ΕΔΑΦΟΛΟΓΙΑ.— **Phosphorus fixation parameters of representative soils and their relationship to soil properties,** *by A. D. Simonis**, διὰ τοῦ Ἀκαδημαϊκοῦ κ. Ἰωάννου Παπαδάκη.

INTRODUCTION

The capacity of soils to fix applied P in forms unavailable to plants influences, directly, the mechanisms which control the nutrition of plants with P. Each soil has its fixing capacity for P, which muct be satisfied, before a change in soil solution occurs. Hence, the knowledge of the phosphorus fixation parameters of soils is imperative for making rational statements about P availability and P fertilizer requirements. Soils of an area can be grouped according to their phosporus fixation parameters, and this information can be used with soil test data, for the purpose of making fertilizer recommendations.

Various methods and techniques are used for estimating soil phosphorus fixation parameters. Among them the sorption approach method has much to comment it (5, 14, 18). The P concentration of the soil solution, in combination with the amount of P adsorbed in the solid phase of the soil (i.e. the adsorption isotherms) determines the amount transferred to the plant roots [15]. Modern considerations on the problems of soil P fixation, have been deeply, influenced by the concept of external P requirements of crops (optimum P concentration in soil solution for plant growth), which can be combined with P adsorption curves of soils to determine fertilizer P requirements [4].

Many soil properties affect the P fixation capacity of soils, such as clay minerology, clay content, x-ray amorphous colloid content, exchangeable Al and Fe and soil organic matter [18]. Saunders [20] reported that fixation of phosphate by New Zealant topsoils, was closely, correlated with organic C, total N, loss on ignition, organic P and extractable Al and Fe.

In the current study, we continue our work on the P problems in Greek

* Α. Δ. ΣΙΜΩΝΗ, **Παράμετροι δέσμευσης φωσφόρου ἀντιπροσωπευτικῶν ἐδαφῶν καὶ ἡ σχέση τους μὲ τὶς ἰδιότητες τοῦ ἐδάφους.**

soils [21, 22, 23]. The purpose is to investigate the P-fixation parameters of 27 representative soils and their relationship to soil properties.

MATERIALS AND METHODS

Twenty-seven representative surface soil samples were selected from different locations of Northern Greece, for the purpose of this work. Their parent material, classification and some physicochemical characteristics, are given in Table 1.

The determination of general characteristics of the soils was carried out according to the standard procedures [9]. The free iron and alluminum oxides of the soils were determined by the dithionate-citrate-bicarbonate (DCB) method [11]. The available P of the soils was determined by the methods of Olsen [13], resin [3], Bontorf [2] and Electro-Ultrafilration (EUF) [12] and the P buffering capacity P-BC) according to the procedure of Ozanne and Shaw [16].

The P fixing capacity of the soils was assessed from the phosphorus fixation (absorption) isotherms (curves), which were constructed according to the procedure of Fox and Kamprath [5]. A known amount of soil (3 g) was equilibrated with various amounts of $Ca(H_2PO_4)_2$ in 0,01 M $CaCl_2$ (30 ml) and shaken for 30 min, twice a day, for 6 days, after which the P remaining in solution, was measured. The fixing capacity was, also, assessed by shaking samples, in a solution of 50 ppm KH_2PO_4 (soil: solution ratio was 1:10), for 24 hours. The P-fixation index of soils - the quantity of P_2O_5 required to increase the available P value (Olsen-P) of soils by 1 mg P_2O_5/100 soil - was, also, used as a P fixation parameter of the soils. To this and, various levels of P_2O_5 were added to the soil samples, and after the fixation, the extraction of P was carried out with a solution of 0.5 M $NaHCO_3$.

RESULTS

The P fixation (absorption) curves for the 27 soils studied, are presented in Fig. 1. The amounts of P which were fixed by the soils, are plotted in Fig 1. The amounts of P which were fixed by the soils, are plotted on the y axis and that remaining in solution, on the logarithmic x axis. The vertical line indicates the standard concentration of 0.2 ppm in solution [1] and the amount of P required to give this concentration in solution was considered, as the agronomically relevant estimate of P fixation [5].

