https://doi.org/10.29321/MAJ.10.A03717

Availability of Phosphorus in Nilgiri Soils*

by

K. K. MATHAN[1] and D. JOHN DURAIRAJ[2]

Introduction: Availability of phosphorus in soils is one of the factors affecting crop production. In acid soils, though total phosphorus is high, its availability is very low due to adverse environmental and resulting pedogenic factors. An attempt was made therefore, to assess the phosphorus availability in soils of Nilgiris, and to study the effect of rainfall, elevation and various chemical constituents like organic carbon, sesquioxides, calcium, magnesium, cation exchange capacity, on the availability of phosphorus. Based on the observations made, a tentative division of the soils was done with reference to availability of phosphorus and response to lime.

Review of Literature: An integrated action of the factors like organic carbon, finer fractions of soil and pH has been emphasised by Mehta and Patel (1963). Mcgeorge (1939) stated that pH was the principal limiting factor in phosphate availability in Arizona soils. Raychaudhuri and Landy (1960) reported the influence of pH on available phosphorus. Robertson, Neller and Bartlett (1954) reported lower available phosphoric acid with higher sesquioxides.

Hilgard (1907) found that liming favoured availability of soil phosphorus. Struthers and Seiling (1950) reported that increase in phosphorus availability associated with liming of acid soils might be due primarily to the presence of higher quantities of organic anion produced as a result of stimulated microbial activity.

Work in the Chemistry Section of Agricultural College and Research Institute, Coimbatore (Reports for 1948–'51) showed that lime did not confer any beneficial effect on potato crop. In 1951–'54 an increased yield and higher availability of phosphorus was attained in low level laterite soils at Pattambi (Kerala) by the application of lime along with superphosphate. Effect of lime was found to be due to rise in pH, reducing chances for reversion on applied soluble phosphate. Naga Bhushana (1961) observed increase in phosphorus availability due to liming brought about by better oxidation of organic matter, decrease in iron and aluminium activity and increase in pH.

* Formed part of the M. Sc. (Ag.), dissertation submitted to the Madras University by the first author under the guidance of the second author.

[1] Assistant in Chemistry, [2] Professor of Soil Science, Agricultural College and Research Institute, Coimbatore - 3.

Received on 21—5—1966.

Chang and Jackson (1958) attributed the lack of crop growth response added phosphorus, even though surface soils had low pH test, to higher content of available phosphorus in the sub-soils and release of phosphorus in the surface soils brought about by liming through decrease in iron and aluminium activity. Kereszteny and Perjamosi (1961) observed a positive correlation between availability of added phosphorus and the available phosphorus content of the soil. Durairaj (1960), working on Dewey, Grenada and Hartsells soils in United States observed that phosphate extracted by common extractants decreased with passage of time. Forms of soil phosphorus were found by Patel and Mehta (1961) to influence availability.

Experimental details: Forty surface soil samples in the Nilgiris were collected mainly from uncultivated areas representing the wide range of rainfall and elevation. The soils were analysed for physical and chemical properties related to the present study (Table I).

TABLE I

Range and mean values of chemical analysis, pH and cation exchange capacity.

S. No.	Particulars of Chemical analysis	Range of values Minimum	Maximum	Mean of 40 samples
1.	Lime (CaO) (Percentage)	0.05	1.80	0.28
2.	Magnesia (MgO) (Percentage)	0.01	0.76	0.28
3.	Total P_2O_5 (Percentage)	0.024	0.347	0.142
4.	Available P_2O_5 (Citric acid soluble) (Percentage)	0.0003	0.0194	0.0033
5.	Bray and Kurtz No. 2 (ppm)	9.08	225.20	20.70
6.	Olson's method (ppm)	1.24	89.66	6.47
7.	Cation Exchange Capacity (m. e. %)	3.05	17.66	9.52
8.	Exchangeable cations-Ca (m. e. %)	1.74	10.68	4.36
9.	Exchangeable cations-Mg (m. e. %)	0.29	8.08	3.54
10.	pH	4.2	6.9	—
11.	SiO_2/R_2O_3	0.15	3.16	0.847

Details of the soil samples, mean annual rainfall, elevation, organic carbon, total phosphoric acid and the various fractions of phosphorus are furnished by Mathan and Durairaj (1965). The methods followed in the analysis were those described by Piper (1950), Methods of Association of Officials Agricultural Chemist (U. S. A.) (1955) and Jackson (1958). The data obtained from the above studies were analysed statistically and relationships were established (Table III).

