UF IFAS Extension
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SL400

Comparison of Soil Test Extractants for Available Soil Phosphorus in High pH Sandy Soils of South Florida[1]

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Introduction

This document addresses the selection of soil nutrient extractants in high pH soils and discusses their relationship to both nutrition and fertilizer management. This document's objective is to describe the impact of selected soil extractants on nutrient management and their ability to determine soil phosphorus availability.

The target audience for this series dealing with citrus nutrition includes Certified Crop Advisers; citrus, vegetable and sugarcane producers; fertilizer dealers; and other parties interested in crop fertilization practices.

With the exception of organic soils in the Everglades Agricultural Area and mineral soils in Miami-Dade County, soils used for citrus, vegetable, and sugarcane production in south Florida are sandy in the upper 18 inches. These sandy soils are typically low in water- and nutrient-holding capacities, and they have low organic matter content. During the past 50 years in south Florida, soil pH has increased to levels greater than 6.5 with high to very high concentrations of calcium (Ca) because of irrigation and repeated lime applications. Many farms containing these sandy soils border the Everglades Agricultural Area and ultimately drain into the Everglades. The Everglades Forever Act mandates that landowners ensure water leaving the agricultural areas does not exceed well-defined phosphorus (P) loads. Agricultural producers are required to implement best management practices (BMP) to maintain long-term economic viability, while fostering environmental stewardship.

Because of the hydrological characteristics of south Florida's sandy soils, many agricultural producers rely largely on seepage irrigation from elevated water tables. These elevated water tables, combined with the sandy soils' low nutrient-holding capacity, increase the leaching potential of nutrients from these soils.

Fertilizer can be a large production cost to most farmers. Unfortunately, nutrients (including P) can also be major contributors to groundwater contamination. Management strategies, such as soil testing, should be used as a BMP in vegetable production to maximize crop yields and quality, while minimizing nutrient loss to the environment. Nitrogen concentrations in soil are typically not determined because this element leaches so readily and does not accumulate in sandy soils. Nitrogen, therefore, must be replaced each year for optimum production.

Soil should be tested each year to determine the amount of P required to maintain high production levels. Nitrogen and P move at different rates in the soil based on their affinity for soil particles and soil water content. However, once these elements reach the groundwater, they can move off the farm by mass flow as water enters ditches. Large quantities of P reach the water table and impact off-site surface

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water bodies. The dynamics of soil P must be understood to determine the fertilizer application's environmental impact.

High soil pH and large quantities of iron, aluminum, and/or calcium cause soluble P applied as fertilizer to precipitate out of the soil solution through time, making it unavailable to crops. Therefore, those growing on high pH soils must apply large quantities of P to maintain crop production and to compensate for the binding of P in these soils. If P is not provided, then crops can become deficient, resulting in reduced yields and stunted plants with drooping, curled, and purple leaves. Soluble P that has not been transformed into insoluble precipitates is vulnerable to leaching. 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.

From 2008 to 2011, we conducted a demonstration project to evaluate the ability of common soil extractants used by commercial soil testing laboratories to accurately extract P from soils with high pH and calcium carbonate. Several different soil tests for P were used to estimate available P (e.g., Mehlich-1, Mehlich-3, Bray, Olsen, and AB-DTPA).

Mehlich-1 is a soil test extractant containing two acids (hydrochloric and sulfuric acids) and is sometimes called a double acid extraction. The strong acids dissolve nutrients in the soil that would normally be available to plants in acidic soils and are only appropriate for acidic soils (pH less than 6). UF/IFAS has been using the results to base P recommendations, but it is considering using Mehlich-3 extractant, which is highly buffered compared with Mehlich-1 and can be used with a wider range of soil pH. Bray and Olsen extractants are typically used for alkaline soils (pH greater than 7). Olsen, a relatively new extractant that determines available nutrients in neutral and calcareous soils, is mostly used for soils high in Ca ammonium bicarbonate. Olsen was also used in our study. Therefore, we needed to compare and/or determine the best soil P test method for growers to use as a base for their P application recommendations.

