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Predicting Phosphorus Requirements of Some Hawaii Soils

N. V. Hue, H. Ikawa, and X. Huang—Department of Agronomy and Soil Science

Along with nitrogen and potassium, phosphorus (P) is a nutrient that plants need in relatively large quantities for normal growth. In living organisms, P is a structural component of deoxyribonucleic acid (DNA) and ribonucleic acid (RNA), which are essential for reproduction. Plants and animals derive their internal energy from P-containing compounds, mainly adenosine triphosphate (ATP). Inadequate P supply thus results in a decreased synthesis of RNA—the protein maker—leading to depressed growth. P-deficient plants are stunted, with limited root systems and thin stems. Symptoms in cereals include reduced tillering; corn seedlings look stunted, and older leaves may be purple because of high levels of anthocyanin (purple pigment). Fruit trees deficient in P have fewer and shorter new shoots and malformed fruits and seeds. Thus not only low yields but also poor quality result from P deficiency. Most crops need from 0.2 to 0.5% P in tissue dry matter for normal growth, and P deficiency is likely when the P content drops below 0.1% (Table 1).

While humans and animals obtain P from various food sources, plants must get their P from the soil. Unfortunately, most soils of Hawaii contain high amounts of iron and aluminum oxides or amorphous aluminosilicate clays, which react strongly with P, making it virtually unavailable for plant uptake. When this occurs, acceptable crop production is not possible unless adequate P fertilizers are applied. The key question for growers is: Does the soil need P, and if so, how much? An accurate soil test for P, accompanied by a site-specific, research-based recommendation on the amount of P fertilizer, is needed to answer the question. Excessive P fertilization is counter-productive, wastes money and resources, and may pollute the environment.

CTAHR's Agricultural Diagnostic Service Center (ADSC) recently changed its P analysis procedure from the Rapid Chemical Method to a "research method" known as the Modified Truog Method. It uses a solution of 0.01 M H_2SO_4 + 0.3% $(NH_4)_2SO_4$ at a 1:100 soil:solution ratio, which is shaken 30 minutes to extract phosphorus for analysis. This change has improved soil test precision for P. However, precise fertilizer recommendations are still difficult, since they depend on site-specific, research-based information, ideally based on long-term soil fertility trials conducted on specific soils. Regretably, for many soils in Hawaii, data for "calibration" of the P requirement of particular crops, to establish the specific relationship between applied P and the yield and quality of that crop, are often unavailable—and expensive to obtain. We do have data on the "external" P requirements of some crops (Table 1). The soil-solution P concentration is often used to express

Table 1. Levels of P in plant tissue and soil solution associated with 80–95% of maximum yield of some crops grown in Hawaii.

Crop	Plant P[x] (%)	Soil-solution P (mg/liter)	Soil series[y]
Cabbage (*Brassica oleracea*)	0.4 – 0.8	0.02 – 0.04	Kula
Corn (*Zea mays*)	0.3 – 0.5	0.03 – 0.05	Halii, Wahiawa
Head lettuce (*Lactuca sativa*)	0.4 – 1.0	0.20 – 0.40	Kula, Lualualei
Macadamia (*Macadamia integrifolia*)[z]	0.08 – 0.10	0.02 – 0.04	Kapaa, Puna, Wahiawa
Sorghum (*Sorghum bicolor*)	0.2 – 0.6	0.02 – 0.06	Honokaa
Soybean (*Glycine max*)	0.25 – 0.50	0.10 – 0.20	Halii, Wahiawa
Sugarcane (*Saccharum officinarum*)	0.18 – 0.30	0.02 – 0.04	Wahiawa
Tomato (*Lycopersicon esculentum*)	0.4 – 1.0	0.10 – 0.20	Kula, Waimanalo

[x] Plant P concentration may vary considerably with plant age and part. [y] Soils of Hawaii used for establishing critical concentrations of soil-solution P.
[z] Macadamia is an exception to the general rule that tissue levels of P should be in the range 0.2 to 0.5%; iron chlorosis may occur when P is above 0.15%.

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*Replaces "Fact Sheet no. 2 10/06/94"

Figure 1. Relationship between sorbed P and soil-solution P in 12 soils of Hawaii.