A soil incubation study was carried out in backers to evaluate the effect of superphosphate, Nanjanad mixture with and without lime on the availability of phosphorus in the soil. Throughout the period, the soil was kept at their respective water holding capacity. 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 (Table II).

TABLE II

Incubation Study - Availability of Phosphorus

	Treatments	Mean ppm. P
1.	EFFECT OF TREATMENT:	
A.	Control	2.560
B.	3000 lb. $CaCO_3$ per acre	3.160
C.	Super alone at the rate of 214 lb. P_2O_5 per acre	2.556
D.	Super at the of 214 lb. P_2O_5 per acre + 3000 lb. $CaCO_3$ / ac.	3.834
E.	Nanjanad mixture alone at 214 lb. P_2O_5 / ac.	2.441
F.	Nanjanad mixture at 214 lb. P_2O_5 / ac + 3000 lb. $CaCO_3$ / ac.	3.688
	S. Ed. : 0.3980	
	C. D. (P=0.05) : 0.8040	
	Conclusion : D F B C A E	

Periods	Days	Mean ppm. P
2. EFFECT OF PERIODS:		
I	(3)	4·359
II	(40)	2·529
III	(60)	3·238
S. Ed. : 0·2816		
C. D. (P=0·05) : 0·5688		
Conclusion : I II III		

Results and discussion: The soils of Nilgiris in Madras State are acidic, having a very low percentage of available phosphoric acid inspite of the presence of appreciably high amounts of total phosphoric acid. Rainfall and elevation, through their various manifested effects cause a complex phosphate problem throughout the district. The observed data, therefore, have been discussed with reference to the various factors which influence the availability of phosphorus.

TABLE III

Results of Statistical Analysis

S. No.	Relationship between: X	Relationship between: Y	Correlation Coefficients	Regression equation	No. of pairs of values
1.	Elevation (Below 5000')	Available P_2O_5 (Dyer's method)	+ 0·784 †	Y = 0·0125 X — 17·76	18
2.	Elevation (Above 5000')	Available P_2O_5 (Dyer's method)	+ 0·880 †	Y = 0·03 X — 158·9	11
3.	Elevation	Alumina	+ 0·575 †	Y = 4·85 + 0·0019 X	38
4.	Elevation	Reciprocal of calcium	+ 0·678 ‡	Y = 0·0011 X — 0·244	29
5.	Elevation (Soils with more than 14% alumina)	Reciprocal of magnesium	+ 0·980 †	Y = 0·0011 X — 1·179	12
6.	Elevation (Soils with less than 14% alumina)	Reciprocal of magnesium	+ 0·978 †	Y = 0·0018 X — 2·296	7
7.	Rainfall	Available P_2O_5 (Olsen's method)	— 0·872 †	Y = 8·132 — 0·0437 X	24
8.	Rainfall	Calcium Oxide	— 0·780 ‡	Y = 6600 — 50·46 X	8
9.	Rainfall	Magnesium Oxide	— 0·440 *	Y = 4280 — 13·9 X	25
10.	Rainfall	Exchangeable Calcium	— 0·243	Y = 0·987 — 0·0483 X	20
11.	Rainfall	pH	— 0·676 †	Y = 6·280 — 0·101 X	21
12.	Total P_2O_5	Available P_2O_5 (Olsen's method)	+ 0·488 ‡	Y = 2·413 + 0·0008 X	37
13.	Calcium phosphate	Available P_2O_5 (Olsen's method)	+ 0·474 †	Y = 2·407 + 0·0906 X	37
14.	Occluded Aluminium phosphate	Available P_2O_5 (Dyer's method)	+ 0·805 †	Y = 1·209 X — 55·26	29
15.	Occulded Aluminium phosphate	Available P_2O_5 (Olsen's method)	+ 0·767 †	Y = 0·909 X + 0·027	33
16.	Cation exchange capacity	Available P_2O_5 (Olsen's method)	+ 0·340 *	Y = 2·273 + 0·1481 X	38
17.	Exchangeable calcium	Available P_2O_5 (Dyer's method)	+ 0·532 ‡	Y = 11·64 X — 0·59	3[illegible]
18.	Aluminium phosphate (Soils from above 5000')	Available P_2O_5 (Dyer's method)	+ 0·823 ‡	Y = 0·8191 X — 81·0	1[illegible]

