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9. ABSTRACT

Field plots of corn (ZEA mays), Chinese cabbage (Brassica pekinensis), head lettuce (Lactuca sativa), sweet potato (Ipomoea batatas), and Desmodium aparines were phosphate fertilized so that the concentration of phosphate in equilibrated soil solutions ranged in ten increments, from 0.003 to 1.6 ppm. Fertilizer requirements for phosphate were determined from individual phosphate sorption curves for each plot. Four soils were used to provide a wide range of weathering and mineralogy: Typic Haplustoll, Tropeptic Eutrustox, Typic Gibbsihumox, and Typic Hydrandept. The results showed that phosphate adsorption was related to soil mineralogy and rainfall. Highly weathered soils, especially the Hydrandept, adsorbed much phosphate, while the soil which contained expanding lattice clays (and much more soluble Si) adsorbed much less phosphate. The P requirements (ppm) for adjusting soil solutions to 0.2 ppm were: Haplustoll, 0; Eutrustox, 400; Gibbsihumox, 900; Hydrandept, 2500. The yield curves for corn were similar for different soils when relative yields were plotted against the concentration of phosphate in soil solutions. Yields were 95% at 0.06 ppm phosphate. For sweet potato, the external P requirement was 0.003 and 0.1 ppm P in solution for 75% and 95% yield. For lettuce it was 0.4 ppm for 95% yield. For Desmodium the external requirement decreased from 0.2 ppm during establishment to about 0.01 ppm after first harvest. Residual efficiencies of P following corn ranged from 65% for gel-like, Si-depleted soil (Hydrandept) to 100% for a 2:1 clay rich in soluble Si.

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COMPARATIVE EXTERNAL PHOSPHORUS REQUIREMENTS OF PLANTS GROWING IN TROPICAL SOILS 1/

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From earlier pot studies we have concluded that P concentration in soil solutions is the major factor controlling the flux of P to plant roots. However, relationships between solution concentration and adequacy of P nutrition for diverse crops growing in the field remained to be determined. Field investigations are emphasized since "barrier effects" of pot walls can lead to serious discrepencies between field and pot data (Fox and Kamprath, 1970).

Field plots were phosphate fertilized so that P concentration in equilibrated soil solutions ranged in 10 increments from <0.003 to 1.6 ppm. Fertilizer P requirements were determined from individual P sorption curves for each plot. Equilibrating conditions were: 3 grams soil, graded amounts of $Ca(H_2PO_4)_2$, 30 minutes shaking twice daily, 6 days, 25°C. Phosphate disappearing from solution was considered as sorbed.

Data for only 5 of the 12 species grown are presented here. These are: corn (*Zea mays*), Chinese cabbage (*Brassica pekinensis*), head lettuce (*Lactuca sativa*), sweet potato (*Ipomoea batatas*) and *Desmodium aparines*. Four soils were used giving a wide range in weathering and mineralogy (Table 1). Phosphate in solution corresponding to 95% yield was estimated from yield response curves.

New P sorption curves were plotted after each crop and P was reapplied to each plot as necessary to reestablish assigned P concentrations. Residual phosphate fertilizer efficiency as defined by Fox et al. (1968) was estimated from the relationship:

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$$\text{Residual efficiency (\%)} = \frac{\text{Adsorption Difference}}{\text{Net Fertilizer in Soil}} \times 100$$

Where the adsorption difference is adsorption before fertilization minus final adsorption, both determined at some standard concentration of phosphate in solution, and net fertilizer in soil is fertilizer initially applied minus fertilizer P utilized by ensuing crops.

The 4 intermediate P concentrations were replicated 3 times; other concentrations were unreplicated. Lime and nutrients other than P were added as thought necessary for optimum yields. Zinc was applied at 20 kg per ha.

Results and Discussion

Phosphate adsorption was related to soil mineralogy and rainfall. Highly weathered soils, especially the Hydrandept, adsorbed much phosphate while the soil which contained expanding lattice clays (and much more soluble Si) adsorbed much less phosphate. The Eutrustox with kaolin type clay exhibited intermediate phosphate sorption.

The Hydrandept contains large amounts of amorphous material low in Si. Phosphate adsorption is inversely related to Si in the amorphous fraction (Fox et al 1971, Saunders 1965). Also the Gibbsihumox contains 10-25% of amorphous material. We believe that coatings of amorphous material (gel hulls) control initial reactions of phosphates in many highly weathered soils. Phosphate adsorption is presumed to involve ligand exchange reactions between $H_2PO_4^-$ and the OH^- groups of aluminum and iron hydroxide surfaces in these soils.

