Fixation and Availability of Phosphorus in Soils of Kerala*

(M. M. KOSHY & A. P. A. BRITO-MUTUNAYAGAM) **

INTRODUCTION

THE MAGNITUDE AND SERIOUSNESS OF THE phosphorus problems of the soils of Kerala State have been recognised for several years. Extensive fertility surveys carried out during the past three decades reveal that about 90 percent of the cultivated soils in the State are deficient in both total and available phosphorus and that this nutrient is frequently a limiting factor in crop growth. Liberal phosphate fertilization is, therefore, essential for successful crop production in Kerala. The problem of phosphorus fertilization is complicated by the fact that these soils which are of lateritic origin have very high phosphorus fixing capacities. The purpose of this investigation was to make a systematic study of certain aspects of phosphorus fixation in soils of Kerala which are important from a practical standpoint. The main phases of the problem that have been studied and reported herein are

(a) the extent of phosphorus fixation in different soils,

(b) the penetration of added phosphate into the soil, and

(c) the availability of added phosphatic fertilizers.

REVIEW OF LITERATURE

The phenomenon of phosphate fixation was first demonstrated by Way (20) in 1850. It has since been studied by a number of investigators and the literature bearing on the subject is voluminous. Historical discussions and rather extensive bibliographies, have been made available by Williams (24), Wieser (22), Midgley (15), Wild (23) and more recently by Dean (4) and Hemwall (11). As the present investigation concerns itself with a study of the extent of fixation and availability of added phosphates in Kerala soils only such publications as appeared immediately pertinent to these various aspects of the problem are cited.

(a) *Measurement of phosphate fixation:*- Various methods have been suggested for the measurement of phosphate fixation. Bryan (2) leached a column of soil with phosphate solution in successive lots until the solution came out unchanged in concentration. The amount of P_2O_5 absorbed from the solution was taken to represent the fixing capacity of the soil. Heck (10) brought the phosphate and soil to equilibrium by boiling phosphate solution with soil and extracted the available P_2O_5 with dilute acid. Hibbard (12) reckoned the fixing capacity of a soil as the number of milligrams of PO_4 to be added to one kilogram of the soil in a 1 : 1 soil-solvent ratio to give a concentration of 1 p. p. m PO_4 in the extract. This method was adopted by Kandiah (13) in his study of Ceylon soils.

* This work was carried out in the Central Research Institute of the University of Kerala.

** Senior Lecturer in Agricultural Chemistry and Professor of Agricultural Chemistry respectively Agricultural College and Research Institute, Vellayani.

(b) *Penetration of phosphate into the soil:-* A serious consequence of fixation is the low penetration into the soil of phosphate applied on the surface. Heck (9) found that in Hawaiian laterites the soluble phosphate added was held in the top half inch of the soil. Percolation studies conducted by Owen (16) with Malayan soils showed very little downward movement of phosphorus. Harrison and Das (7) reported only slight penetration of phosphates in the calcareous soils of India.

(c) *Availability of added phosphatic ferti-* fem.'-Owen (16) traced the availability of different phosphatic fertilizers in Malayan soils and found that the amount of readily soluble phosphorus decreased with increasing time of contact of the fertilizer with the soils. There was a tendency to a state of equilibrium after about three months, the amount of phosphorus extracted after this period being fairly constant. Ghani and Islam (6) studied the reversion of phosphatic fertilizers in incubated soil samples by fractionation and concluded that in acid soils phosphates reverted mainly to phosphates of iron and aluminium.

MATERIALS AND METHODS

(a) *Measurement of phosphate fixation:-* The extent of phosphate fixation in six surface soils was measured by the methods suggested by Heck (10) and Hibbard (12), with slight modifications. I he more important chemical characteristics of the soils used in this study are given below :-

TABLE I.