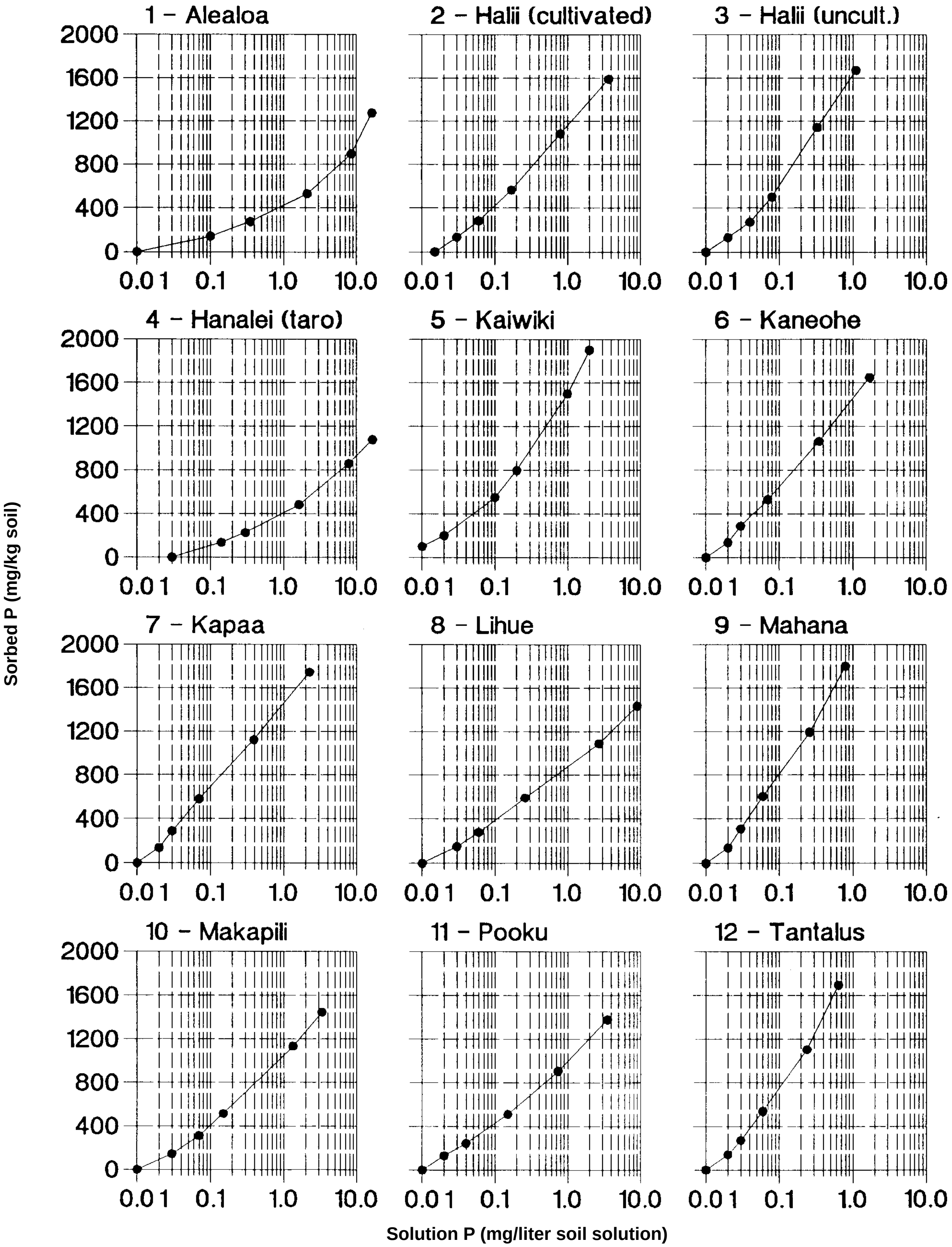


Figure 2. Relationship between fertilizer P and modified Truog P for some soils of Hawaii.

