

INTERACTION OF FOREST FLOOR MATERIAL AND MINERAL SOIL ON ORTHOPHOSPHATE SORPTION

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ABSTRACT

The effect of forest floor materials on phosphorus sorption by high and low phosphorus-fixing soils was investigated. Organic matter and soil were either incubated for 1 month and equilibrated in 2N potassium chloride or simply mixed and equilibrated. Orthophosphate levels then were measured. Admixing organic matter decreased the phosphorus sorption on both high and low phosphorus-fixing soil, presumably by the action of organic anions also in the leachate. When soil and organic material are mixed during cultivation, changes in phosphorus sorption characteristics of soils should be considered in evaluating cycling and mineralisation.

Keywords: forest floor; phosphorus; phosphorus cycling; phosphorus fixing; phosphorus sorption.

INTRODUCTION

The fate of phosphorus in the forest-floor/surface-soil component of a forest ecosystem has often been estimated by a mass balance approach. The loss of phosphorus from litter has been compared with phosphorus uptake by biomass and phosphorus loss by leaching. How the inorganic phosphorus released by decomposing forest floor materials interacts with mineral soil has received less attention. If phosphorus mineralisation occurs in the presence of mineral soil, the soil must then play some role in the fate of phosphorus. The soil solution equilibrium orthophosphate concentration (P_e) would be regulated either by precipitation or adsorption. The extent of the soil's influence must depend on its phosphorus-fixing capacity, reaction, and content of labile elements that complex or precipitate phosphorus. The organic detritus (and associated organisms), besides being a source of phosphorus to the soil solution, can affect the role the mineral soil plays in controlling P_e by immobilising soil phosphorus during decomposition (Broadbent 1953; Singh & Jones 1976), by masking the adsorption sites with organic anions in its leachate (Deb & Datta 1967; Earl *et al.* 1979; Nagarajah *et al.* 1970), or by complexing iron, aluminium, and calcium with organic anions, effectively preventing precipitation reactions with phosphorus.

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Site cultivation techniques that incorporate forest floor organic matter with mineral soil are likely to affect Pe and hence availability of phosphorus to planted seedlings. For soils with a high phosphorus-fixing capacity, such practices may decrease available phosphorus, whereas for soils with a low P-fixing capacity they may have little effect.

This study was conducted to evaluate the Pe in high and low phosphorus-fixing soil materials when admixed with forest floor material.

METHODS

Mineral Soil Material Used

The high phosphorus-fixing soil material was from the sandy loam subsoil of a Ngakuru sandy loam in Whakarewarewa Forest Park (60–80 cm deep). The Ngakuru soil is of volcanic origin and dominated by allophane. Since it was subsoil material, organic matter was less than 1% by weight.

The low phosphorus-fixing material was the surface soil of an Ohia sand collected near Te Kao in Northland. It is a weathered, siliceous sand with low organic matter. A low labile iron and aluminium content give it a low phosphorus-fixing capacity.

Incubation of Litter with a High Phosphorus-fixing Mineral Soil

The litter layer (L) from a first rotation, 14-year-old *Pinus radiata* D. Don stand growing on the Mamaku plateau of the North Island of New Zealand was dried at 70°C and ground to pass a 2-mm sieve. The L layer weighed approximately 6 t/ha and was 30% of the total forest floor (L + F) weight. No H layer was present. Eight grams of litter were placed in a plastic container to which 0, 2, or 4 g of a subsoil of a Ngakuru sandy loam (Table 1) were added. The subsoil was used to provide a high phosphorus-fixing soil material. Two replicates of each treatment were prepared. The material in each container was thoroughly mixed, moistened to field capacity, and placed in an incubator at 20°C. Samples were allowed to dry and then rewet to field capacity. They were incubated for 1 month. During this time samples were subjected to three drying/wetting cycles.

After incubation samples were transferred to beakers, 122 ml 2N KCl was added, and the samples were left to stand at room temperature (20°C ± 2°C) for 16 hours

TABLE 1—Characteristics of soil and forest floor materials

Soils	Classification (NZ genetic)	Sample depth (cm)	Horizon	N (%)	P (%)
Ngakuru sandy loam	Strongly leached yellow-brown loam	60–80	C	—	—
Ohia soil	Strongly leached yellow-brown sand	0–20	A	—	—
Oranui sandy loam	Podsolised yellow-brown loam	5–0	L	0.95	0.084
Pinaki soil	Podsolised yellow-brown sand	2–0	F+H	1.29	0.084

with occasional shaking. The 2N potassium chloride was used because measurements were in conjunction with nitrogen mineralisation measurements. Samples were filtered through Watman #44 paper and inorganic orthophosphate-phosphorus (OP) was determined by the colorimetric method of Murphy & Riley (1962) measuring light absorbance at 880 nm. Selected characteristics of the litter and soil are provided in Table 1.