Chemical character of soils

Sl. No.	Locality	PH	Organic Carbon percent	Sesqui-oxides percent	CaO percent	P_2O_5 percent
1.	Mundar–Vaikom	4.0	4.17	21.62	Trace	0.060
2.	Vazhappally-Changanacherry	4.4	2.02	15.22		0.024
3.	Kayamkulam–Karthikappally	5.5	0.28	5.50		0.024
4.	Karaikkal- Thiruvalla	5.5	0.85	27.30		0.078
5.	Kaviyoor-Thiruvalla	6.4	1.32	26.30		0.090
6	Vallamkulam–Thiruvalla	6.8	2.22	35.26		0.256

In the modified Heck's method 5 g. of the soil were placed in a 500 ml. Erlenmeyer flask and the specified amount of P_2O_5 as H_3PO_4 in 50 ml solution added to it. The flask was heated and the contents slowly evaporated to dryness on a sand bath. 2 g. of the treated soil were extracted with 200 ml. of $\frac{N}{5}$ acetic acid. A control was also run. The amount of phosphate extracted from the treated sample minus the amount dissolved from the untreated sample gives the amount of the applied phosphorus recovered. The value so obtained subtracted from the added phosphate gives the phosphate fixed in an unavailable form. The results obtained are presented in Table III .

In Hibbard's method 100 g. of the air-dried soil were mixed with 100 ml portions of aqueous solutions containing three different amounts of KH_2PO_4. The mixtures were shaken in an end-over-end shaker for half an hour, kept overnight, filtered and the amount of PA in the filtrates estimated. From the data thus obtained the amount of P_2O_5 that must be added to give an extract containing 1 p, p. m. P_2O_5 was determined. This value expressed as mg. P_2O_5 per kg of soil gives its fixing capacity. The results are shown in Table IV.

(b) *Penetration of phosphate into the soil:*— Percolation studies similar to those conducted by Owen (16) were carried out to determine the extent of downward movement of phosphate in soils. Typical samples of two well defined soil types were used, viz.,

(i) an acid peat *(Kari)*, and

(ii) an alluvival clay (Kuttanad).

The important chemical characteristics of these soils are presented in Table II and the results of the percolation studies in Table V.

TABLE II.

Chemical character of *Kari* and Kuttanad soils.

Soil	pH	Organic Carbon percent	Sesqui-oxides percent	CaO percent	PA percent
Kari	4.2	8.76	10.19	0.18	0.032
Kuttanad	5.8	2.21	28.40	Trace	0.060

(c) *Availability of phosphatic fertilizers:*— The phosphatic fertilizers used in this investigation were superphosphate, ammophos, bonemeal and rock phosphate. The availability of these different fertilizers was also studied in typical *Kari* and Kuttanad soils by incubating 50 g. portions of the soil mixed with two different levels of the fertilizer and extracting the readily available phosphorus at various [illegible] using N/2 acetic acid. The results are given in Tables VI and VII.

RESULTS

The measurement of phosphate fixation by Heck's method (Table III) shows a high percentage of fixed phosphorus in all the soils studied. For a rate of application of 100 mg. per 100 g. of soil fixation in these soils varied from 79.7 percent in the sandy soil from Kayamkulam to 98.8 percent for the clay soil from Karaikkal. Fixing capacities determined by Hibbard's method (Table IV) shows a wide variation ranging from 33 mg. to 955 mg. P_2O_5 per kilogram of soil. The highest fixation occurs in the acid clay from Karaikkal and the lowest in the *Kari* soil from Mundar.

TABLE III.

Fixation and availability of phosphate in soils (Heck's method).

Mg. P_2O_5 per 300 g. of soil.

Sl. No.	Locality	Phosphate applied	Phosphate fixed	Phosphate available
1	Mundar	20.0	19.2	0.8
		40.0	38.1	1.9
		100.0	97.3	2.7
2	Vazhappally	20.0	19.3	0.7
		40.0	37.9	2.1
		100.0	96.5	3.5
3	Kayamkulam	20.0	18.9	1.1
		40.0	37.6	2.4
		100.0	79.7	20.3
4	Karaikkal	20.0	19.8	0.2
		40.0	39.6	0.4
		100.0	98.8	1.2
5	Kaviyoor	20.0	19.6	0.4
		40.0	38.6	1.4
		100.0	96.3	3.7
6	Vallamkulam		19.3	0.7
		40.0	38.8	1.2
		100.0	97 6	2.4

TABLE IV.

