

Phosphorus Fixation in Nilgiri Soils¹

by

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Introduction: Rorty (1946) as quoted by McKelvy *et al.* (1953) declared rightly that phosphorus is the bottleneck of world's hunger. Acid soils as those found in the Nilgiris pose an economic problem, due to the undesirable nature of the transformation, phosphorus undergoes in acid soils. The applied phosphorus is rapidly fixed as insoluble and unavailable compounds. The native reserve of phosphorus also remains unavailable due to the acid conditions which prevent the sesquioxidic phosphates from being released as phosphorus in available forms, as is possible in a limed soil. The magnitude of this problem of phosphorus unavailability can be seen from the abnormal rate of 214 lb of P_2O_5 in the Nanjanad mixture used extensively on the Nilgiris, though a normal potato crop removes on an average 40 lb P_2O_5 per acre. Detailed information regarding the phosphorus fixation problem in the Nilgiris is not available. Therefore, a detailed study of the tract is indispensable to supply information on this aspect.

Review of literature: Wild (1950) reviewed the work done on phosphorus fixation and suggested the following as the factors affecting phosphate retention: (a) mechanical composition (b) phosphorus concentration (c) time and temperature (d) effect of salts (e) nature of the soil phosphorus fractions (f) other inorganic soil constitutions (g) organic matter and (h) pH. Murphy (1939) noted the highest fixation of phosphate under acid conditions. Chandler (1941) attributed fixation in acid soils to the formation of iron and aluminium phosphates. Chai Moo Cho and Caldwell (1959) and in India, Kanwar and Grewal (1960) showed that phosphate retention capacity decreased with increases in pH and degree of base saturation of acid soils.

Dean (1955) observed that the amount of retention increased as the concentration of phosphorus in solution increased. Kurtz *et al.* (1946) working on Illinois soils found a gradual change in the form of adsorbed phosphate. Chang and Chu (1961) observed that in time, the aluminium and calcium phosphate gradually changed to the less soluble iron phosphate, the rate of transformation increasing with the moisture content of the soil.

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Heck (1934) found least penetration of soil phosphorus in laterites which contained relatively large amounts of sesquioxides. Tiulin (1936) ascribed phosphorus fixation to the sesquioxides reduced phosphorus retention. Metzger (1940) and Leaver and Russell (1957) showed that fixation was associated with sesquioxides. Murphy (1939) and Patel and Viswanath (1946) noted that the higher the silica-sesquioxide ratio, the lower the fixation of phosphorus. Raychaudhuri and Mukherjee (1941) studied phosphate fixation by gels of ferric oxide and titanium oxide. Ferric oxide showed higher power of fixation as compared to aluminium oxide.

Scarseth and Tidmore (1934) found that clays with a low silica-sesquioxide ratio fixed more phosphates. Murphy (1939) reported more fixation of phosphorus in kaolinite clays. Block (1941) attributed fixation of phosphorus in kaolinite crystals to penetration of phosphate between the lattice layers from which it was no longer readily extracted. Low and Black (1947) showed decomposition of kaolinites and the precipitation of phosphate by the alumina of the dissociated kaolinite as the main source of retention as aluminium phosphate, but not as kaolinite phosphate. In 1950, they concluded that phosphate fixation by kaolinite was due to the replacement of silicon tetra-hedrons by phosphate tetra-hedrons. Murphy (1939) showed that kaolinite had a larger capacity to take up phosphate because of an exchange of phosphorus with layers of hydroxyl ions on the surface of the minerals.

Experimental details: With the object of assessing the extent of phosphorus fixation and its relation to various chemical components and the discrete forms of soil phosphorus, forty surface soil samples were collected representing the wide range of rainfall and elevation on the Nilgiris. They were examined for chemical and physical properties pertaining to the study by methods described by Piper (1950), Jackson (1958) and methods of Association of Official Agricultural Chemists (U. S. A., 1955).

The fixation capacity of soil was determined by the method described by Patel and Viswanath (1946). Ten grams of the air dry soil were placed in a 250 ml glass stoppered measuring cylinder and 100 ml of the phosphate solution of known concentration were added. The mixture was shaken for 24 hours in a mechanical shaker, filtered through Whatman No. 2 filter paper. Five milli litre of the filtrate was used for the estimation of phosphorus in Klett-Summerson colorimeter. From this, phosphorus fixation capacity was calculated and expressed as percentage (Table I).

TABLE I.

Range and mean values of pH, sesquioxides, fractions of soil phosphorus and phosphorus fixation capacity.