An example of how phosphate requirements were determined is given for the 0.2 ppm concentration in Figure 1, and Table 1 shows these values, corrected for bulk density and 15 cm depth, converted to kg per ha.

Although fertilizer requirements were very different for the soils, and the locations have different climates, the external P requirement for

95% yield of corn was in the range 0.05 to 0.07 ppm P (Fig. 2). However, external P requirements varied among crops. For example, Chinese cabbage which grows more rapidly than head lettuce has a lower external P requirement (Figure 3). It is not safe to generalize that rapidly growing crops are phosphate responsive crops. Sweet potato required only 0.003 ppm P in solution for 75% of maximum yield (Fig. 3) although 0.1 ppm was required for 95% yield.

The external phosphate requirements of crops can change with advancing state of development. During early growth stages Zea mays made near maximum growth at about 0.2 ppm P in solution, but grain production was 95% at about 0.06 ppm. During establishment the forage legume Desmodium aparines growing on the Hydrandept requires about 0.2 ppm P in solution, but for regrowth after the first harvest about 0.01 ppm was adequate.

For the Eustroxtox, phosphate in solution was increased 4 fold (0.025 to 0.1 ppm) by doubling the amount of fertilizer applied (170 to 340 µg P/g soil); so a 4 fold increase in P concentration should be obtained by decreasing the volume of soil fertilized by one half.

Residual effects of the initial phosphate adjustments are seen as parallel shifts in the sorption curve which are more or less proportional to amounts of P added (Figure 4). Langmuir adsorption maxima cannot be used to evaluate the residual effects of phosphate fertilizer.

After the initial corn crop, mean residual efficiencies (4 highest P treatments) for the experimental soils were: Hydrandept 65%, Eutrustox 71%, Gibbsihumox 90% and Haplustoll 107%. These values agree with long term residual efficiencies for a Gibbsihumox in grass sward (80%) reported by Fox et al. (1968), but are higher than for a Hapludult (mean 42%) which had been cultivated to annual crops for 10 years after heavy fertilization (Fox

and Kamprath, 1970). The order among soils given above suggests that residual efficiency will decrease with increasing disorganization of crystals and silicon depletion of the mineral fraction.

Surface coatings, especially those depleted of Si, have been implicated in phosphate sorption; but it was the composition of the coatings rather than amounts of material in them which seemed to be important in short term adsorption (Fox et al., 1971). The thickness of amorphous, gel-like coatings should be relatively more important in account for long term reactions of phosphate in soils (Rajan and Fox 1972).

References

Fox, R. L., Hasan, S. M., and Jones, R. C. (1971) Phosphate and sulfate sorption by Latosols. Proc. Int. Symp. Soil Fertility Evaluation, New Delhi. 1, 857-864.

Fox, R. L., and Kamprath, E. J. (1970) Phosphate sorption isotherms for evaluating the phosphate requirements of soils. Soil Sci. Soc. Amer. Proc. 34, 902-907.

Fox, R. L., Plucknett, D. L., and Whitney, A. S. (1968) Phosphate requirements of Hawaiian Latosols and residual effects of fertilizer phosphorus. Trans. 9th Int. Congr. Soil Sci. (Adelaide, Aust.) 2, 301-310.

Rajan, S. S. S., and Fox, R. L. (1972) Phosphate adsorption by soils. 1. Influence of time and ionic environment on phosphate adsorption. Communications in Soil Sci. and Plant Analysis 3, 493-504.

Saunders, W. M. H. (1965) Phosphate retention by New Zealand soils and its relationship to free sesquioxides, organic matters, and other soil properties. New Zealand J. Agric. Res. 8, 30-57.

Summary

The P requirements (ppm) for adjusting soil solutions to 0.2 ppm were: Haplustoll, 0; Eutrustox, 400; Gibbsihumox, 900; Hydrandept, 2500. Yield curves for corn were similar for different soils when relative yields were plotted against P concentration in soil solutions. Yields were 95% at 0.06 ppm P. The external P requirement was 0.003 and 0.1 ppm P in solution for 75% and 95% yield of sweet potato and was 0.4 ppm for 95% yield of

lettuce. The external P requirement of Desmodium decreased from 0.2 ppm during establishment to about 0.01 ppm after first harvest. Residual efficiencies of P following corn ranged from 65% for gel-like, Si-depleted soil (Hydrandept) to 100% for a 2:1 clay rich in soluble Si.