The Dyer's citric acid extractable phosphorus gave positive correlation with aluminium phosphate and occluded aluminium phosphate. This is presumbly due to the fact that citric acid is known to extract insoluble iron phosphate also (Russell 1963) which in turn, was positively correlated with aluminium phosphate in the present work. Citric acid extractable phosphoric acid exhibited a positive correlation with calcium phosphate. Olsen's bicarbonate extractable phosphorus correlated positively with occluded aluminium phosphate and calcium phosphate. Similar results were reported by Patel and Mehta (1961). Ghani and Islam (1946) reported a positive relationship between total phosphoric acid and the available phosphoric acid. Similar results were obtained during the present study also (Fig. 1).

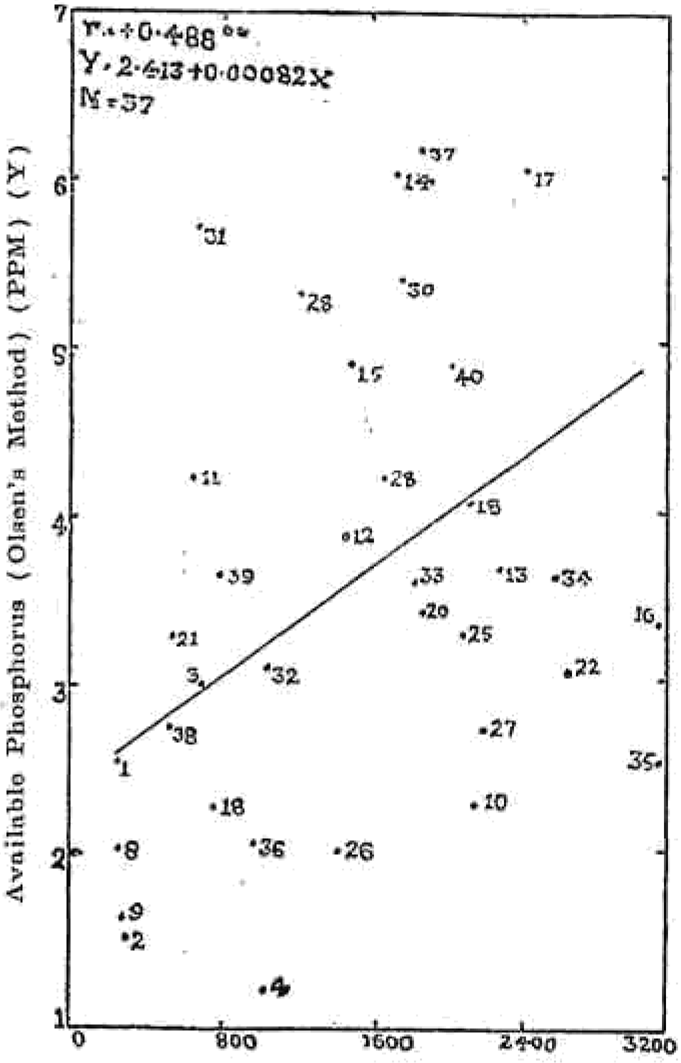


Fig. 1. Total P_2O_5 – Available Phosphorus (Olsen's Method) Relationship

Rainfall and elevation : With increasing rainfall, available phosphorus (Olsen's Method) decreased (Fig. 2). This might again be an indirect effect of lowered calcium, magnesium and pH due to increased rainfall.

Magnesium positively influenced the available phosphorus (Fig. 3). Rudhra Setty (1962) observed a similar effect of magnesium on phosphorus availability.