S. No.	Property or Constituent	Minimum	Maximum	Mean of 40 samples
1.	Phosphorus in Aluminium phosphate (ppm) ...	49.4	163.5	116.9
2.	Phosphorus in Iron phosphate (ppm) ...	trace	377.0	119.3
3.	Phosphorus in Calcium phosphate (ppm) ...	trace	67.0	12.3
4.	Phosphorus in Occluded Al. phosphate (ppm) ...	30.6	190.6	101.7
5.	Phosphorus in Occluded Iron phosphate (ppm) ...	59.7	164.3	133.4
6.	Phosphorus in Organic phosphate (ppm) ...	trace	3017.2	917.6
7.	Phosphorus fixation capacity (percentage) ...	0.0	100.0	79.6
8.	Iron oxide (Fe_2O_3) (percentage) ...	3.4	17.7	10.1
9.	Alumina (Al_2O_3) (percentage) ...	2.9	24.4	15.7
10.	pH — ...	4.2	6.9	—

An incubation study was carried out to evaluate the effect of phosphates with and without lime on the availability of phosphorus in the soil. At regular periodical intervals representative samples were drawn from each of the incubated beakers and analysed for available phosphorus by Bray and Kurtz No. 2 extraction method (Jackson 1958). The Klett-Summerson colorimeter was used for the estimation. The results were statistically worked out and relationships established (Table II).

TABLE II.

Availability of Phosphorus.

1. EFFECT OF PERIOD:

Period (Days)	Mean ppm, P.
I (3)	4.9614
II (40)	2.5304
III (60)	2.3112
S. Ed.	: 0.2237
C. D. (P = 0.05):	0.4452
Conclusion	: I <u>II</u> III

TABLE II (Contd.)

EFFECT OF SOILS:

Soil No.	(3)	(6)	(12)	(14)	(15)	(23)	(35)	(36)	(38)	(40)
Mean ppm. P	3.577	4.788	2.869	2.841	3.273	2.707	2.805	2.686	3.876	3.260
S. Ed.						: 0.4092				
C. D. (P=0.05)						: 0.8143				
Conclusion:	6	38	3	15	40	12	14	35	23	36

Results and Discussion : The capacity for phosphorus fixation was found to be very high and ranged from nil to as high as 100 per cent (Table I). The correlation study indicated a negative correlation between phosphorus fixing capacity of the soil and calcium phosphate ($r = -0.562$) (Fig. 1) or occluded iron phosphate ($r = -0.664$) (Fig. 2). Tiulin (1936) and Metzger (1940) showed that fixation was positively related to sesquioxides. In the present study a positive correlation between sesquioxides and fixation was observed, which however was not significant. The fixing capacity of soil did not correlate with soil pH, calcium, magnesium, rainfall or elevation.

