

Laboratory Estimates of Soil P Buffer Coefficients: an Example with Soils from Costa Rica

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Background

Soil test-based fertilizer P recommendations for a given crop and soil requires knowledge about (a) the optimum soil test P level for the crop, (b) the existing P level in the soil, and (c) the amount of P which must be added to raise the existing soil P level to the targeted optimum value (Kamprath and Watson, 1980). The last item, the buffer coefficient, provides a measure of the soil's ability to transform added P into forms that are "less plant-available" through sorption and precipitation processes. Lack of knowledge or erroneous predictions of soil-specific buffer coefficients can lead to large over- or under-estimations of fertilizer P required to achieve the optimum soil test P levels.

Investigations were conducted in Costa Rica to develop short-term estimates of soil P buffer coefficients that could be performed in laboratories equipped for routine soil testing procedures. These studies were conducted in 1973 by Dr. Gordon Miner and investigators of the Ministry of Agriculture (MAG) in Costa Rica, as part of the U.S.A.I.D.-funded International Soil Fertility Evaluation and Improvement Program (ISFEIP) (Hunter, 1975).

Methodology

Twenty-one soil samples randomly selected from the MAG soils laboratory were used in the studies. All samples contained less than 15 mg L⁻¹ of Modified Olsen-extractable P and 11 samples had 4 mg P L⁻¹. Although the exact origin of these samples is not known, distribution of dominant soil orders in Costa Rica would suggest that these samples included Andisols, Inceptisols, Vertisols and Ultisols (Figure 1).

Solutions with 17.5, 35, 70, 140, 210, 280, 350, 420 and 560 mg P L⁻¹ (as KH₂PO₄) were added to 2.5 mL samples of each soil at a 1:1 soil

to solution ratio. Samples were stirred and left open to air dry. Under high humidity conditions of Costa Rica, seven days were required to reach air dry conditions. This allowed P reactions to proceed under soil moisture changing progressively from complete saturation to an air dry state. Hopefully, this simulates in a short period the reactions which take place under field conditions. An additional set of samples were dried in a room with a dehumidifier where samples reached the air dry state in two days. Both two and seven day drying times were investigated to evaluate the effect of drying time on extractable P.

Upon completion of the incubations, soil P was measured by a modified Olsen procedure (0.5 N NaHCO₃ + 0.01 M EDTA + 0.1g Superfloc 127 L⁻¹ at pH 8.5; 1:10 soil-solution ratio; 10 minutes shaking at 400 rpm). The 2.5 mL soil volume chosen for these incubation studies matched the soil volume used in the laboratory for soil P analysis, thus enabling the P extraction to be performed without modifications to the routine soil testing procedures. Laboratory procedures allowed detection of P concentrations up to 100 mg L⁻¹ of soil without dilutions. Data for any samples above this concentration were, therefore discarded. For samples used in this study, Mod. Olsen soil P only exceeded this level with solution treatments >280 mg P L⁻¹.

Preliminary inspections of the data revealed that relations between extracted P and added P were linear for all soils. Analysis of variance was performed for each soil with the PROC GLM procedure in SAS (SAS, 1985) to determine whether the interaction term between added P and incubation times was significant. When the interaction term for a given soil was non-significant, this indicated there was no difference among

