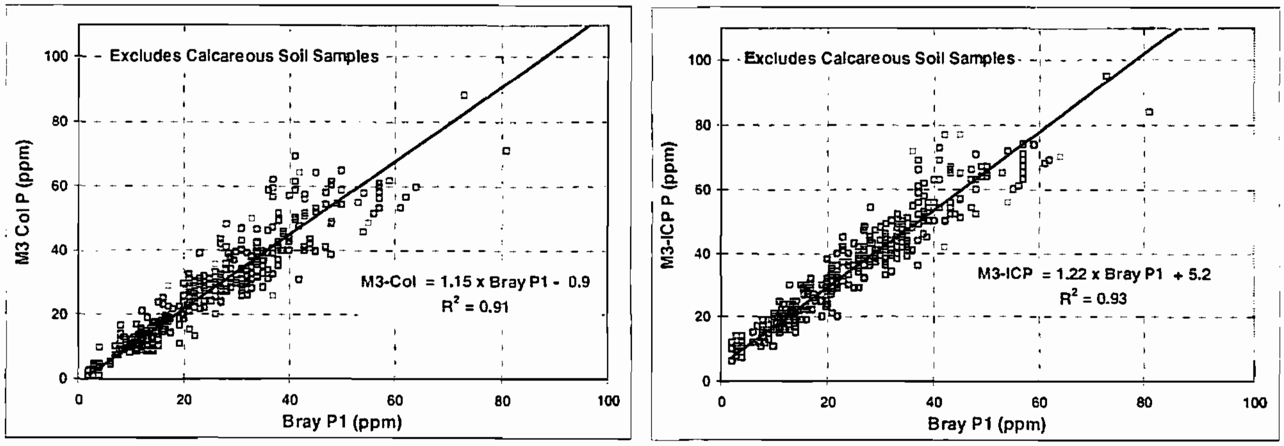

Figure 2. Overall Relationship of M3-Col and M3-ICP with Bray P1 Soil Tests Values on Non-calcareous Soils (10 locations, 2003).

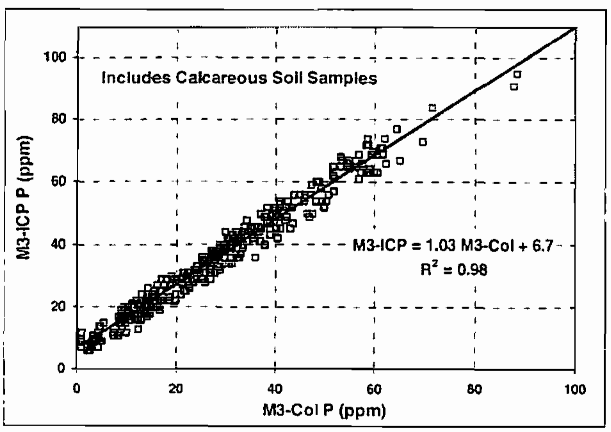

Figure 3. Overall Relationship of M3-Col and M3-ICP P Soil Test Values (10 locations, 2003)

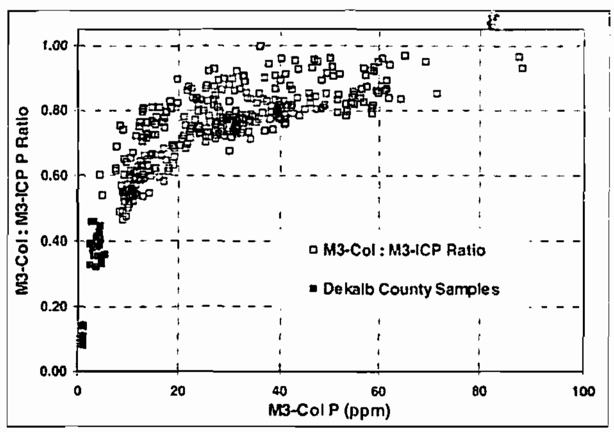

Figure 4. Relationship of M3-Col : M3-ICP P Ratio To M3-Col Soil Test Value (10 locations, 2003)

Table 1. Soil Sample Locations and Properties.				
Location	**Soil Organic Matter (%)**	**Soil pH**	**Free Lime**	**Number of Samples**
Brown County	2.2 – 2.7	5.9 – 6.8	None	40
Clay County	1.7 – 3.2	4.9 – 5.5	None	32
Cherokee County	1.5 – 2.1	5.9 – 6.8	None	45
Decatur County	1.6 – 2.1	5.9 – 6.5	None	25
Dekalb County (MO)	2.5 – 3.4	5.7 – 6.8	None	30
Dickinson County	2.3 – 3.8	6.1 – 7.4	None	40
Ellis County	1.5 – 3.4	5.9 – 8.3	None - High	90
Gove County	2.2 – 3.3	5.9 – 7.0	None	24
Hodgeman County	1.6 – 2.2	6.1 – 7.3	None	9
Saline County	1.9 – 2.8	NA	NA	32

Table 2. Relationship Of Mehlich 3 Colorimetric and ICP Determinations With Bray P1 Soil Test Values		
Location	**Regression Equation**	**R^2**
Brown	M3-Col = 0..68 BP + 2.3	0.43
	M3-ICP = 0.83 BP + 8.8	0.36
Clay	M3-Col = 0.95 BP + 1.5	0.84
	M3-ICP = 0.95 BP + 10.2	0.63
Cherokee	M3-Col = 1.48 BP - 3.7	0.83
	M3-ICP = 1.65 BP - 1.6	0.87
Decatur	M3-Col = 0.96 BP - 0.6	0.65
	M-3 ICP = 1.07 BP + 5.0	0.61
Dekalb (MO)	M3-Col = 0.72 BP + 0.6	0.51
	M3-ICP = 0.74 BP + 7.1	0.34
Dickinson	M3-Col = 1.29 BP - 2.2	0.99
	M3-ICP = 1.34 BP + 1.3	0.99
Ellis (with CaCO3 soils)	M3-Col = 0.72 BP + 13.9	0.79
Ellis (with CaCO3 soils)	M3-ICP = 0.82 BP + 20.0	0.84
Ellis (w/o CaCO3 soils)	M3-Col = 0.85 BP + 8.0	0.85
Ellis (w/o CaCO3 soils)	M3-ICP = 0.93 BP + 15.1	0.84
Gove	M3-Col = 0.80 BP + 5.7	0.76
	M3-ICP = 0.92 BP + 12.5	0.78
Hodgeman	M3-Col = 0.91 BP + 2.5	0.75
	M3-ICP = 1.21 BP + 4.3	0.88
Saline	M3-Col = 0.90 BP + 12.2	0.68
	M3-ICP = 1.00 BP + 13.8	0.71

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