

# Phosphorus Retention in Cheju Volcanic Soils

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濟州火山灰土壤에서의 磷酸의 固定

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摘 要

濟州道の 火山灰土인 黑色 및 褐色土에  $^{32}\text{P}$ 로 標識된 磷酸을 加해주기 前과 後에 침출력이 서로 다른 용액으로 침출시켰다. 加해준 磷酸은 水溶性分劃에서 速히 除去되었고 침가해준 大部分의 磷酸은 14日間에 걸쳐 土壤에 吸着되었다. 酸溶解性 磷酸은 낮은 편이었는데 褐色土에서는 時間이 경과함에 따라 증가하는 경향이였다. 침가해준 인산이 침출액에 의해서 침출되는 정도는 黑色土에서 33%이었고 褐色土에서는 66%정도이었다.

## INTRODUCTION

The island province of Cheju-Do, Korea, is composed of the remains of a volcano, Mt. Halla. The soils on the island are therefore derived from volcanic ash and, while having high porosity and accumulation of humus, are also characterized by having low levels of available phosphorus (Shin and Kim 1975; Lee and Lee 1975). This occurs because the soils maintain a high phosphorus (P) absorption coefficient with aluminum-bound P as the largest inorganic soil P component (Shin and Kim 1975; Kim 1974). This agrees with Prasad and Motto (1982) who found for volcanic soils of Guatemala that a significant correlation exists between the amounts of extractable Al in soils and

the quantity of P retained. Kim (1974) has characterized the soils and fixed forms of P for the Cheju volcanic soils. However, with isotope-aided studies, the actual quantities of added P fixed in various forms can be measured. The present study attempts to measure the quantities of P extractable with various extracting solutions following addition of a small quantity of  $^{32}\text{P}$ -labelled orthophosphate to two volcanic Cheju soils in order to determine how quickly added P is tied up in the soil.

## MATERIALS AND METHODS

A Brown volcanic soil (pH=5.8) and a Black volcanic soil (pH=5.4) were collected from citrus

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fields on Cheju-do, air-dried, and sieved to 2-mm size. Samples of the soils (500g) were placed in plastic bags for incubation. A  $^{32}\text{P}$  solution was prepared by diluting 1.5mCi  $^{32}\text{P}$  as orthophosphate in 350ml of distilled water.  $\text{KH}_2\text{PO}_4$  (0.1535g) was dissolved in the labelled solution to produce a labelled P stock solution with a specific activity of 43 $\mu\text{Ci}/\text{mg}$  P. The stock solution was added to the soil in the bags in five 10ml aliquots. The soil was thoroughly mixed between aliquot additions. A total of 215 $\mu\text{Ci}$   $^{32}\text{P}$  and 5mg P was added to each 500g soil sample. Three replicate bags were used for each soil. The bag tops were tied to maintain soil moisture at 10%(field capacity Brown soil, 12% Black soil, 9%) and the soils were incubated at room temperature. On days 2, 6, 10, and 14, samples of soil were removed from each bag. One subsample from each bag, equivalent to 10g dry soil, was analyzed for water soluble P by shaking it for 15min in 100ml distilled water, then filtering (Olsen and Dean 1982). The second subsample was analyzed for adsorbed P by shaking 4g soil for 1 min in 28ml of 0.03N  $\text{NH}_4\text{F}$  and 0.024 N HCl (Bray+

Kurtz I) (Bray and Kurtz 1945), then filtering it. The third subsample was analyzed for acid soluble and adsorbed P by shaking 4g of soil for 1 min in 28ml of 0.03 N  $\text{NH}_4\text{F}$  and 0.1N HCl (Bray+Kurtz II), then filtering it (Bray and Kurtz 1945). Ten ml of each soil extract was placed in a glass scintillation vial and counted by Cerenkov counting procedures. Cerenkov counting efficiency of the samples was found to be 40%. Inorganic P concentrations were determined colorimetrically using  $\text{NH}_4\text{M}_2\text{O}_4$  and  $\text{SnCl}_2$  (Olsen et al. 1954).

## RESULTS

Levels of water extractable P were very low for the soils prior to stock solution addition (Table 1). The levels of P extracted by Bray+Kurtz I (B+K I) and B+K II were higher for the Brown than the Black soil. In both soils, the B+K I fraction (adsorbed P) was approximately three times larger than the P extracted and characterized as acid soluble ([B+K II] - [B+K I]).

Following the addition of the  $^{32}\text{P}$  solution, water soluble P was not found to be higher than

Table 1. Phosphorus extracted ( $\mu\text{g}$  P/g soil) from two volcanic Cheju soils before and after addition of 10 $\mu\text{g}$  P/g soil.

P fraction	Soil type	Before addition	Days after addition			
			2	6	10	14
Water soluble P	Brown	1.2	1.7	1.4	1.6	1.3
	Black	0.5	0.5	0.5	0.6	0.5
Adsorbed P	Brown	21.4	28.7	25.5	26.0	24.9
	Black	14.5	18.8	18.6	17.7	17.9
Acid soluble P	Brown	8.5	10.6	10.7	11.2	11.7
	Black	4.0	4.9	4.5	5.0	4.7

pre-addition levels (Table 1) for either soil. The adsorbed P fraction after two days incubation was higher for both soils following P addition; however, the levels in the Brown soil increased by 7 $\mu\text{g}$

P/g while the Black soil levels were increased by only 4 $\mu\text{g}$  P/g soil. The adsorbed P fraction in the brown soil decreased over the 14-day period following P addition but this P fraction remained

fairly constant for the Black soil.