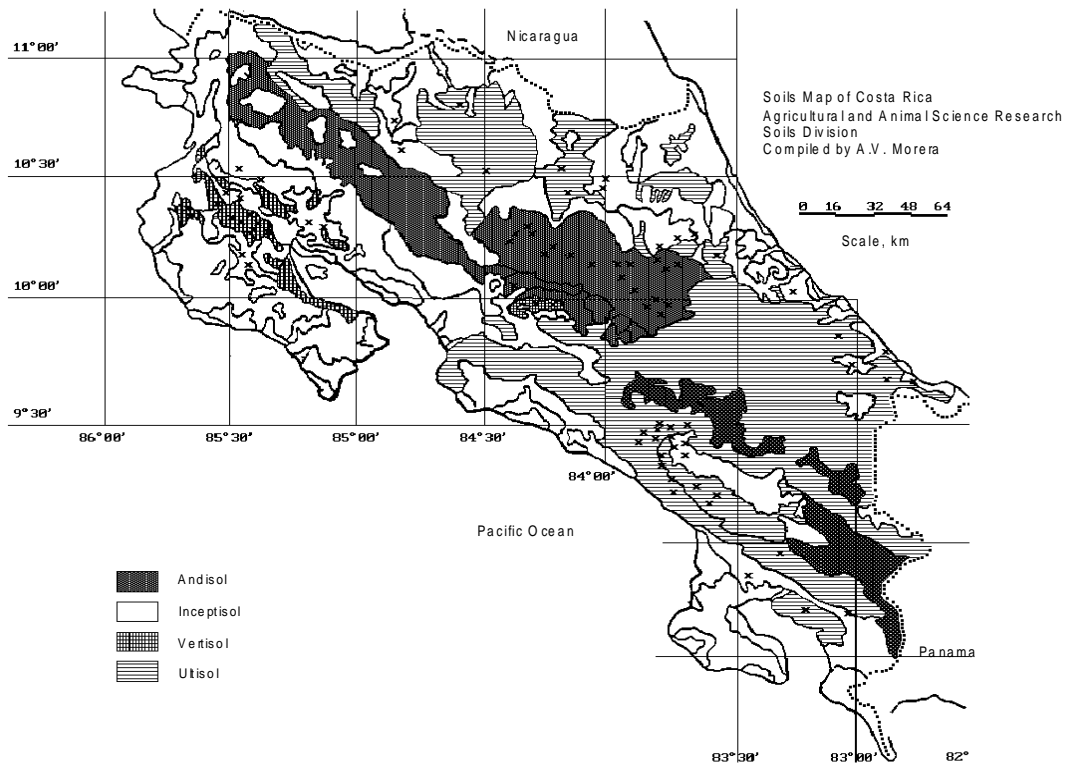


Figure 1. Distribution of dominant soil orders in Costa Rica. (Adapted from Henriques et al., 1991).

incubation times for slopes of the relation between extracted and added P, and linear regressions were developed with pooled data from both 2 and 7-day drying times. Otherwise, linear regressions were developed for each incubation time. A common intercept was assumed for both incubation times in each soil, because Mod. Olsen P at zero or low concentrations of added P deviated by less than 3 mg P L⁻¹ of soil.

Results

There was a linear relation between added P and extractable P in all soils, with r values ranging from 0.97 to 0.99. Linear regression slopes for the relation between added P and extractable P ranged from 0.13 to 0.43 (mg extractable P L⁻¹ of soil/mg added P L⁻¹ of soil). Frequency distribution of these values are shown in Figure 2. Most of the coefficients are concentrated within the range of 0.26 to 0.35.

There was a significant difference in linear regression slopes between 2 and 7 days of incubation in only 6 of the 21 soils. In all soils, except one with questionable data, increased incubation time decreased the proportion of added P that was extracted with the Mod. Olsen solution. Among the

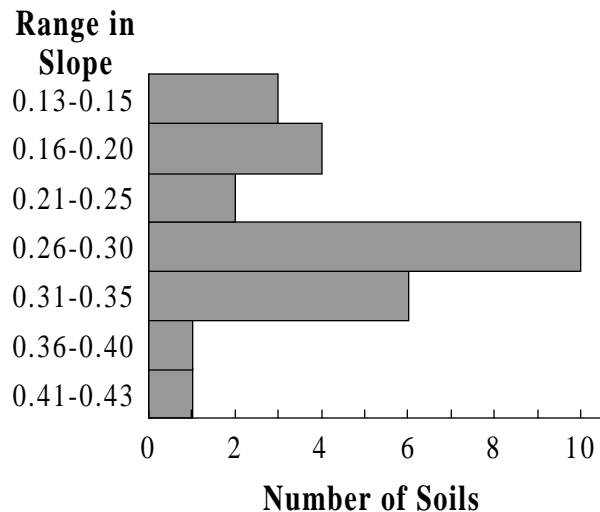


Figure 2. Frequency distribution for P buffer coefficient values among 21 soils from Costa Rica.

5 remaining soils with significantly different slopes for incubation time the maximum reduction in the linear coefficient was 0.07. Examples of incubation time effects are illustrated in Figure 3 for soils representative of low, intermediate and high P sorption capacities.

The importance of a proper estimate of the soil's P buffer coefficient is illustrated in Table 1 for