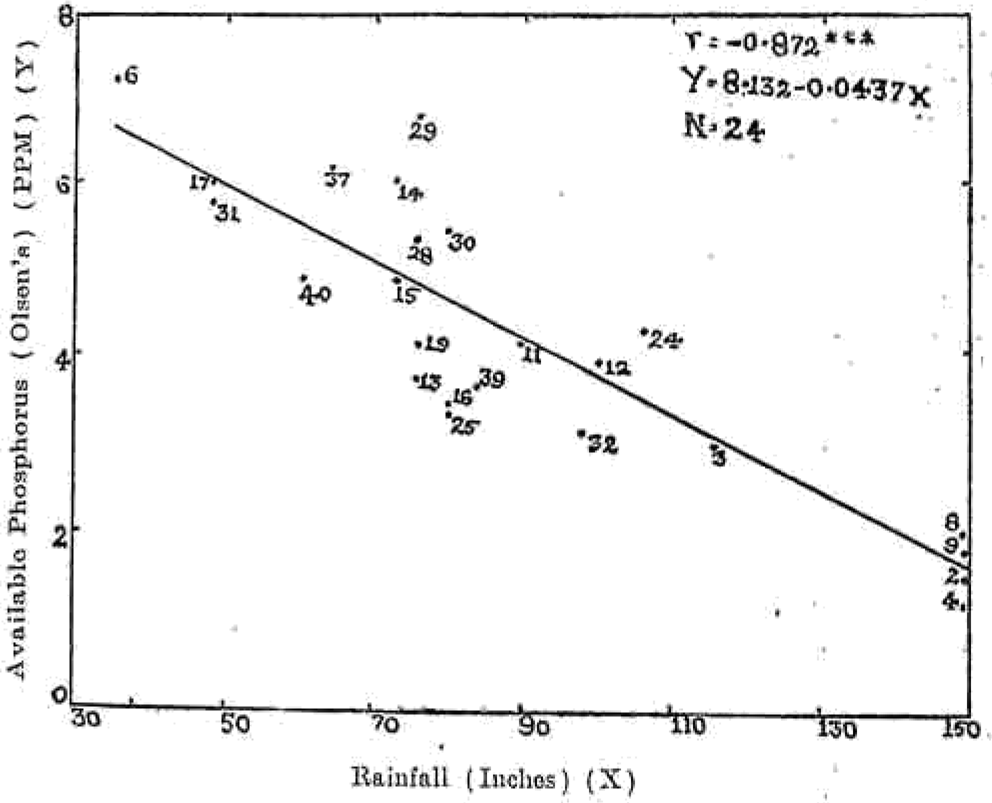
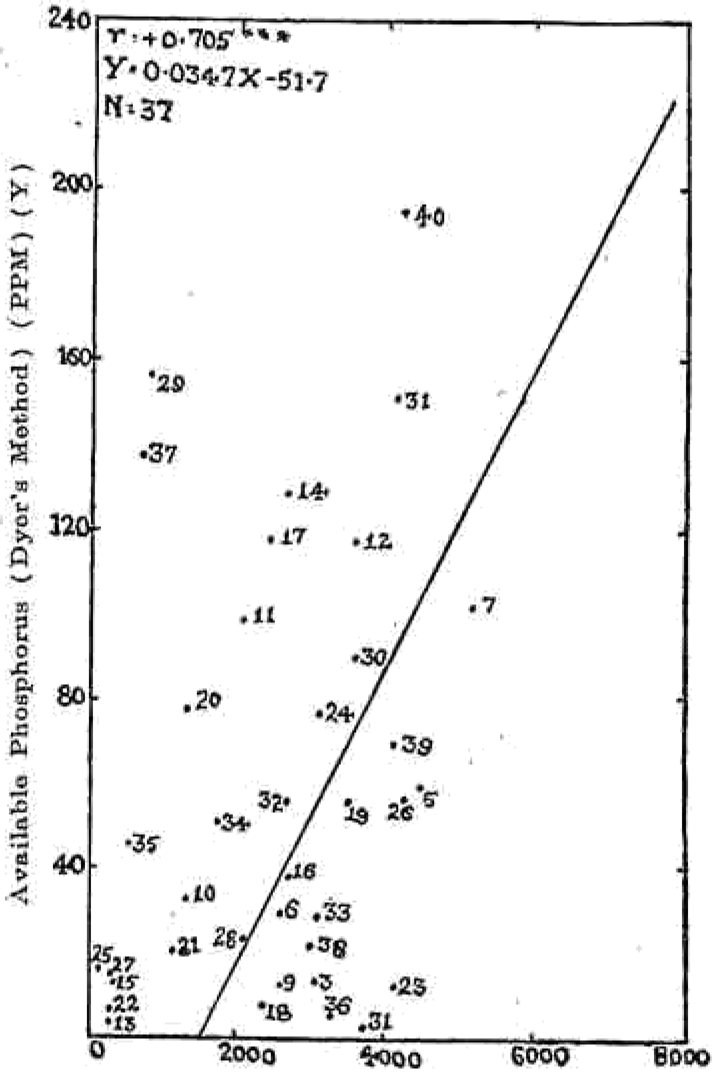


Fig. 2. Rainfall - Available Phosphorus (Olsen's) Relationship

Available phosphorus (Dyer's method) increased with elevation. This seemed to be the indirect effect of increase in the alumina content, aluminium phosphate and iron phosphate. At higher altitudes, since calcium and magnesium decreased considerably, the possibility of available phosphorus being higher due to calcium and magnesium was ruled out, thus explaining the indirect influence of alumina.

