Evaluation of soil extractants on sandy soils with high calcium concentrations in southern Florida

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Abstract
Acidic soil extractants (Mehlich 1 and 3) were found to overestimate plant available soil P in soils with conditions that lead to P precipitaiton (i.e. pH > 7.0 and Ca > 1500 mg/kg). Bray and AB-DTPA are found to extract soil P concentrations similar to water and carbonate extractable soil P concentration and Olsen underestimated water and carbonate extractable soil P. Numerically, extracted soil P concentrations using higher soil to extractant ratios values were not significantly greater for Mehlich 1 and 3 but were significantly greater for Bray, Olsen, and AB-DTPA. Therefore, a conclusion of this study is that current soil to extractants ratios for Bray, Olsen and AB-DTPA are inadequate in soils with high soil pH and Ca concentrations and should be increased to extract soil P more representative of plant available P concentrations.

Key Words
Sandy soil, calcium, Florida.

Introduction
The C-139 Basin (C-139) consists of 170,000-acres of agricultural land in eastern Hendry County, Florida, USA that drains into the Everglades, an ecologically sensitive region at the southern tip of Florida. Crops in the area have traditionally consisted of pasture, sugarcane, and citrus; however, recent trends show that vegetable production is beginning to dominate. Movement of excess fertilizer nutrients (e.g. phosphorus) from agricultural fields has been found to increase eutrophication of sensitive water bodies.

Soils in the C-139 are sandy mineral soil (>95 % sand), predominantly Spodosols, which have low organic matter (< 3 %) and low nutrient retention capacity above the Bh or spodic horizon which is typically less than 1 m below the soil surface. After many years of vegetable production the sandy horizons above the spodic horizon in the C-139 have increased soil pH (>7.3) and have high Ca concentrations (>1500 mg/kg). Fertilizer P goes into soil solution and is initially available for the crops. However, P in solution quickly forms water insoluble precipitates in soil with high soil pH and high Ca concentrations. Phosphorus from P-Ca precipitates are not readily available to crop plants and P from these precipitates is dissolved very slowly in water, and only in water with low soluble P concentrations. Thus, once formed, P from P-Ca precipitates may take many years to dissolve into the soil solution.

Standard soil test methods developed for agriculture have been used to assess environmental risk of P loss from soils. Application of soil test P as an environmental indicator requires additional calibration to specific soil types. Best management practices (BMP) should be used in vegetable production to maximize crop yields and quality while minimizing loss of nutrients to the environment. One BMP is that soil be tested each year to determine the need for P applications to maintain production levels (soil test P index). Current soil test P index for vegetables of high = P concentration >30 mg/kg was determined for soils with pH values under 7.0 and with relatively low Ca levels. A portion of the extractable P detected by acidic soil test extractants come from insoluble P-Ca precipitates and are not available to crop plants. Use of specific soil extractants should be based on soil chemical reactions. The University of Florida/IFAS has been utilizing Mehlich-1 results to base P recommendations, however, Mehlich-1 method is known to be appropriate for acidic soils (pH< 7.0) only, which typically not the case for soils found in the C-139. Bray and Olsen extractants are typically used for soils high in Ca (pH>7.0), and Olsen is most used for alkaline soils. Therefore, there is a need to compare and/or determine the best soil P test method on which the growers can base their P application recommendations.

It has been determined that crops in the C-139 basin benefited from added fertilizer P even at soil P indices of high and very high. Soils on commercial farms in the C-139 basin commonly have extractable P concentrations greater than100 mg/kg and can be in excess of 300 mg/kg. To better evaluate current soil test

P indices, a field research project was initiated that evaluates selected soil extractants including extractants used in other states with similar soil pH and Ca concentration found in the C-139 basin. The goals of this project are to 1) determine the affect of initial soil P concentrations and fertilizer P applications on crop growth and yield in the C-139 Basin, 2) determine the most appropriate soil test for soils in the C-139 Basin, and 3) evaluate crop growth and yield to determine indices for selected soils.

Results

To determine the most effective soil extractant for use in soil test P index for soils in the C-139 Basin samples collected from commercial farms were extracted with Mehlich 1, Mehlich 3, Olsen, Bray and AB-DTPA using standard soil to extractant ratios. Soil P concentrations using each extractant were correlated with soil P concentrations using Mehlich 1, the current standard soil test extractant in the state of Florida. As one would predict, Mehlich 3 correlated closest to Mehlich 1 due to the similar chemistries among the two extractants. Regression analysis indicated that Mehlich 3 recovered less P than Mehlich 1 at soil concentrations of P greater than 125 mg/kg. The other selected extractants correlated less closely to Mehlich 1 in the following order Bray > AB-DTPA > Olsen. The ratio of extractable P using Mehlich 1 compared with Mehlich 3, Bray, and Olsen were 1:0.77, 1:0.85, and 1:0.12, respectively. It was also determined that the maximum extractable soil P concentrations was 250 mg P/kg for Mehlich 1 using current recommended extractant to dry soil ratios (1:4). Ratios were determined for each extractant to extend the rage of these extractable soil P tests to 600 mg/kg. Optimum soil to extractant ratios were 1:4, 1:20, 1:40, 1:50 and 1:30 for Mehlich 1, Mehlich 3, Bray, Olsen and AB-DTPA, respectively.