High and Low Phosphorus-fixing Mineral Soil Mixed with a F + H Forest Floor Material

The F + H forest floor material from a 42-year-old *Pinus radiata* stand growing on a recent sand dune near Woodhill, North Auckland, was collected, mixed, and stored in a field-moist condition at 6°C until used. The total weight of the forest floor at this site was 36 t/ha.

Approximately 12 g (4 g dry weight) of well-mixed material were placed in a glass beaker and mixed with 0, 0.15, 0.30, 0.60, and 1.20 g of the Ngakuru subsoil material or the surface soil sample of an Ohia sand. Two replicates of each treatment were prepared. Soil weights were chosen to approximate 0, 4, 8, 16, and 30% of the dry weight of the organic material. One hundred ml 2N KCl were added and left to stand at room temperature (20°C ± 2°C) for 16 hours with occasional shaking. Samples were then filtered through Watman #44 paper and OP was measured as stated above.

Soil Adsorption Isotherms

Phosphorus sorption isotherms of Ngakuru and Ohia soil materials were accomplished by placing, in duplicate, 1 g soil in 100 ml 2N KCl that contained 0, 100, 200, 300, or 400 µg OP. The 2N potassium chloride solution was used to be consistent with the background electrolyte of the previous experiments. Samples were treated as described above.

RESULTS

Incubation of Litter with a High Phosphorus-fixing Mineral Soil

Phosphorus in the potassium chloride extract (Pe) decreased as the amount of soil added to litter increased (Fig. 1). In the absence of soil the Mamaku litter had a Pe of 1.74 mg OP/l. This concentration decreased by 56% and 85% when 2 and 4 g (25% or 50% of the litter weight) soil were present. The sorption isotherm (Fig. 2) indicated that 1 g Ngakuru soil material at an initial solution content of OP similar to that released by the litter (1.73 mg OP/l) would sorb practically all the OP (Pe≅0). A straight line interpolation of Fig. 1 for 1 g soil mixed with litter indicated a Pe of approximately 1.25 mg OP/l. This is a 28% decrease in the Pe of the forest floor extract; however, the soil-only extract showed a Pe decrease of close to 100%.

High and Low Phosphorus-fixing Mineral Soil Mixed with a F + H Forest Floor Material

The trend in Pe when forest floor material was mixed with Ngakuru soil material was similar to the previous experiment. As the amount of soil increased the Pe decreased

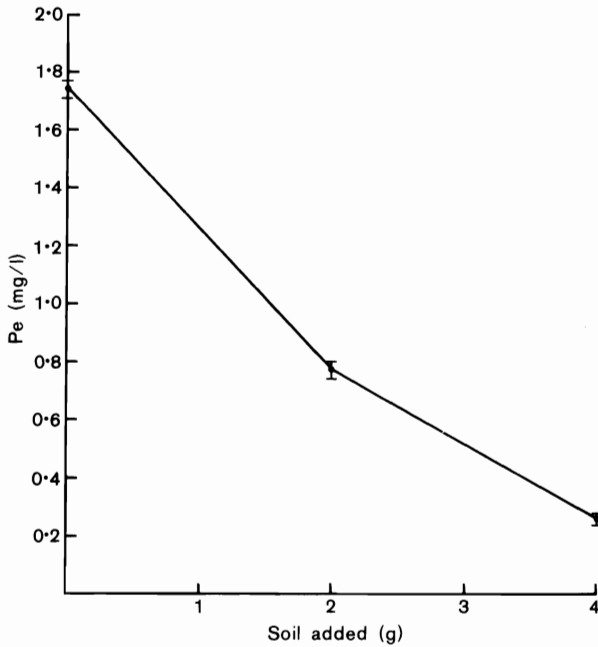


FIG. 1—Effect of incubating soil with the Mamaku litter on the equilibrium phosphorus concentration (Pe). Background electrolyte is 2N potassium chloride and soil is Ngakuru sandy loam. Vertical lines are ranges of two replicates.

