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Managing Phosphorus Fertilization of Citrus using Soil Testing[1]

Thomas A. Obreza[2]

Introduction

The purpose of this publication is to provide a brief review of phosphorus (P) fertilization practices in citrus production and the use of soil testing in citrus P fertilization, and to outline a comprehensive soil test P calibration experiment being carried out in the flatwoods of southwest Florida.

Background on Florida Citrus and Phosphorus

Phosphorus fertilizer is regularly applied to Florida citrus, ranging from annual applications in young orchards to applications of up to 100 lbs P_2O_5/acre every 1 to 4 years in bearing orchards. However, numerous worldwide field experiments have shown that a positive citrus response to applied P is rare. In the late 1950s and early 1960s, a series of experiments conducted near Lake Alfred showed that P fertilizer applications improved growth of young citrus trees planted on a previously non-fertilized deep sandy soil, but no yield response to applied P occurred in bearing Valencia orange groves where P fertilizer had been applied when the trees were young (Table 1).

In another 1960s P fertilizer trial, Valencia orange yield response to P fertilizer was observed in 3 out of 5 years in a grove where soil-test P was near the accepted “minimum adequate level” (Table 2). This observation emphasizes the need for a properly-calibrated P soil test for citrus.

Excessive P can adversely affect citrus growth and development, especially fruit quality. High P fertilization has lowered juice soluble solids concentration and caused delayed external color development and re-greening of oranges. On the positive side, adding plant-available P to the soil was shown to promote citrus root growth.

There is some evidence that P concentrations in various south Florida surface water bodies have increased with time. In soils that have a high capacity to hold P (a process called *P adsorption*), P is transported primarily with eroding sediment. However, acidic south Florida flatwoods soils composed of quartz sand grains that are not coated with aluminosilicate or metal oxide clays have little capacity to retain P (Table 3).

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2. Thomas A. Obreza, Professor, Soil and Water Science Department, Southwest Florida Research and Education Center, Immokalee, FL, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL 32611.

Studies of the P retention capacity of flatwoods soils used for citrus production have shown that the surface soil (A horizon) and the sub-surface organic hard pan (Bh horizon) of poorly-drained soils can adsorb a substantial amount of P, but P adsorption by the E horizon (the light-colored layer in between the A and Bh layers) is almost zero. Similarly, it was found that a typical flatwoods citrus soil with a subsurface loamy layer (Bt horizon) had low P sorption capacity in the upper sandy layers (Table 4), and P mobility through it was relatively high.

In another study, application of P fertilizer increased P concentration in the soil water much more above the Bt horizon than below it (Table 5). Thus, soil water moving from the A horizon through the E horizon to the top of the Bt horizon may be a potential P source to surface waters. It is likely that P can be transported in soluble forms via lateral seepage through the E horizon of flatwoods soils used for citrus production, and may impact the quality of adjacent surface water. Soil test calibration relates crop response to the amount of plant nutrient that a particular chemical solution (the "extractant") removes from the soil. A properly calibrated soil test identifies the degree of deficiency or sufficiency of an element, and identifies how much of the element should be applied to meet the cultivated crops needs. Florida researchers last attempted to calibrate a P soil test for citrus about 40 years ago, but the derived critical values of soil test P were not determined through the classical calibration procedure. Field experiments were conducted in commercial citrus orchards, and little or no response to P fertilizer was observed (Table 1). The lowest soil test values measured in these groves were 11, 40, and 65 ppm P by the ammonium acetate (pH 4.8), Bray P1, and Bray P2 tests, respectively. It was concluded that soils that test higher than these (critical) values probably do not need immediate P fertilizer addition.

Soil test data from Florida citrus groves reflect the ability of most surface (root zone) soils to retain applied P to some extent. For example:

- At the start of the P fertilizer experiment shown in Table 2, Bray P1 soil test was 44 ppm P, but increased to 100 ppm following 8 consecutive years of fertilization with 120 lbs P_2O_5/acre.

- An exercise designed to compare soil extractants found soil test P values of 20 to 59 ppm (Bray P1) and 40 to 92 ppm (Mehlich 1) in mature citrus orchards planted on central Florida ridge soils. The "medium" range of Mehlich 1 soil test P for Florida crops is 16 to 30 ppm.

- A survey of 122 Florida citrus production blocks on poorly-drained flatwoods soils found an average Mehlich 1 soil test P of 55 ppm in the top 6 inches of soil.