Sequential analysis of a soil is an effective tool in determining the availability of P to crop plants. The sequential analysis procedure determines the amount of P in a soil as increasingly less available forms of P. The most readily plant available form of P in the soil is water soluble P followed by carbonate extractable forms. These two fractions were used to represent labile soil P (water soluble) and marginally available P (carbonate extractable). Soil P results using the five soil extractants (Mehlich 1, Mehlich 3, Olsen, Bray, and AB-DTPA) at standard ratios were compared with water soluble and carbonate extractable soil P (Table 1). These results provided more insight into the correlation the selected extractants and the plant availability of P in soil solution. Mehlich 1, Mehlich 3 and Bray extracted more soil P than is water soluble P. Whereas, both AB-DTPA and Olsen extracted less soil P compared with water soluble P. Mehlich 1 and Mehlich 3 extracted similar to slightly lower P concentrations when compared with the sum of water soluble and bicarbonate extractable P. Bray, AB-DTPA and Olsen extracted lower soil P concentrations compared with water and bicarbonate extracted soil P. Soil extracted P concentrations at higher (test) soil to extractant ratios found extracted soil P concentrations were not significantly greater for Mehlich 1 and 3 but were significantly greater for Bray, Olsen, and AB-DTPA when compared with the currently recommended ratios (Table 1). It was determined that Bray extracts simular amounts of P compared with water and carbonate extracted forms using the increased soil to extractant ratios. AB-DTPA and Olsen etracted more soil P than water extraction when the increased soil to extractant ratios were used.

Conclusions

Acidic soil extractants (Mehlich 1 and 3) were found to overestimate plant available soil P in soils with conditions that lead to P precipitaiton (i.e. pH > 7.0 and Ca > 1500 mg/kg). Bray and AB-DTPA are found to extract soil P concentrations similar to water and carbonate extractable soil P concentration and Olsen underestimated water and carbonate extractable soil P. Numerically, extracted soil P concentrations using higher soil to extractant ratios values were not significantly greater for Mehlich 1 and 3 but were significantly greater for Bray, Olsen, and AB-DTPA. Therefore, a conclusion of this study is that current soil to extractants ratios for Bray, Olsen and AB-DTPA are inadequate in soils with high soil pH and Ca concentrations and should be increased to extract soil P more representative of plant available P concentrations.

Future Research

Correlations between extracted P concentrations with the selected extractants and crop yield using several seasons of crops will be used to indicate appropriate P index values for soils in the C-139 basin with high Ca concentrations and soil pH. Extractable P data and crop yield will be used to develop appropriate soil P index values for each crop. This project will ultimately provide information on better use of existing soil P in soils with high Ca concentrations that will reduce leaching potential of P to surface water bodies.

Table 1. Soil extracted Phosphorus with Melich 1, Mehlich 3, Bray, Olsen and AB-DTPA compared with water and carbonate extractable soil P at standard and test soil to extractant ratios. Range of soil P concentrations are ± one standard error.

Extractant	Water + Carbonate Extractable P (mg/kg)	Standard Ratio	Phosphorus Concentration (mg/kg)	Test Ratio	Phosphorus Concentration (mg/kg)
Mehlich 1	70	1:4	69.2 ± 9.72	1 : 40	74.8 ± 3.38
Mehlich 1	150	1:4	139.4 ± 6.52	1 : 40	160.9 ± 35.16
Mehlich 1	370	1:4	431.2 ± 2.93	1 : 40	441.2 ± 16.27
Mehlich 3	70	1:10	43.6 ± 1.78	1 : 40	49.5 ± 5.47
Mehlich 3	150	1:10	124.1 ± 5.31	1 : 40	153.3 ± 7.77
Mehlich 3	370	1:10	362.4 ± 14.49	1 : 40	375.7 ± 43.62
Bray	70	1:10	48.1 ± 1.14	1 : 40	53.8 ±3.16
Bray	150	1:10	124.5 ± 4.58	1 : 40	137.1 ± 6.88
Bray	370	1:10	316.6 ± 9.27	1 : 40	369.4 ± 65.07
Olsen	70	1:10	13.6 ± 0.52	1 : 50	20.1 ± 1.19
Olsen	150	1:10	28.7 ± 1.20	1 : 50	50.1 ± 2.37
Olsen	370	1:10	63.2 ± 7.66	1 : 50	88.3 ± 3.27
AB-DTPA	70	1:2	18.4 ± 0.11	1 : 30	37.1 ± 6.67
AB-DTPA	150	1:2	47.9 ± 0.85	1 : 30	89.1 ± 5.81
AB-DTPA	370	1:2	79.7 ± 1.53	1 : 30	268.5 ± 42.15