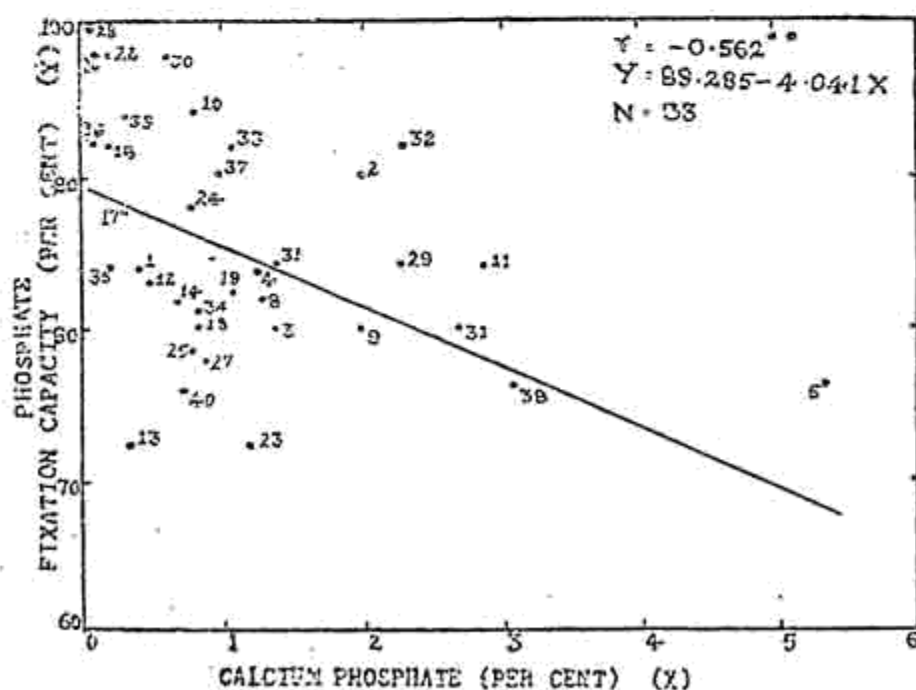


FIG. 1. CALCIUM PHOSPHATE AS PERCENTAGE OF THE TOTAL P_{205} -FIXATION CAPACITY RELATIONSHIP

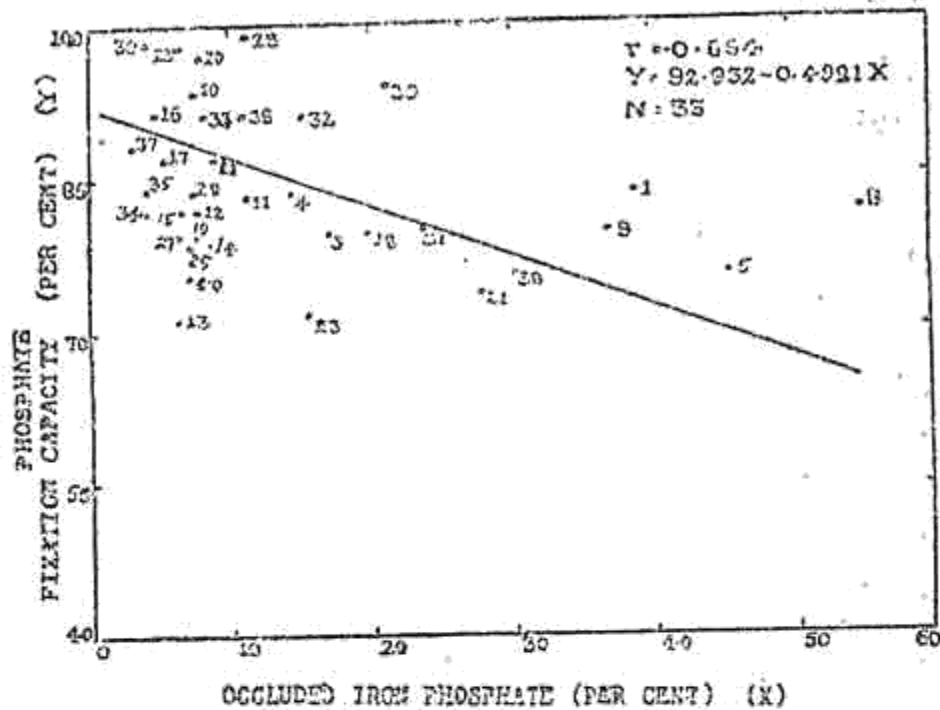


FIG. 2. OCCLUDED IRON PHOSPHATE AS PERCENTAGE OF TOTAL P_2O_5 -FIXATION CAPACITY RELATIONSHIP

The soil which was observed to have minimum pH of 4.2 and only traces of calcium phosphate showed the highest fixation of 100 per cent, while that which registered the highest calcium phosphate and pH showed minimum fixation. The available phosphorus estimated both by Bray and Kurtz No. 2 and Olsen's method, was found to be maximum where the phosphorus fixation capacity of the soil was minimum.

Kurtz, DeTurk and Bray (1946) observed a decrease in the amount of phosphate which could be removed by extractants with passage of time. Chatterjee and Datta (1951) demonstrated the possibility of increased fixation of phosphorus with time. From the incubation experiment of the present study (Table II), a similar result could be arrived at since the extractable phosphorus (Bray and Kurtz No. 2) decreased gradually with passage of time, thereby showing conversion of added phosphate into unavailable forms.

An attempt has been made to classify the soils of Nilgiris based on the observed chemical properties during analysis of variance as follows:

- Class A = Soils having a higher capacity to fix added phosphates.
- Class B = Soils having a higher capacity to fix added phosphates.

The details of some of the important properties or influencing factors are presented in the Table below:

No. S _i	Properties or influencing factors	Class A	Class B
1.	Rainfall	Below 55 inches	More than 55 inches
2.	Soil reaction	5.7 to 6.9	Less than 5.7
3.	Sesquioxides	Less than 15.0 per cent	More than 15.0 per cent
4.	Iron oxide	Less than 6.0 „	More than 6.0 „
5.	Alumina	Less than 9.0 „	More than 9.0 „
6.	Calcium oxide	More than 0.2 „	Less than 0.2 „

Summary and conclusion: The effect of the chemical forms of phosphorus of Nilgiris and the rainfall and elevation on the fixation of phosphorus was studied and the following conclusion could be made:

In spite of appreciably high phosphorus content, only very little is available. The phosphorus mineralised from the organic phosphates was very rapidly occluded and fixed as iron and aluminium phosphates. Phosphorus in aluminium phosphate was converted to occluded phosphate which might become available under favourable conditions. As one moved from a lower rainfall area to a higher rainfall area, the phosphorus was present more as insoluble aluminium phosphates than as soluble calcium phosphates and *vice versa*. Both aluminium and iron phosphates increased with elevation.

The phosphorus fixing capacity of the acid soils of Nilgiris was very high. Phosphorus fixing capacity however, did not correlate with pH, calcium, magnesium, rainfall or elevation, but gave a negative correlation with calcium phosphate and occluded iron phosphate.

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