Table 1. Some properties of soils and climates used for determining the external phosphate requirements of crops.

Property	Soil Series			
	Waialua	Wahiawa	Halii	Honokaa
Soil Subgroup	Typic Haplustoll	Tropeptic Eutrustox	Typic Gibbsihumox	Typic Hydrandept
Family	Very fine, kaolinitic, isohyperthermic	Clayey, kaolinitic, isothermic	Clayey, ferritic, isothermic	Thixotropic, isothermic
Important Secondary Minerals	2:1 expanding clays, Kaolin	Kaolin, Hematite	Gibbsite, Goethite	Amorphous gels
Parent Material	Alluvium	Basalt	Basalt	Volcanic ash
Initial Soil pH (Soil: water, 1:1)	6.3	5.0	5.0	4.7
Si (saturation extract, ppm)	15.7	0.9	1.2	2.5
Rainfall (mm)	1000	1100	2400	2500
Elevation (m)	20	200	150	750
Phosphate Adsorption Maximum (μg P/g soil)	500	800	2500	7000
Fertilizer P for 0.2 ppm (kg/ha)	0	870	2220	1680

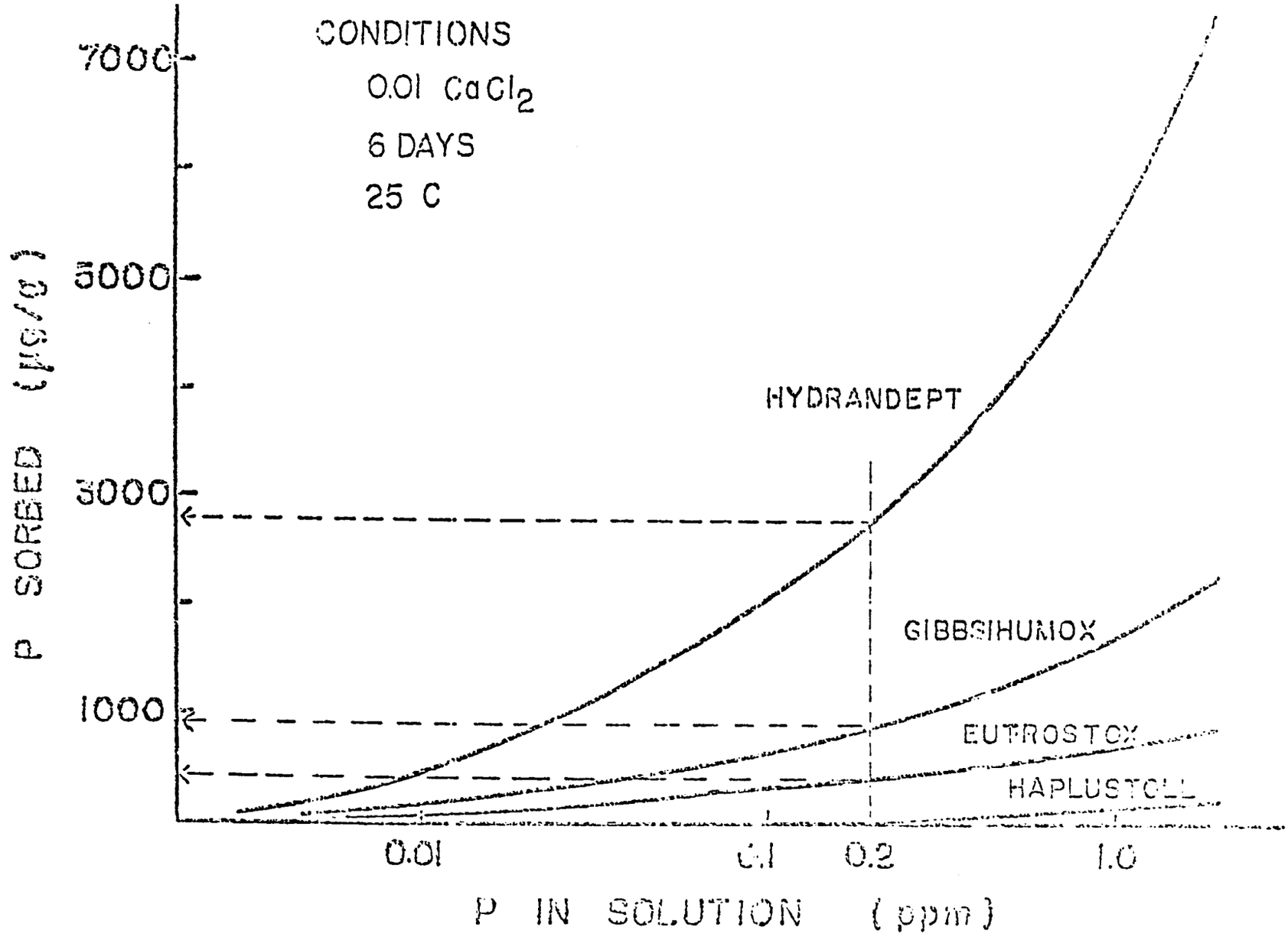

Figure 1. Phosphate sorption isotherms for four soils showing the relationship of [illegible] to phosphate adsorption. Horizontal dashed lines indicate P sorbed at 0.2 ppm P in equilibrated solutions.