For example, at a pH less than 7, P will be readily soluble, and most extractants should extract P amounts close to the P amount available for plant uptake. However, in soils with high Ca concentrations and a pH greater than 7, an increasing portion of soil P will precipitate in the form of various calcium phosphate compounds. These compounds dissolve in acidic solutions, but they are not available for plant uptake. Therefore, the relationship among soil extractants must be determined, so soil test results using the various extractants can be compared with one another. A representative soil-test P index can also be determined for soils with elevated pH and calcium content. The soil-test P index is the amount of P in the soils at which additional P application would not be necessary to obtain optimal and realistic yields.

Most soil extractants use standard extractant to soil ratios of 10:1 or less (10 ml of solution per gram of soil), and they are typically used on soils with less than 200 mg kg^{-1} of extractable soil P. Initial results with the five test extractants indicated that extractable soil P concentrations did not increase with increasing water- and bicarbonate-extractable P greater than 300 mg kg^{-1}, when the extractant to soil ratio was 10:1 or less. The lack of correlation with increased soil P suggested the standard ratio was not reliable at extractable soil P concentrations greater than 300 mg kg^{-1}. The ratios found in Table 1 for Mehlich-1 (M1), Mehlich-3 (M3), Bray, Olsen, and AB-DTPA should be used.

The sequential analysis procedure determines the amount of P in a soil at increasingly less available forms of P. The most readily available form of P is water soluble, or hydroxide soluble, followed by bicarbonate extractable forms. However, not all water and bicarbonate P forms are readily available to the plant. These soil P forms are considered partially plant available sources. Thus, extractants providing soil P concentrations at or slightly greater than the sum of water- and bicarbonate-extractable P, approach the amount of P available to plants with some level of overestimation. Figure 1 illustrates the relationship between Mehlich-1-extractable P and water-extractable P for the five farms used in our study. The line in the figure indicates a 1:1 ratio between the two extractions. Thus, if the Mehlich-1 solution extracted only water-extractable P, the data would fall on the 1:1 line. It can be observed under the demonstration soil characteristics that the majority of data points for all farms are above the 1:1 line, indicating Mehlich-1 overestimates water-extractable P. Mehlich-3, Bray, and AB-DTPA also overestimate water-extractable P. Contrary to the other extractants, Olsen underestimates water-extractable P (Figure 2).

The results indicate that current soil P test using Mehlich-1 may not accurately represent available soil P in soils with high pH and Ca concentrations because of reduced P availability. Sequential analysis of soils with apparent soil P precipitation by Ca indicates the water and bicarbonate soluble forms are most available to tomato plants. Tests comparing sequential analysis results and extractable soil P indicate that all common soil P test extracts overestimated available soil P when compared with water and bicarbonate soluble forms of soil with pH greater than 7.2.

However, all extracts worked well in soil with P less than 300 ppm, Ca less than 1500 ppm, and pH less than 7.2. The

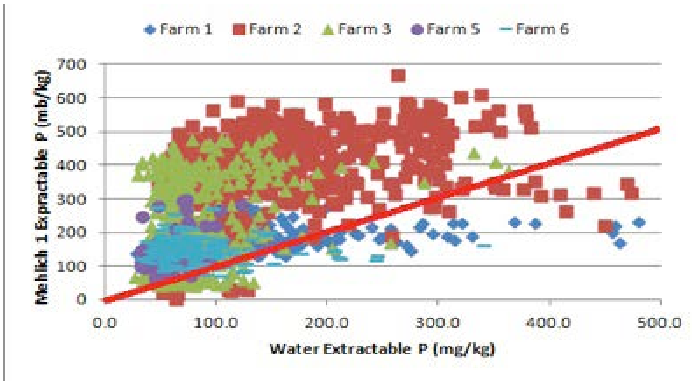

Figure 1. Water-extractable P for five farms in demonstration compared with Mehlich-1-extractable P. Note that water-extractable P above the red 1:1 ratio line indicates an overestimation of water extractable P by Mehlich-1.