Clay: The silica, sesquioxides ratio (SiO_2/R_2O_3) usually never exceeded two (Table I), the maximum limit for kaolinite. Moreover, the cation exchange capacity was within the theoretical value of 3 to 15 m. e per 100 gms. for kaolinite. Thus the Nilgiri soils appeared to have kaolini as the dominant clay mineral and the available phosphorus was observed be low in Nilgiris wherever the kaolinite clay minerals dominated. could be accounted for by the fact that kaolinite is stable and restricted interface and low adsorptive capacity for cations, but same time exibiting a higher anion exchange capacity, (Buckm Brady, 1960). Low phosphorus availability in kaolinite has been by Murphy (1939).



Magnesium Oxide (PPM) (X)

Fig. 3. Magnesia - Available P_2O_5 (Dyer's Method) Relationship

Liming and time: A significant increase in the release of phosphorus due to liming the low level laterites of Pattambi had been reported by the Chemistry Section, Agricultural College and Research Institute, Coimbatore in its report on the studies on the laterite soils of Madras State (1954). Rai *et al* (1963) also reported similar effects of liming. In the present study liming superphosphate and Nanjanad mixture seems to increase significantly the release of available phosphorus carrier. Durairaj (1960) reported that phosphorus became more difficultly extractable with time in acid soils of South East United States. Similar effect has been obtained in the present study.

Effect of pH and other factors: The available phosphorus was not influenced by the pH or organic carbon. This was in line with the work of Rajagopal and Idnani (1963) who stressed that pH alone could not be assumed to be a major factor in soil phosphorus availability for Nilgiris soils.

Ghani and Islan (1346) reported a positive relationship between available phosphoric acid on the one hand and the cation exchange capacity, exchangeable calcium, total phosphoric acid content of the soil on the other. Similar results were obtained in the present study also. The available phosphorus did not correlate with sesquioxides. This was in line with the findings of Ghani and Aleem (1943).

Summary and conclusion: The study on the influence of rainfall, elevation, chemical components and various discrete forms of soil phosphorus present in the soils of Nilgiris on the availability of phosphorus revealed that in spite of the presence of high amounts of total phosphoric acid only very little was in the available form. Unreliability of the Dyer's citric acid extraction method for estimating available phosphoric acid in acid soils of Nilgiris was indicated by a positive correlation of citric acid extractable phosphorus with aluminium phosphate. A positive correlation with calcium phosphate was aiso observed in the present work. Olsen's bicarbonate extractable phosphorus correlated positively with calcium phosphate, occluded aluminium phosphate and total phosphoric acid.

Available phosphorus (Olsen's method) increased with decrease in rainfall. Available phosphorus (Dyer's method) increased with elevation indirectly due to rise in alumina content with elevation. Available phosphorus was observed to be low in soils when kaolinite type of clay minerals dominated. This might be due to higher anion exchange capacity of kaolinite and its low adsorptive capacity for cations.

Liming laterite soils increased the release of available phosphorus. Added phosphates decreased gradually in their availability with time. Available phosphorus increased with magnesium, calcium, cation exchange capacity, exchangeable calcium and the total phosphoric acid content of soil. No correlation was obtained between available phosphorus and pH or organic carbon.

Acknowledgement: Thanks are due to the University of Madras for granting permission to publish the dissertation to the Government of Madras for granting merit scholarship to the first author during the period of study.

REFERENCES

Anonymous (Agricultural Department, Madras) 1951 Fertilizer studies with potato (Studies on the reduction of manure without detriment to crop yield or productivity of the soil). (Unpublished).

——— 1954 Report on studies on laterite soils in Madras State. (Unpublished).

——— 1963 Annual report of scheme for maximisation of phosphate potential in soils of Madras State.