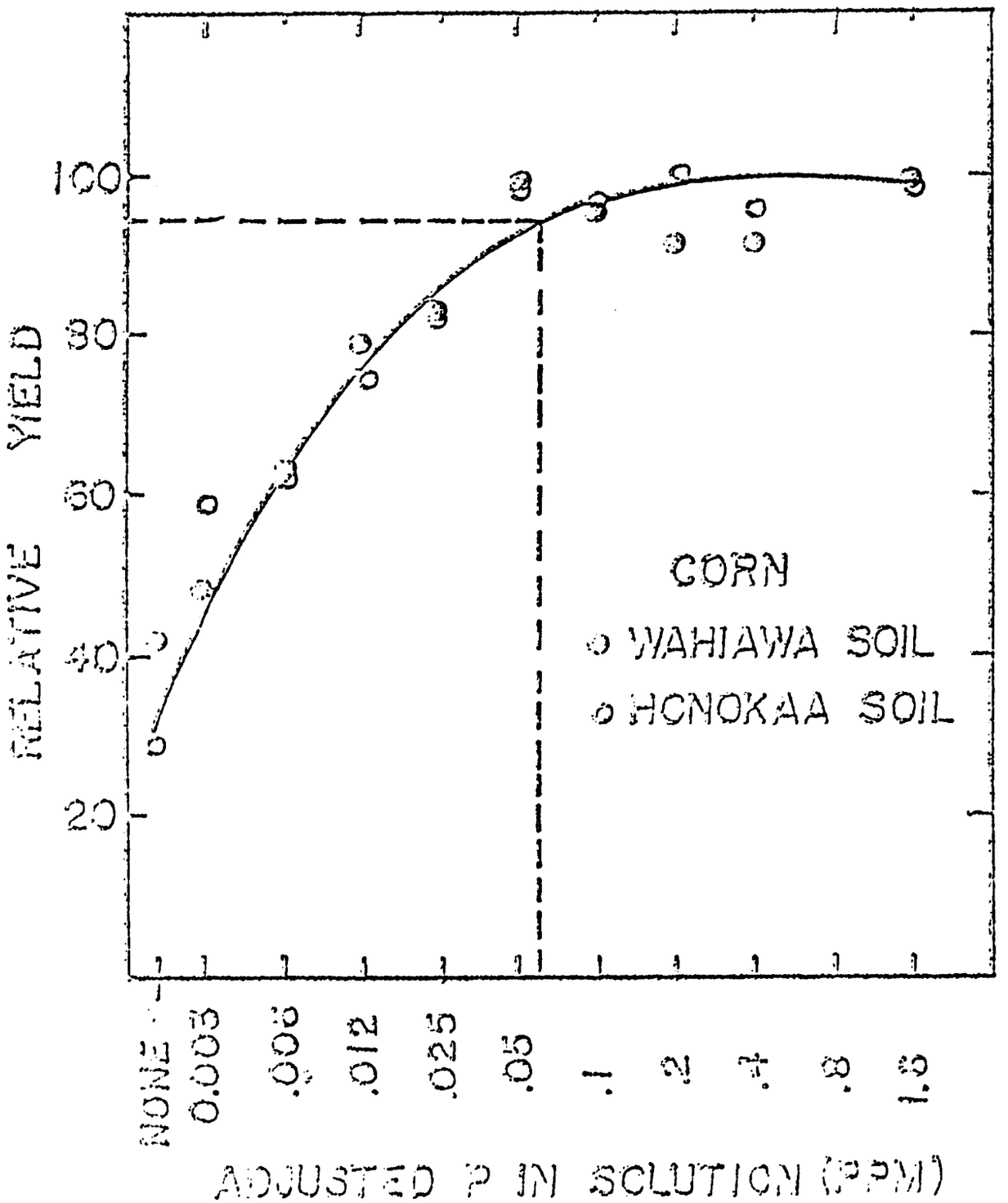

Figure 2. Growth of corn in relation to adjusted concentrations of P in the solutions of soils having different mineralogical systems.