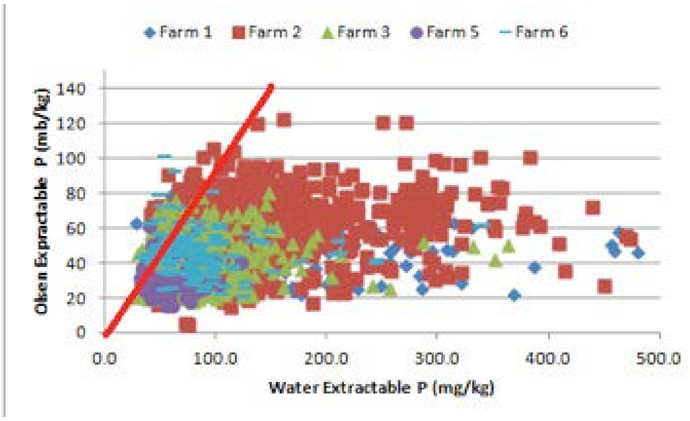

Figure 2. Water-extractable P for five farms in demonstration compared with Olsen-extractable P. Note that water-extractable P above the red 1:1 ratio indicates an underestimation of water-extractable P by Olsen.

Mehlich-1, Mehlich-3, and Bray provided results similar or greater than available P. Thus, Olsen and AB-DTPA may provide better numbers for soil test P indexing.

Table 1. Soil Extractant Ratios[1]

Extractant	P Concentration Category	P Conc. (mg kg^{-1}) Standard Ratio	Optimum Ratio	P Conc. (mg kg^{-1}) Optimum Ratio
M1	Low	59.9 ± 3.86	1:40	70.4 ± 4.88
M1	Low	69.2 ± 9.72	1:40	74.8 ± 3.38
M1	Medium	134.3 ± 5.17	1:40	162.7 ± 26.84
M1	Medium	139.4 ± 6.52	1:40	160.9 ± 35.16
M1	High	431.2 ± 2.93	1:40	441.2 ± 16.27
M1	High	364.8 ± 33.66	1:40	409.0 ± 52.81
M3	Low	43.6 ± 1.78	1:40	49.5 ± 5.47
M3	Low	46.5 ± 1.60	1:40	53.4 ± 3.34
M3	Medium	124.1 ± 5.31	1:40	153.3 ± 7.77
M3	Medium	128.1 ± 8.06	1:40	141.9 ± 12.37
M3	High	362.4 ± 14.49	1:40	375.7 ± 43.62
M3	High	326.9 ± 8.74	1:40	378.2 ± 18.06
Bray	Low	37.7 ± 1.76	1:40	48.5 ± 1.36
Bray	Low	48.1 ± 1.14	1:40	53.8 ±3.16
Bray	Medium	124.5 ± 4.58	1:40	137.1 ± 6.88
Bray	Medium	113.0 ± 5.35	1:40	117.5 ± 1.01
Bray	High	316.6 ± 9.27	1:40	369.4 ± 65.07
Bray	High	317.0 ± 33.48	1:40	345.1 ± 20.65
Olsen	Low	11.6 ± 0.18	1:50	16.3 ± 2.22
Olsen	Low	13.6 ± 0.52	1:50	20.1 ± 1.19
Olsen	Medium	28.7 ± 1.20	1:50	50.1 ± 2.37
Olsen	Medium	29.0 ± 2.74	1:50	46.9 ± 1.13
Olsen	High	63.2 ± 7.66	1:50	88.3 ± 3.27
Olsen	High	48.0 ± 3.54	1:50	72.8 ± 3.63
AB-DTPA	Low	15.6 ± 0.30	1:30	33.1 ± 0.92
AB-DTPA	Low	18.4 ± 0.11	1:30	37.1 ± 6.67
AB-DTPA	Medium	47.9 ± 0.85	1:30	89.1 ± 5.81
AB-DTPA	Medium	45.5 ± 0.32	1:30	72.3 ± 0.88
AB-DTPA	High	79.7 ± 1.53	1:30	268.5 ± 42.15
AB-DTPA	High	53.0 ± 0.51	1:30	198.5 ± 8.99