Association of official Agricultural Chemists 1955 *Methods of Analysis.*

Buckman, H. O. and N. C. Brady 1960 *The Nature and Properties of Soils.* The Macmillan Company, New York. Bratt—Macmillan Ltd. Galt, Ontario. p. 75 and 440.

Chang, S. C. and M. L. Jackson 1958 Soil phosphorus fractions in some representative soils. *J. Soil Sci.*, 9: 109—118.

Durairaj, D. J. 1960 *Solubility measurements as a means of studying the reaction of phosphorus compound with soils at different pH levels. A thesis presented to the Graduate Council of the University of Tennessee in partial fulfilment of the requirement for the degree of Master of Science, 1960.*

Ghani, M. O. and S. A. Aleem 1943 Fractionation of soil phosphorus I. Studies on the distribution of different forms of phosphorus in some Indian soils. I. Surface distribution. *Indian J. agic. sci.*, **13**: 377—381.

Ghani, M. O. and Islam, M. A. 1946 Phosphate fixation in acid soils and its mechanism. *Soil Sci.*, 62 : 293—306.

Hilgard, E. W. 1907 *Soils, their formation, properties, composition and relation to climate and plant growth in the Humid and Arid region. The Macmillan Company, New York. (Abstracted by Pierre W. H. and Norman, A. G. Soil and Fertilizar Phosphorus in Crop Nutrition. Acadenic Press Inc. Publishers. New York.* 1953 *)*

Jackson, M. L. 1958 *Soils, Chemical Analysis.* Constable Co., Ltd , London.

Koreszteny, B. and M. Poreamosi 1961 The effect of soil characteristics on the phosphorus fixing Capacity. Abstracted *Soils and Fert.* 25 : 180.

Mathan, K. K. and D. J. Durairaj 1965 Distribution of phosphorus in Nilgiri soils (Under publication).

Mc George, W. T. 1939 Factors influencing the availability of native soil phosphate and phosphate fertilizers in Arizona soils. *Arizona Agr. Expt. Sta. Tech. bull.*, 82 : 1939. (Abstracted by *Pierre, W. H. and Norman, A. G. Soil and Fertilizer Phosphorus in Crop Nutrition.* Academic Press Inc. Publishers, New York, pp. 102 1953.)

Mehta and J. M. Patel 1963 Some aspects of the phosphorus availability in Gujarat soils. *J. Indian Soc. Soil. Sci.*, **11** : 151-158.

Murphy, H. F. 1939 The role of kaolinite in phosphate fixation. *Hilgardia*, **12** : 343–382.

Nagabhushana, S. R. 1961 *The effect of liming on the fixation and availability of phosphorus in high level lateritic soils of Mysore State.* Dissertation submitted to and accepted by the University of Madras for the award of the degree of Master of Science in Agriculture.

Patel, J. M. and B. E. Mehta 1961 Soil phosphorus fractionation studies. *Soil Sci. Soc. Amer. Proc.*, **25** : 190–192.

Piper, C. S. 1950 *Soil and Plant Analysis.* New York Inter Science Publishers.

Rai, A. K., C. R. Prasad, and S. C. Manda 1963 Effect of liming on availability of phosphate in an acidic red loam soil. *J. Indian Soc. Soil Sci.*, **11** : 137–140.

Rajagopal, C. K. and M. A. Idnani 1963 Some aspects of phosphorus fertilization in the Nilgiris soils. *J. Indian Soc. Soil Sci.*, **11** : 141–150.

Raychaudhuri, S. P. and R. J. Landy 1960 Effect of soil reaction on the availability of phosphorus and potassium. *J. Indian Soc. Soil Sci.*, **8** : 171–175.

Rudhra Setty, T. M. 1962 *Influence of magnesium, on phosphorus availability and on nutrient element uptake by Ragi in three South Indian Soil types.* Dissertation submitted to and accepted by the University of Madras for the award the degree of Master of Science in Agriculture.

Robertson, W. K., J. R. Neller, and F. D. Bartlette 1954 Effect of lime on the availability of phosphorus in soils of high to low sesquioxide contents. *Soil Sci. Soc. Amer. Proc.*, **18** : 184–187.

Russell, E. W. 1963 *Soil conditions and plant growth.* Longmans Green and Co. Ltd. p. 493–496.

Struthers, P. H. and D. H. Siling 1950 Effect of organic anions in phosphates precipitation by iron and alumina as influenced by pH. *Soil Sci.*, **69** : 205–213.