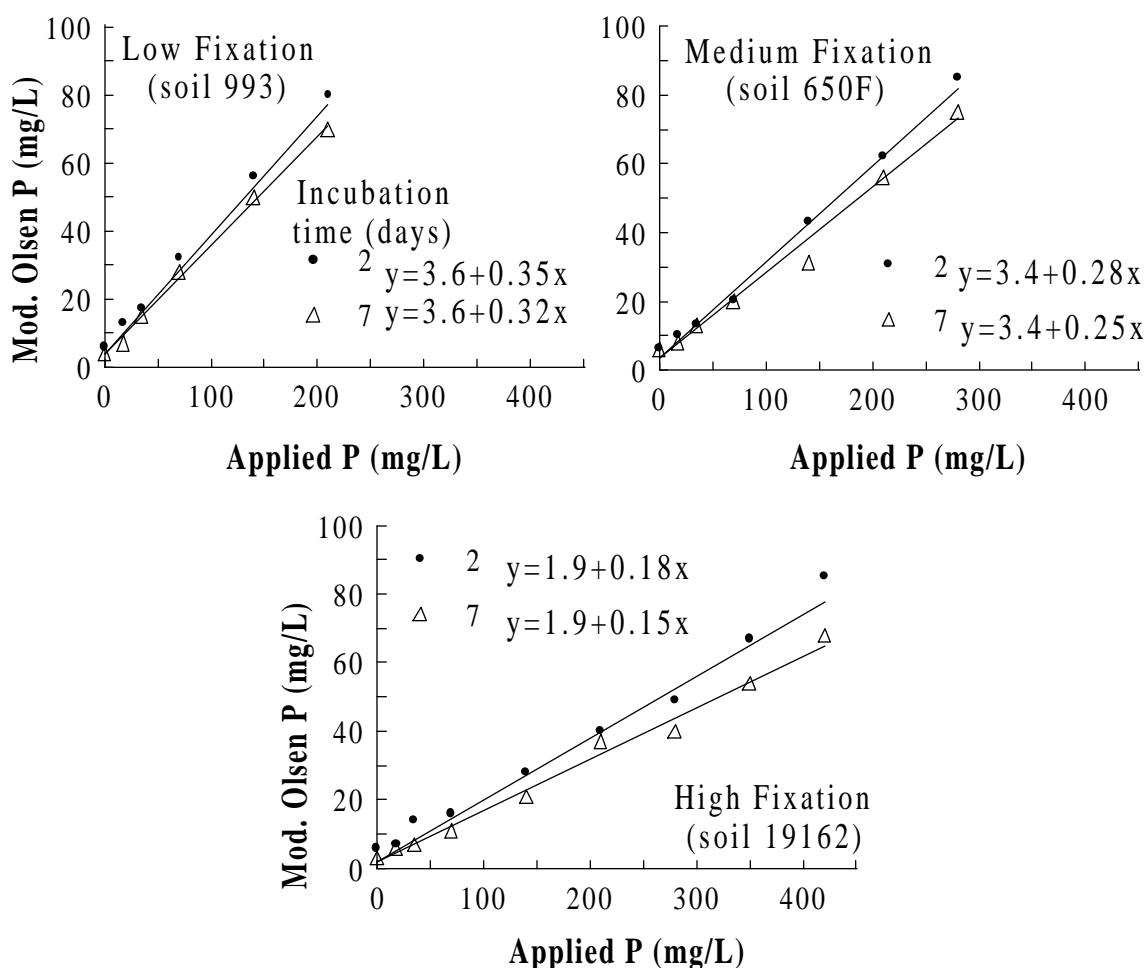


Figure 3. Relations between Mod. Olsen soil P and added P at 2 and 7-day incubation periods for soils from Costa Rica with low, medium and high P fixation capacity.

six soils which initially tested 2 mg P L⁻¹ of soil. Assuming all soils had a bulk density of 1 kg L⁻¹ and fertilizer incorporation to a 0.2 m depth, fertilizer P requirements to raise the Mod. Olsen soil P level to 10 mg L⁻¹ ranged from 53 to 107 kg P ha⁻¹. Obviously, fertilizer P recommendation schemes which fail to properly account for differences in P fixation properties among these soils would have serious economic consequences.

Implications

The procedure for estimating soil P buffer coefficients could be incorporated into routines for a soil testing lab without modifications of existing operations or the need for additional equipment. For soils in Costa Rica a 2-day drying period gave suitable results, implying that routine determination of buffer coefficients would take about three days.

Table 1. Comparison of fertilizer P required to raise Mod. Olsen soil P levels to 10 mg L⁻¹ in six Costa Rica soils which initially contained 2 mg P L⁻¹

SOIL	BUFFER COEF.	REQUIRED FERT. P
		kg ha ⁻¹
613F	0.30	53
612F	0.29	55
614F	0.27	59
17824	0.26	62
1963	0.19	84
18010	0.15	107

Prior to routine use of this method, incubation tests should be made with representative soils and the preferred soil P extracting solution of the laboratory. Depending on soil characteristics and the extracting solution, incubation times may need to be changed and/or the relation between added P and extracted P may be curvilinear. Several investigations have shown that Mehlich 1 and Bray 1 soil extractable-fertilizer P relations deviated from linearity at soil P levels above the optimum for most crops (Cox et al., 1981; Lins and Cox, 1991; Smyth and Cravo, 1990). The ultimate test of the validity of such a procedure would be to determine whether such short-term laboratory estimates of buffer coefficients provide reasonable predictions of coefficients that are obtained from field trials containing various fertilizer P treatments.

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