Fixing capacities of soils (Hibbard's method)

Sl. No.	Locality	P_2O_5 added per 100g. of soil mg.	P_2O_5 remaining in solution p.p.m.	Fixing capacity-mg. P_2O_5 per kg. soil
I	Mundar	2.5	0.86	
		5.0	1.33	33
		10.0	1.76	
2	Vazhappally	40.0	0.66	
		50.0	0.88	575
		60.0	1.04	
3	Kayamkulam	15.0	0.75	
		20.0	1.82	165
4	Karaikkal	40.0	0.38	
		80.0	0.70	955
		120.0	1.48	
5	Kaviyoor	60.0	0.66	
		80.0	0.92	820
		100.0	1.82	
6	Vallamkulam	40.0	0.56	
		75.0	0.80	875
		100.0	1.20	

The data in Table V relating to the downward movement of phosphorus reveal that the soil allows penetration to a greater degree than the less acid soil from Kuttanad. It will be observed that about 28 percent of the phosphate applied on the surface is held in the first one inch and about 50 percent in the first two inches of this soil. The corresponding values for the Kuttanad soil are 46 percent and 80 percent indicating considerably less phosphate penetration.

The results of the treatment of soils with phosphatic fertilizers are presented in Tables VI and VII. The available phosphorus decreases progressively with time of contact of the soil and the fertilizer and there are indications of a state of equilibrium being reached after about eight to twelve weeks. Rock phosphate gives the highest amount of phosphorus soluble in N/2 acetic acid in both the soils studied. Ammophos also leaves appreciable amounts of available phosphorus

TABLE V

Penetration of phosphate in soils.

Depth	Total P_2O_5 retained in the soil expressed as percent of amount added					
	Kari soil			Kuttanad soil		
	Tube I	Tube II	Mean	Tube I	Tube II	Mean
0″–1″	28.0	27.4	27.7	44.0	42.8	43.4
1″–2″	21.0	24.4	22.7	41.6	38.6	40.1
2″–3″	15.2	19.6	17.4	9.6	10.9	10.3
3″–4″	10.4	13.4	11.9	2.0	7.1	4.6
4″–5″	6.0	6.4	6.2	1.0	1.4	1.2
5″–6′	4.0	2.2	3.2	Trace	1.3	0.7
6″–8″	5.6	6.0	5.8	..	0.8	0.4
8″–10″	4.0	3.0	3.5	..	Trace	Trace
10″–12″	4.0	2.5	3.0	..	..	

immediately after mixing, but with time the available amounts tend to be more or less equal for the different fertilizers.

DISCUSSION

The results of this investigation reveai that the soils of Kerala possess very high capacities for phosphate fixation. This may be attributed to the acidic nature and the high sesquioxide content of these soils. Several investigators (3, 8, 14, 17) have demonstrated that the oxides of iron and aluminium play an important role in the fixation of phosphorus by soils under acid conditions. The low fixing capacity of the *Kari* soil from Mundar might be due to its high content of organic matter. Doughty (5) has established that natural or synthetic humus does not fix phosphorus. The investigations of Kandiah (13) confirm the view that organic matter plays only a minor role in fixation. The high sesquioxide content of Kuttanad soil is also responsible for the poor penetration of phosphorus while in the *Kari* soil the relatively low amount of sesquioxides and the high level of organic matter facilitate the downward movement of phosphorus.

It is significant to note that rock phosphate gives the highest amount of acetic-acid soluble phosphorus when mixed with these acid soils. This is evidently because this insoluble form of phosphate is not easily reverted in the but is slowly dissolved by the soil solution. According to Bauer and Haas (1), if the [illegible] removes calcium together with phosphorus from the soil, the rock phosphate continues to go into solution, whereas under conditions of calcium accumulation rock phosphate is not dissolved. Roberts (19) found that rock phosphate produced as good results as superphosphate under acid conditions. The results obtained

TABLE VI.

Change in available phosphate in *Kari* soil with time, amount and kind of fertilizer.