TABLE 1

Parent material, Classification and general physical and chemical characteristics of soils studied

No soil	*Parent material	Creat soil group		Clay %	silt %	pH	$CaCO_3$ %	organie matter %	CEC me]100 soil
1	sch. micaceous	Typic	Eutrcchrepts	18.8	45.6	4.72	-	3.80	19.90
2	sch. micaceous	Lithic	Dystrochrepts	17.2	40.8	4.18	-	1.01	35.10
3	col. limest.	Typic	Eutrochrepts	7.2	33.2	6.35	-	3.52	25.20
4	granite	Typic	Dystrochrepts	9.2	29.6	5.45	-	1.44	25.17
5	dep. mic. sch.	Ultic	Haploxeralfs	17.2	24 8	5.45	-	1.79	15.33
6	dep. mic. sch.	Ultic	Haploxeralfs	8.8	17.6	4 45	-	3.38	12.08
7	alluvium	Mallic	Xerofluvents	24 8	35.6	4 95	-	6.83	35.20
8	alluvium	Typic	Xerofluvents	17.2	45.2	6.60	-	2.61	36.37
9	alluvium	Typic	Xerofluvents	7.2	43.6	7.12	neg	1.65	35.91
10	alluvium	Typic	Xerofluvents	27.1	46 5	7.53	1.2	2.70	20.95
11	dep. cal. mat.	Typic	Haploxeralfs	35.5	26 9	6.94	2.0	4.41	35.33
12	dep. cal. mat.	Typic	Haploxeralfs	32.8	28 8	7.15	0.6	4.23	31.33
13	dep. cal. mat.	Vertic	Haploxeralfs	24.8	24 8	6.02	0.6	2.00	22.30
14	dep. mic. sch.	Vertic	Haploxeralfs	10 8	27.6	5.05	0.6	4.81	13.05
15	dep. mic. sch.	Typic	Haploxeralfs	17.2	17.2	4.85	-	6.13	35.10
16	dep. mic. sch.	Ultic	Haploxeralfs	29.2	17.2	5.95	-	0.50	19.83
17	granite	Typic	Photoxeralfs	24.2	17.2	5.05	-	2.11	19.33
18	marl	Lithic	Haploxeralfs	40.8	28.4	7.00	18.5	8.26	55.30
19	marl	Lithic	Haploxeralfs	24.8	33.6	7 20	22.3	3.14	34.80
20	dep.cal. mat	Typic	Haploxeralfs	33.2	27.2	6.95	1.8	4.04	42.50
21	marl	Typic	Haploxeralfs	36.8	27.6	7.03	3.0	1.52	34.98
22	marl	Vertic	Calcixerolls	32 8	33.2	7.05	13.7	3.42	34.58
23	gneiss	Lithic	Dystrochrepts	6.8	23.6	4.18	-	1.07	12.70
24	gneiss	Lithic	Dystrochrepts	5.2	15.2	4.35	-	2.24	12.21
25	greenstone	Lithic	Dystrochrepts	11.2	39.2	4.95	-	10.20	22.83
26	limestone	Typic	Eutrochrepts	48.8	43.2	6.65	neg	1.47	50.00
27	dep. cal. mat.	Calcic	Chromoxerets	31.2	18.2	6.05	1.4	0.72	19.91

*sch. micaceous = shists micaceous, dep. mic. sch = deposits from mica shists. dep. cal. mat. = deposits from calcareus materials, col. limest. = colluvium from limestene.

From the adsorption curves of the soils, the amounts of P adsorbed between equillibrium concentrations of 0.25 to 0.35 ppm P, were estimated. These amounts provide an estimate of the buffering capasities of soils, and their relationship with P adsorption maxima, resulted from the analysis of P adsorption data of soils by Langmuir equation, is shown in Fig. 2. The relationship of P-fixation index values of soils with P-BC values is presented in Fig. 3 and in Fig. 4 the relationship between P fixed (at 0.2 ppm) values and resin - P values of the soils, is shown.

The results od the P fixation parameters correlation with the values of various physical and chemical properties of soils, are given in Fable 2.