- A study of Mehlich 1-extractable P in citrus soils from 118 groves across Florida found a mean value of 103 ppm in the surface 6 inches.

- Mehlich 1 soil test P increased from 15 to 70 ppm in a newly-planted flatwoods citrus grove where a total of 300 lbs P_2O_5/acre was applied in the first 3 yrs after planting.

The University of Florida/IFAS Extension Soil Testing Laboratory uses the Mehlich 1 extractant, but a specific calibrated P test to guide Florida citrus fertilization does not exist. The critical value of Mehlich 1-extractable P currently used for Florida citrus (30 ppm) was determined from field experiments with annual agronomic and horticultural crops. Environmental concerns regarding P movement to surface water and grower concerns regarding nutritional effects on fresh citrus fruit quality emphasize the importance of judiciously using P fertilizer. An experiment described below is underway to calibrate a P soil test for Florida citrus production using the Mehlich 1 extractant, considering tree growth, yield, and fruit quality of Flame grapefruit and Hamlin orange as response variables in the calibration process.

Field Experiment

A field experiment was initiated in south Florida to calibrate a P soil test for Florida citrus using classical methodology. The soil, Immokalee fine sand, had an organic hard pan about 3 feet below the surface. The surface sandy soil had less than 10 ppm Mehlich 1-extractable P in the top 8 inches when the citrus trees were planted in November, 1997.

Field plots were fertilized in October 1998, May 1999, and March 2000 with four rates of P (0, 50, 100, and 200 lbs P_2O_5/acre) using concentrated superphosphate fertilizer. All trees received the UF/IFAS recommended N and K_2O rate each year, and the grove was irrigated with one micro-sprinkler under each tree. All fertilizer was applied broadcast to the herbicide band beneath the tree rows. Soil was sampled to a depth of 8 inches in each plot in August 1998, February 1999, August 1999, and August 2000 and was tested for P using the Mehlich 1 extractant to determine the effect of P fertilizer rate on soil-test P.

Soil Test Results

Applying a range of P fertilizer rates induced a wide range of Mehlich 1 soil-test P values (Figure 1). According to current UF/IFAS soil test interpretations, plots where no P was applied remained in the "very low" range after 2 years, while plots that received 50 or 100 lbs P_2O_5/acre/year were in the "high" range, and plots that received 200 lbs P_2O_5/acre/year were in the "very high" range. Therefore, it appears that Immokalee fine sand in its native state has at least some short-term adsorption capacity for P at the surface.

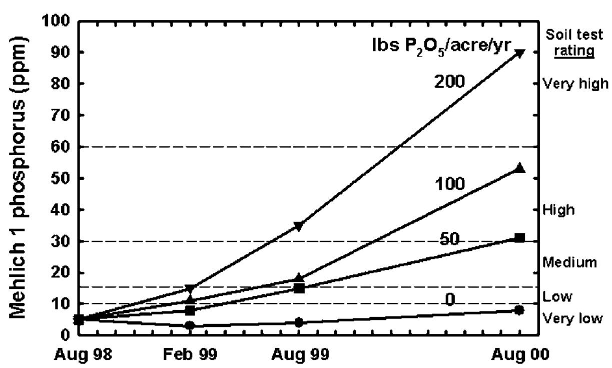

Figure 1. Effect of 3 years of P fertilization in a new citrus grove on Mehlich 1 soil test P (top 8 inches of soil).

Immokalee fine sand contains more than 94% sand throughout the profile, with almost no clay above the hard pan (Bh horizon) (Table 6). Therefore, inorganic coatings like aluminum or iron oxides that could adsorb P do not appear to be present in significant quantity in the A and E horizons. This observation is further supported by the lack of yellow or orange coloring on the sand grain surfaces, which would be typical of sands coated with metal oxide clays. It is likely that P adsorption (hence the increased soil test values) was due to organic matter colloids and coatings on sand in the top 6 inches of soil (Table 6). Since the E horizon contained low concentrations of both clay and organic matter, it is also likely that P would not be adsorbed there.

Conclusions

Upon completion of this field experiment, citrus grove managers will have better soil test interpretations for determining P fertilizer needs, so nutrient input costs can be more appropriately allocated. The citrus industry will minimize its impact on surface water quality because P fertilizer rates will be able to be adjusted by taking into account residual soil P measured by soil testing. In addition, grove managers will gain a more comprehensive understanding of the effect of P on fresh fruit quality, which will lead to higher-quality fruit production.