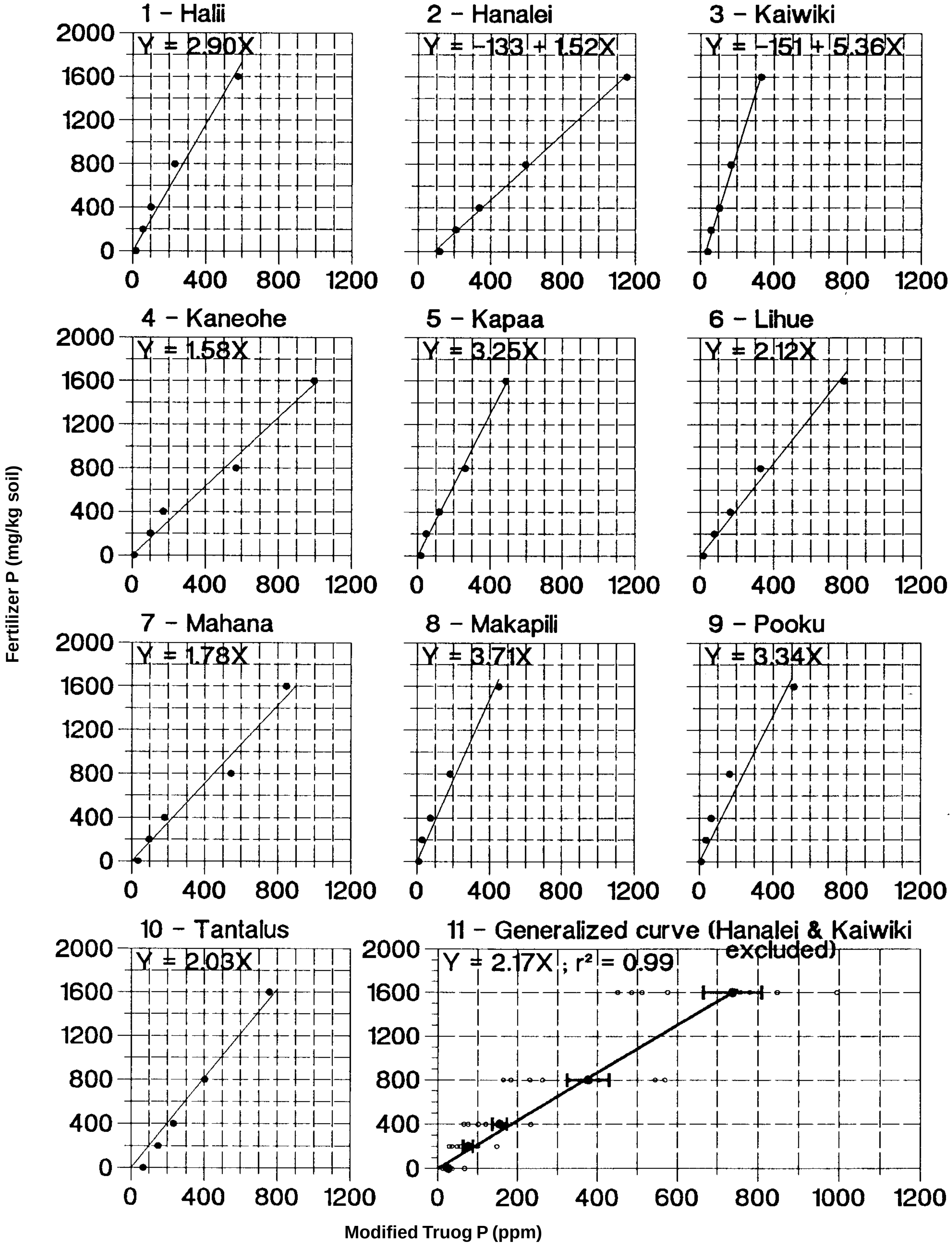
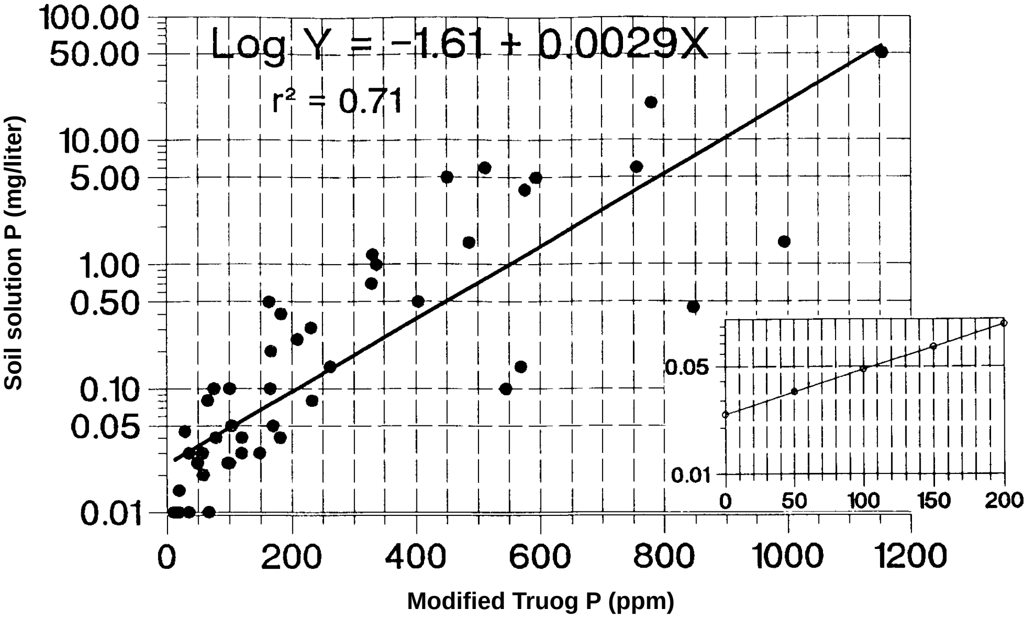