DISCUSSION - CONCLUSIONS

The amounts of P required to provide the optimum concentration of 0.2 ppm P in solution (amounts of P fixed) varied from 56 to 362 ppm P, with an average 191 ppm, which corresponds to about 382 kg P /ha. According to the amounts of P fixed, the soils are considered (10) to be of low to medium P fixed capacity soils. It must be stressed that, although the 0.2 ppm P concentration in solution, cannot be considered to represent an optimum P concentration for all crops (4, 6), nevertheless, the 0.2 ppm P concentration, is considered, as a good choice for the purpose of comparing soils [7].

The P fixation values of soils at the 50 mg /100 g soil level of the P application, varied from 61 to 330 ppm P, with an average 199 ppm P (398 kg P /ha).

The adsorption isotherms af soils were found to fit Langmuir's equation. The coefficients of correlation had values $>$0.955. The P adsorption maxima of the soils varied from 81 to 425 ppm P (Fif. 2), with an average 232 ppm P (464 kg P /ha). The P-BC values of the soils varied from 25 to 75 ppm P and were closely related to P adsorption maxima values of the soils (Fig.2). Similar results are reported in the literature [17].

For raising the available P content (Olsen-P) of the soils by 1 mg P_2O_5 / 100 g soil (the soil fixation index), an average 5.1 mg P_2O_5 was required. The P fixation index values of the soils varied from 3 to 7 mg P_2O_5, and were closely correlatedto the P-BC values of the soils (Fig. 3). In Michigan the soil fixation index was foud to vary from 4.5 to 11.5 mg P_2O_5 [24].

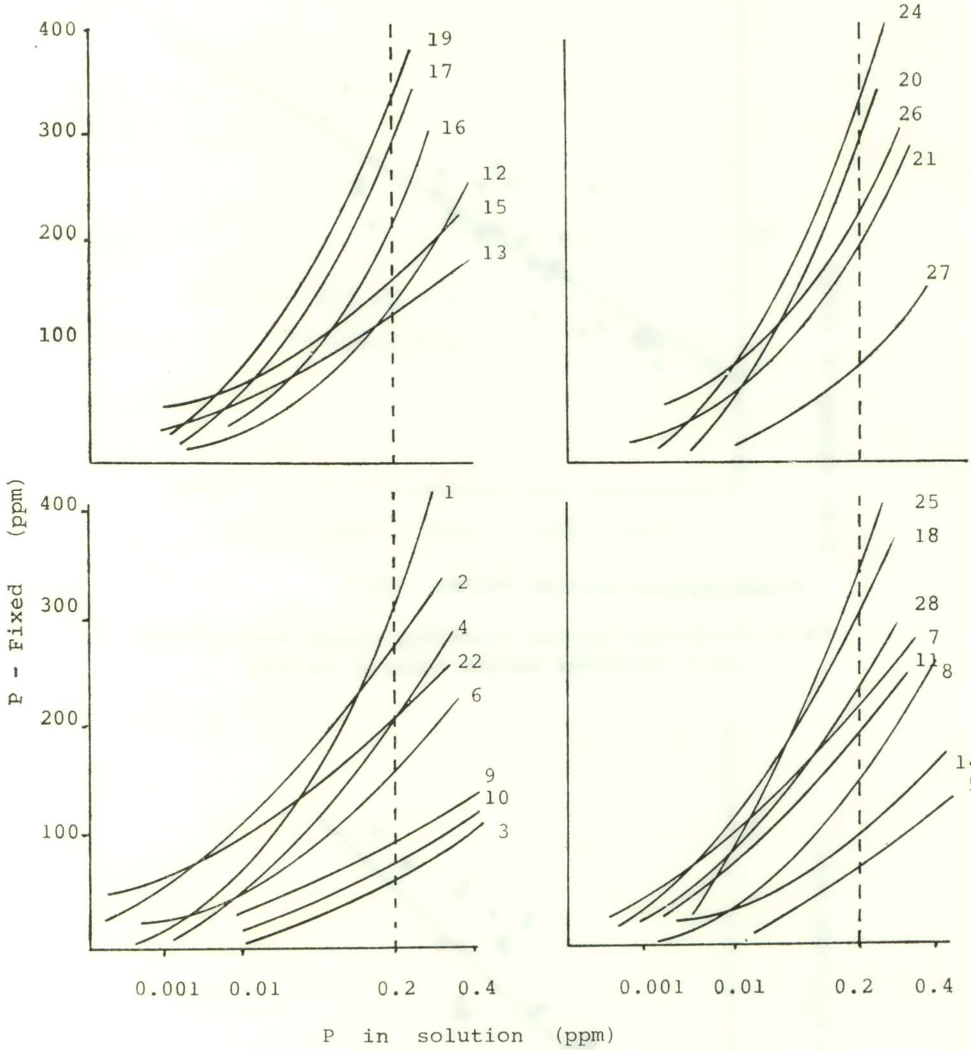
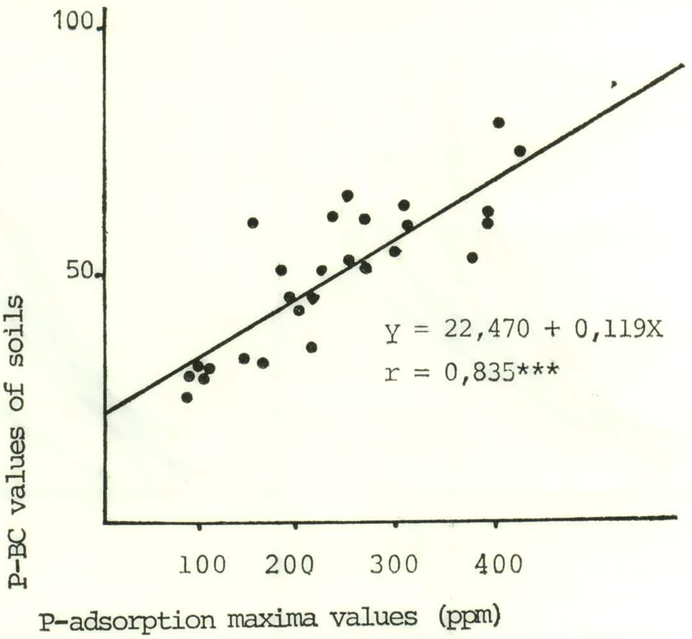