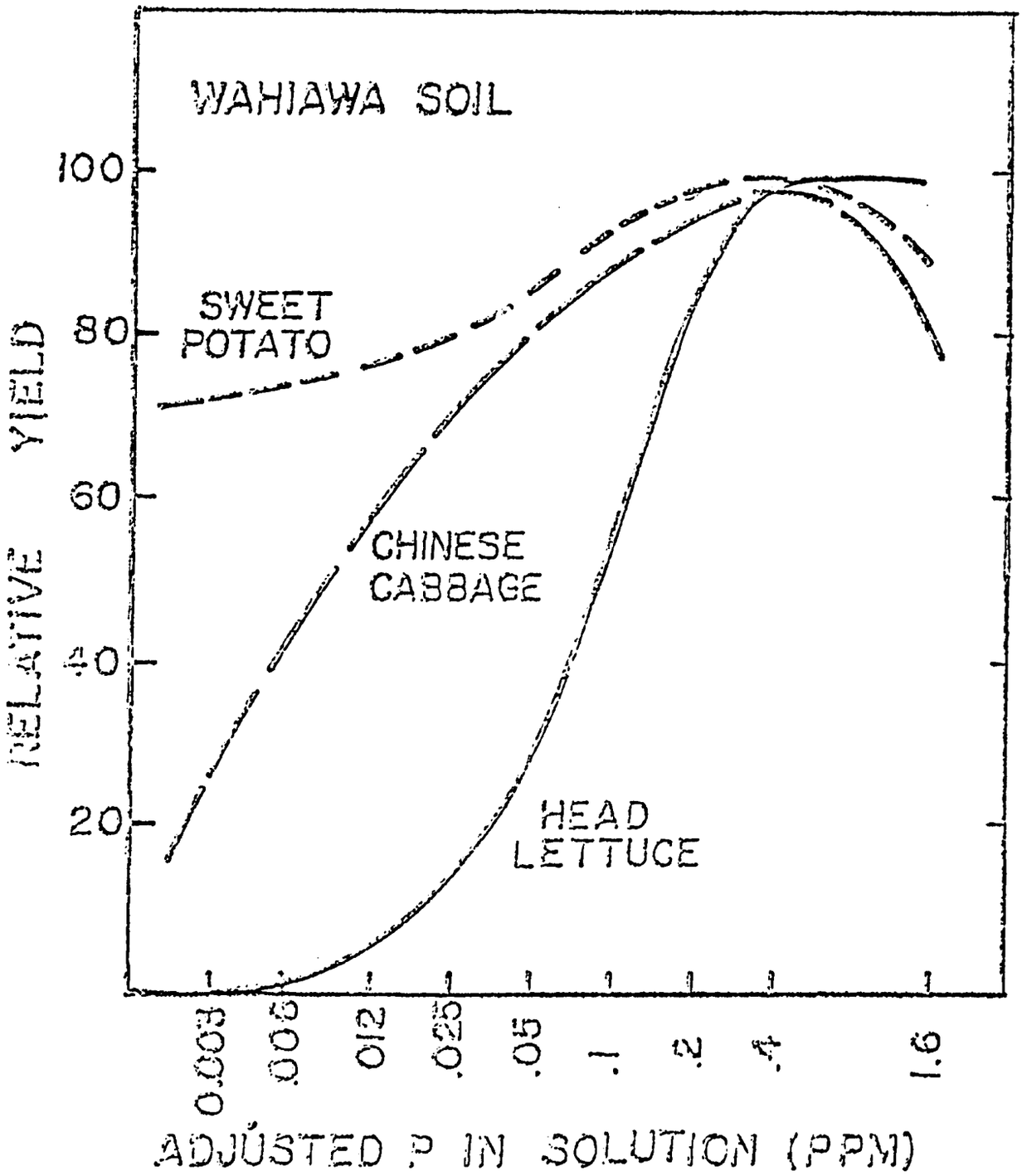

Figure 3. Comparative growth response curves for Chinese Cabbage, sweet potato and lettuce growing on the Wahiawa soil (Typic Eutrostox).