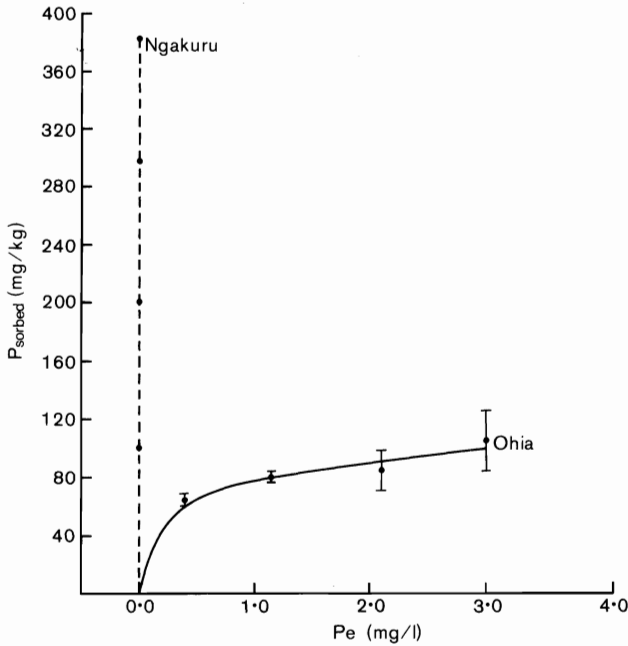


FIG. 2—Phosphorus sorption isotherms for Ngakuru and Ohia soils. Background electrolyte is 2N potassium chloride. Vertical lines are ranges of two replicates.

(Fig. 3). When soil weights were approximately 4, 8, 16, and 30% of the dry organic material weight, the Pe decreased by 42, 55, 63, and 77%, respectively. Interpolating from Fig. 3, the Pe for 1 g soil was 0.78 mg OP/l while the adsorption isotherm at an initial solution phosphorus content of 2.89 mg OP/l (same as Pe for forest floor alone) showed a Pe near zero (Fig. 2).

Data for the Ohia soil material are variable and show only a small effect on Pe when this low phosphorus-fixing soil is added to the forest floor material (Fig. 3). However, the sorption isotherm (Fig. 2) indicates that at an initial OP concentration equivalent to the Pe of the forest floor extract, the Ohia soil material should sorb between 80 and 85 mg OP/kg soil (i.e., reduce the Pe by about 30%).

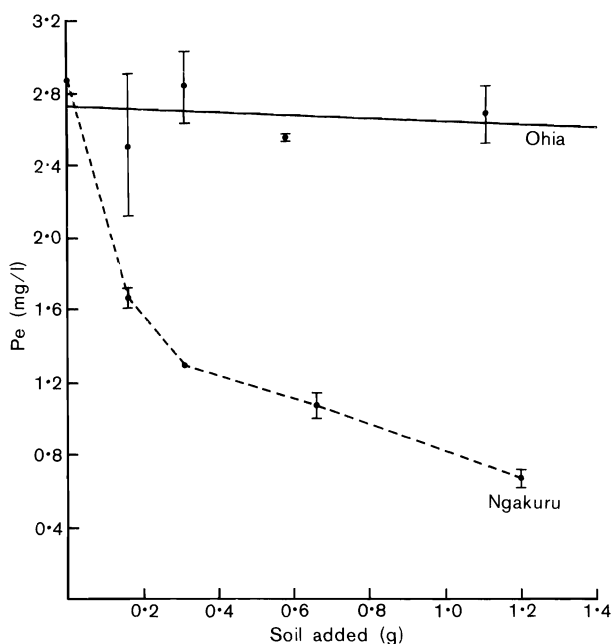


FIG. 3—Effect of adding soil to the Woodhill forest floor material on the equilibrium phosphorus concentration (Pe). Background electrolyte is 2N potassium chloride. Vertical lines are ranges of two replicates.

The influence of the Woodhill forest floor material on phosphorus sorption by mineral soil is summarised in Fig. 4 for 1 g soil with approximately 4 g (dry weight) forest floor material. For both soils the presence of the organic matter decreased the OP sorbed by the mineral soil. Conversely, the soil alone was able to sorb more OP when the forest floor material was not present showing inhibition of OP sorption by the presence of the organic material. On a relative basis, the high phosphorus-fixing soil reduced the Pe of the forest floor the most while the presence of the forest floor had the greatest effect on reducing the sorption capacity of the low phosphorus-fixing soil.