Figure 3. Relationship between soil-solution P and modified Truog P for soils of Hawaii.



the external P requirement of crops, because this P requirement remains nearly constant across soil series, while chemically extractable P varies from soil to soil. ADSC's objective is to establish a clear relationship between soil-solution P (which the plant experiences) and Truog-extractable P (which we measure in the laboratory) so that we can reasonably predict (1) whether a soil needs additional P, and (2) if it does, the amount of P needed for good growth of a given crop.

To achieve this objective, we first establish the P sorption curve—the relationship between soil-solution P concentration and the amount of P sorbed (held in the soil), which varies from soil to soil, as Figure 1 demonstrates. Then we establish the relationship between Truog-extractable P and fertilizer P applied, as shown in Figure 2. Although this latter relationship varies somewhat with soils, the Modified Truog Method generally extracts (recovers) about half of the fertilizer P (Graph 11, Fig. 2). Finally, we combine the two relationships to obtain a connection between the soil-solution P and the Truog-extractable P, as shown in Figure 3. Practical use of these graphs is illustrated in the following examples.

(1) Let's suppose you sent ADSC a soil sample from your garden in Lihue, Kauai (the Lihue series) and you wish to grow tomatoes. The test result came back, showing 12 ppm P. You then look at Figure 3, which shows that 12 ppm Truog P is equivalent to about 0.028 mg/liter P in soil solution. From Table 1, you find that at least 0.10 mg P per liter of soil solution is needed for a good crop of tomato. This translates roughly to 200 ppm Truog P, based on Figure 3. Then you look at Graph 6 of Figure 2 for the amount of fertilizer P needed in the Lihue soil to maintain 200 ppm Truog P, which is 400 mg P per kg soil. Assuming that the surface 6 inches (~15 cm) of 1 acre of soil weighs 1 million kg (or 2 million lb), then you should apply about 800 lb/acre of P fertilizer (20 lb P per 1000 ft^2).

(2) Assume that you want to grow cabbage, and your soil test result from ADSC is 100 ppm P. Figure 3 shows that soils (in general) with this much Truog P have approximately 0.05 mg P per liter of soil solution. Table 1 says this level is adequate for good growth of cabbage, so you may not need P fertilizer.

(3) Assume that you're not certain about the name or origin of a particular soil, which has a soil-test P of 50 ppm, but you know that the intended crop is lettuce. Table 1 and Figure 3 predict that lettuce does well only when there is at least 0.20 mg P per liter of soil solution, which is equivalent to 300 ppm Truog P. Using Graph 11 of Figure 2 (or its equation), you can calculate (2.17 × [300 – 50] = 542.5 mg P/kg) that you need to add aproximately 1100 lb P per acre, or 25 lb P per 1000 ft^2.

In summary, with soil-test P data from ADSC, (1) use Figure 3 to determine soil-solution P, (2) examine Table 1 to find out the critical soil-solution P required for the crop, and decide whether your soil has sufficient P, then (3) return to Figure 3 to find the Truog P level corresponding to the critical soil-solution P, and finally (4) select the appropriate graph in Figure 2 to determine the amount of fertilizer P to apply.