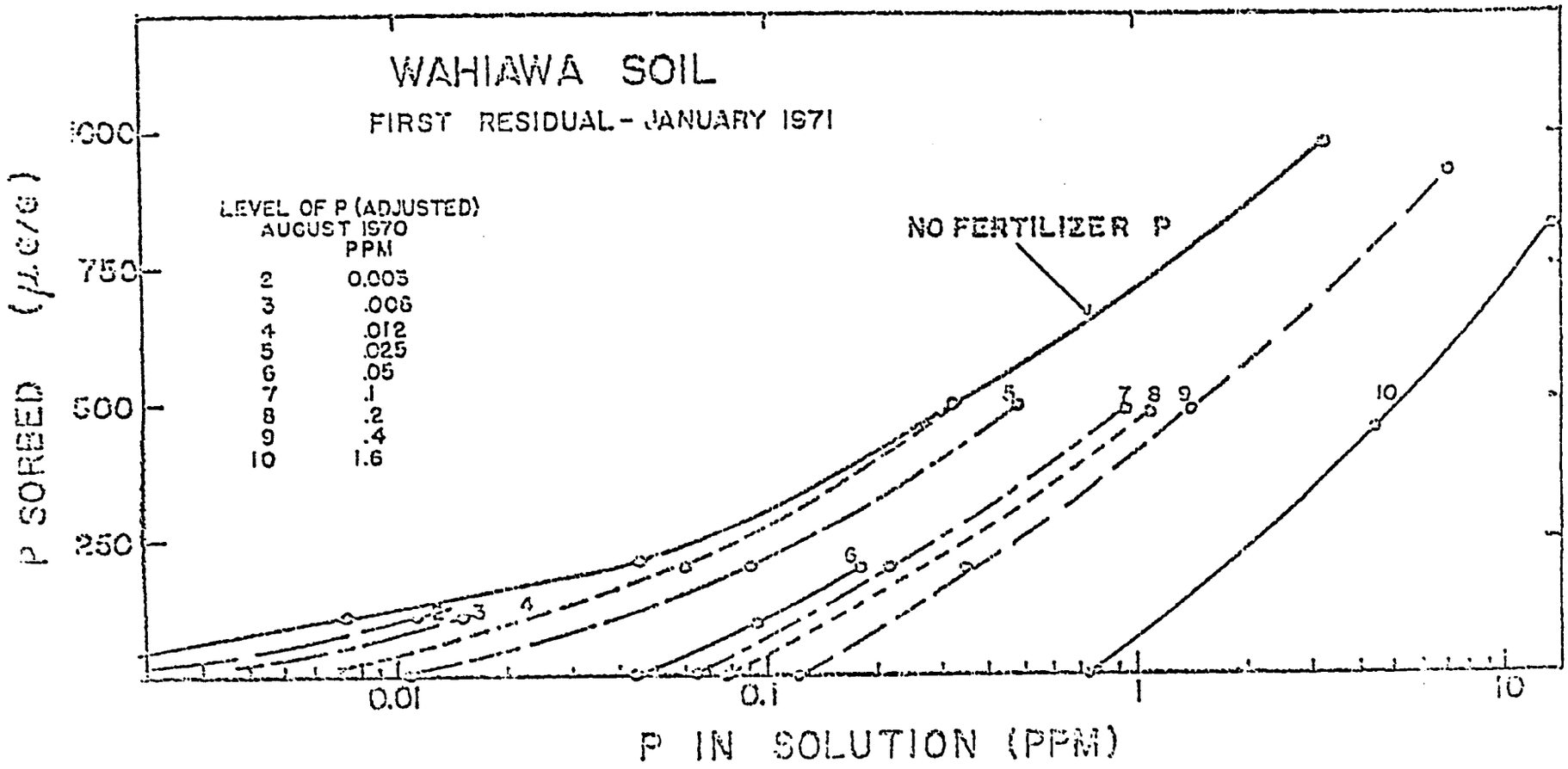

Figure 4. An example of how the initial application of phosphate fertilizer for corn shifted phosphate adsorption curves in samples collected following corn growth.