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Table 1. Effect of P fertilizer on yield of Valencia oranges during a 4-year period in three experiments. Soil tests showed that P had accumulated in the soil from previous fertilizer applications (Data from Spencer, 1963.)

Season	Experiment 1		Experiment 2		Experiment 3	
	lbs P_2O_5/acre					
	0	120	0	120	0	120
	Orange yield, boxes/tree					
1958-59	3.5	3.4	6.1	6.3	---	---
1959-60	7.9	7.6	5.2	5.5	3.8	3.9
1960-61	3.4	3.4	4.5	4.3	3.0	3.1
1961-62	6.2	6.7*	6.1	6.8*	3.6	3.8
Mean	5.3	5.3	5.5	5.7	3.4	3.6

* Statistically higher yield compared with the zero P treatment.

Table 2. Effect of P fertilizer on yield of Valencia oranges during a 5-year period in two experiments. (Data from Anderson, 1966.)

Experiment	Treatment	1961	1962	1963	1964	1965	Mean
		Orange yield, boxes/tree					
1	- P	5.7	3.8	3.2	5.6	6.6	5.0
1	+ P	6.5*	4.1	4.7*	5.9	8.0*	5.8*
2	- P	6.2	4.5	4.8	4.9	4.7	5.0
2	+ P	7.0*	4.4	5.1	5.3	5.6	5.5

* Statistically higher yield compared with the – P treatment.

Table 3. Effect of sand grain coatings and other soil properties on the relative P adsorption capacity (RPA) of several Florida soil groups. The RPA can range from 0 to 1; the P adsorption capacity of a soil increases as RPA increases. (Data from Harris et al., 1996).

Soil type	Horizon	Silt %	Clay %	Organic matter %	*RPA
Flatwoods sand	A (surface)	4.2	1.9	4.6	0.26
	E (light-colored sub-surface horizon)	3.4	1.2	0.3	0.08
	Bh (organic hard pan)	5.7	4.2	5.4	0.96
"Clean" (uncoated) sand	A (surface)	0.5	0.4	0.7	0.05
	C (sub-surface)	0.3	0.3	0.1	0.01
"Slighty-coated" sand	A (surface)	1.3	1.8	1.3	0.48
	C (sub-surface)	1.5	1.7	0.2	0.47
"Coated" sand	A (surface)	4.0	2.1	1.7	0.54
	C (sub-surface)	3.8	3.5	1.0	0.60

Table 3. Effect of sand grain coatings and other soil properties on the relative P adsorption capacity (RPA) of several Florida soil groups. The RPA can range from 0 to 1; the P adsorption capacity of a soil increases as RPA increases. (Data from Harris et al., 1996).

Soil type	Horizon	Silt %	Clay %	Organic matter %	*RPA

* Relative P adsorption capacity.

Table 4. Effect of Riviera find sand soil characteristics on P sorption capacity as measured by sorptivity. (Data from He et al., 1999).

Depth inches	Horizon	Organic matter %	pH	Sand %	Silt %	Clay %	Sorptivity L/kg
0-6	A	1.7	7.5	96	3	1	2.9
6-12	E	1.3	7.6	99	3	1	3.5
12-24	E	1.1	7.5	98	1	1	1.0
24-35	E	0.7	7.4	98	1	1	8.4
35-47	Bt	0.8	7.5	77	1	22	17.8
47-59	Bt	0.5	7.5	82	1	17	14.5

* The higher the sorptivity, the greater the P adsorption capacity.

Table 5. Average concentrations of P in the soil water sampled above and below the loamy layer of a Riviera fine sand. (Data from He et al., 1999).

Fertilizer application method	P fertilizer rate	Average soil solution P concentration	
		Above Bt horizon	Below Bt horizon
	lbs P_2O_5/acre/year	ppm	ppm
Control	0	0.03	0.002
Dry granular	20	0.25	0.004
Dry granular	40	0.35	0.03
Dry granular	60	0.53	0.04
Liquid fertigation	20	0.37	0.01
Liquid fertigation	40	0.81	0.04
Liquid fertigation	60	0.98	0.08

Table 6. Physical characteristics of Immokalee fine sand.

Depth inches	Horizon	Sand %	Silt %	Clay %	Organic matter %
0-6	A	97	2	1	1.6
6-14	E	98	1	1	0.2
14-37	E	98	2	0	0.1
37-60	Bh	94	5	1	3.8
60-80	Bh	95	2	3	2.6