Mg. P_2O_5 per 100 g of soil

Fertilizer		Time								
Kind	Amount	1 hour	1 day	1 week	2 weeks	4 weeks	8 weeks	12 weeks	16 weeks	20 weeks
Superphosphate	20.0	5.4	5.3	3.8	2.3	2.0	1.7	1.6	1.6	1.6
	40.0	9.0	8.9	6.4	4.7	3.6	3.4	3,4	2.9	2.9
Ammophos	20.0	5.5	5.0	3.8	2.4	2.0	1.3	1.3	1.3	1.3
	40.0	12.5	12.2	8.5	6.5	3.4	3.3	3.4	3.2	3.2
Bonemeal	20.0	5.0	5.1	2.5	3.1	2.2	1.8	1.8	1.8	1.8
	40.0	8.8	13.0	10.5	7.5	4.3	4.0	3.9	3.5	3.4
Rock phosphate	20.0	10.0	10.0	6.8	4.8	2.4	2.5	2.5	2.5	2.5
	40.0	17.8	17.8	15.0	13.0	6.2	6.1	6.0	5.9	5.9
Control		1.2	1.1	1.0	0.9	0.9	0.9	0.9	0.9	0.8

TABLE VII.

Change in available phosphate in Kuttanad soil with time, amount and kind of fertilizer

Mg. P_2O_5 per 100 g. of soil.

Fertilizer		Time								
Kind	Amount	1 hour	1 day	1 week	2 weeks	4 weeks	8 weeks	12 weeks	16 weeks	20 week
Superphosphate	20.0	1.6	1.1	0.9	0.7	0.7	0.5	0.3	0.3	0.3
	40.0	4.8	3.1	2.5	2.0	2.0	1.1	1.1	1.1	1,0
Ammophos	20.0	1.7	1.1	0.9	0.7	0.7	0.5	0.3	0.3	0.3
	40.0	5.9	3.7	3.0	2.6	2.0	1.1	1.1	1.1	1.1
Bonemeal	20.0	1.4	1.1	1.5	0.7	0.5	0.4	0.4	0.4	0.3
	40.0	2.8	2.5	2.6	1.2	1.7	1.0	1.0	1.0	1.2
Rock phosphate	20.0	1.9	1.9	1.6	1.2	1.0	1.0	1.0	0.9	0.9
	40.0	5.2	7.8	6.4	6.2	6.0	4.9	4.9	4.9	4.9
Control		0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2

in the present investigation should not, however, be considered as conclusive and more elaborate experiments are required to study the relative availability of different phosphates under field conditions.

Although phosphate fixation is often deplored as a serious problem endangering the economic use of soluble phosphatic fertilizers, there are certain beneficial aspects associated with this phenomenon. Thus the fixation of phosphorus in soils guards against the loss of this nutrient by leaching and results in its conservation in the soil. While considerable amounts of nitrogen and lime together with small amounts of potash are washed out of soils in the drainage waters the loss of phosphorus in this manner is inconsequential (21,25). Further, as soluble phosphates are converted into insoluble iron and aluminium compounds in acid soils, the application of soluble phosphatic fertilizers helps to remove toxic concentrations of aluminium in the soil solution by combining with it (18). The view that available phosphorus is in a state of dynamic equilibrium with the less soluble phosphates in the soil implies that the available supply will be replenished as plants remove the available forms from the soil. These considerations tend to reduce the gravity sometimes attached to the fixation of phosphorus in soils.

SUMMARY

A study was made of the fixation and penetration of soluble phosphates and the availability of different phosphatic fertilizers in some soils of Kerala.

It was found that the soils studied differ widely in their capacities to fix phosphorus. Acid soils with high sesqioxide content have high capacities for fixation. The downward movement of phosphorus in Kuttanad soil was very low. The penetration of phosphorus in *Kan* soil rich in organic matter was much higher.

Incubation studies with different phosphatic fertilizers showed that the available phosphorus was highest immediately after mixing the soil with the fertilizer and that the amount decreased progressively with time. Rock phosphate gave higher amounts of phosphorus soluble in N 2 acetic acid as compared to other fertilizers.

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