The acid soluble P fraction ( $[B+K II] - [B+K I]$ ) also increased for both soils following P addition but the magnitude of the increase was much less than the increase in adsorbed P. This fraction continued a slow rise over 14 days for the Brown soil but remained fairly constant for the Black soil (Table 1).

Water soluble  $^{32}P$  levels in the Brown soil were low within two days following addition of  $^{32}P$ . Most  $^{32}P$  was recovered in the adsorbed fraction (Fig. 1). Both the water soluble P and the adsorbed P levels remained relatively constant from day 6 to day 14. Acid soluble P slowly increased over the 14 days. Only two-thirds of the  $^{32}P$  was extracted from the Brown soil after 14 days.

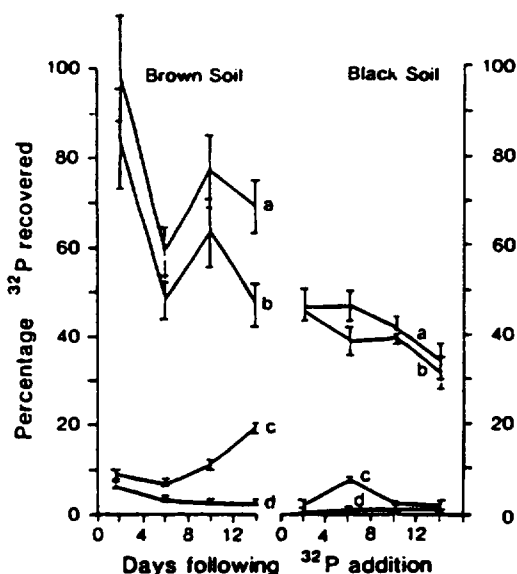


Fig. 1. Percentage  $^{32}P$  ( $\pm$ S.E.) recovered from two Cheju volcanic soils: a) total P recovered; b) adsorbed P; c) acid soluble P; d) water soluble P.

The Black soil differed from the Brown soil in that water soluble P disappeared very rapidly. As in the Brown soil, the majority of the  $^{32}P$  was extracted in the adsorbed P fraction, however, the proportion was much less than found for the Brown soil. The acid soluble P fraction remained small for the 14-day sampling period. Less than half of the  $^{32}P$  was extracted from the Black soil after two days. This fraction dropped to one-third after 14 days.

## DISCUSSION

The B+K I solution has been reported to extract adsorbed P (Bray and Kurtz 1945), however Chang and Jackson (1957) state that the neutral  $NH_4F$  used extracts only aluminum P. If the B+K I fraction extracted in this study is mainly Al-bound P, then the results of this study agree very well with those of Kim (1974) who found that Al-P was the largest component of soil inorganic P for Cheju soils. He also found that calcium P constituted a major part of soil P. The B+K II fraction, because of the more acidic extractant used ( $0.03N NH_4F + 0.1N HCl$ ) can be assumed to remove Ca-P (Chang and Jackson 1957).

The addition of  $10 \mu g$  labelled P per gram of soil to these soils and subsequent extraction with water gives evidence of the ability of these soils to fix small levels of added P. The Black soil, which is generally considered less fertile, maintained very little label as water extractable P and the inorganic P level rose relatively little. Thus, water soluble P forms would be quickly bound up in this soil. The same could be said of Brown soils although to a lesser degree. The major sink for recently added P appears to be in the adsorbed P fraction. In soils of  $pH < 6$ , the adsorbed P forms constitute the major source of P

for plant uptake (Bray and Kurtz 1945). Even in the more fertile Brown soil, only one-half of the added label was held in this fraction. Inorganic P levels were only 3.5  $\mu\text{g P/g}$  soil higher than pre-addition levels. The Black soil only retained one-third of the label as adsorbed P and 3.4  $\mu\text{g P/g}$  soil after two weeks. Therefore, within two weeks after fertilizer addition, 66 to 50% of the P was no longer readily available to plants in the black and brown soils respectively.

The form of the non-recovered  $^{32}\text{P}$  was not determined. If the B+K I fraction consists of Al-P and the B+K II fraction consists of Ca-P, then the remainder may be iron-bound P, or it

may be bound up in the microbial biomass. Indeed, since organic matter is high and P is limiting, P addition may give rise to a burst of microbial activity and P immobilization.

These results would tend to indicate that P fertilizer forms should be used which release P slowly. In this situation, the plants could absorb P as it is released instead of the P being released into the soil where it is quickly tied up. The addition of P to citrus fields and pasture should be performed as closely as possible to the time the plants most require P so that less fertilizer need be added to meet the plants uptake requirements.

### Summary

Phosphorus was extracted from two volcanic ash soils by solutions of different strengths before and after the addition of  $^{32}\text{P}$ -labelled phosphate. The added P disappeared rapidly from the water soluble fraction. Adsorbed P contained the majority of the added phosphorus during the 14-day experiment. Acid soluble P was low but slowly increased during the experiment. Only 33 and 66% of the added P was recovered by the extracting solutions from the black and brown soils respectively.

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