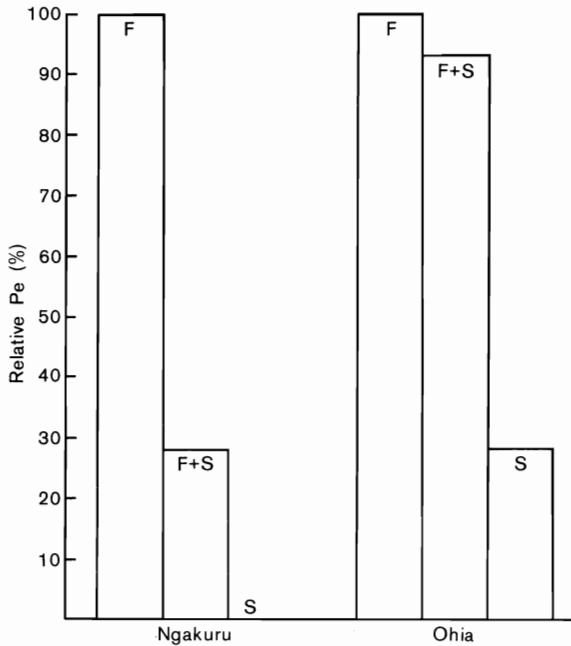


FIG. 4—Effect of forest floor materials on sorption of phosphorus released from forest floor. Relative Pe is in percentage of the equilibrium phosphorus concentration when forest floor materials are alone. F = forest floor alone present, F + S = forest floor material + soil, S = soil alone. Data are interpolated for 1 g soil (25% of organic matter dry weight). Background electrolyte was 2N potassium chloride.

DISCUSSION

Orthophosphate-phosphorus leached or mineralised from organic matter can have several fates. One of these is sorption by mineral soil material when mixed with or just below the forest floor. Results showed that the phosphorus sorption characteristics of these two soils had a marked influence on the OP released from organic matter. A high phosphorus-fixing soil can modify the Pe of decomposing forest floor materials, lowering OP in solution and, presumably, buffering the Pe with sorbed phosphorus.

Numerous authors have considered the effect of organic matter leachates on OP sorption. Anions of organic acids such as citrate, oxalate, phytate, tartrate, malate, malonate (Deb & Datta 1967; Evans 1985; Nagarajah *et al.* 1970), and humic and fulvic acids (Sibanda & Young 1986) have been shown to inhibit OP sorption primarily by competing for sorption sites or complexing OP. These compounds can be present in leachates of forest floor materials and exudates of roots (Gubanova 1970; Maksimova 1969; Rovira & Davey 1971).

Results showed that the presence of forest floor material decreased the OP sorption on mineral soil, probably by the presence of leachate compounds, and in doing so made

Pe higher. The over-all effect of the forest floor material was to decrease the adsorptive capacity of mineral soil and keep more OP in the soil solution for plant use, microbial use, or leaching from the immediate vicinity.

In summary, these data describe two processes that help determine the fate of OP released from forest floor materials. Firstly, OP sorption by mineral soil helps control the Pe, with the effect dependent on the organic matter-soil ratio and the soil phosphorus-fixing capacity. Secondly, the sorption of labile OP by mineral soil is lessened by the presence of organic matter, presumably because leachates contain organic acid anions which either compete for sorption sites or complex metals, thus making OP soluble.

Implications for Forest Management

These results might be interpreted in the context of cultivation as a site preparation practice. The intimate mixing of organic residue with high phosphorus-fixing mineral soil may result in more OP remaining in solution compared to that in uncultivated mineral soil. The outcome could be more OP available for plant use. This effect would be in addition to the increased decomposition and release of phosphorus that is a well-known effect of cultivation. In low phosphorus-fixing soils where phosphorus leaching may be a concern, cultivation may decrease the already low sorptive power of the soil and potentially leave a greater pool of OP in solution for leaching to lower soil horizons.

The importance of these effects to the over-all phosphorus nutrition of a young forest stand is unknown but they certainly have the potential to be significant for both high and low phosphorus-fixing soils.

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