Fig. 1. Phosphorus fixation curves of 27 representative soils.



Fif. 2. Relationship between P-buffering capacity values (P-BC) and P- absorption maxima values of the soils

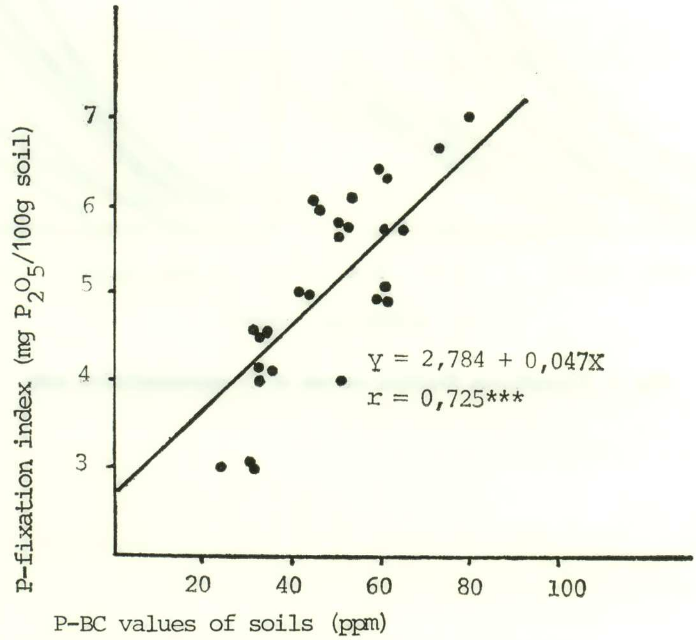


Fig. 3. Relationship between soil P-fixation index and soil P-BC values.

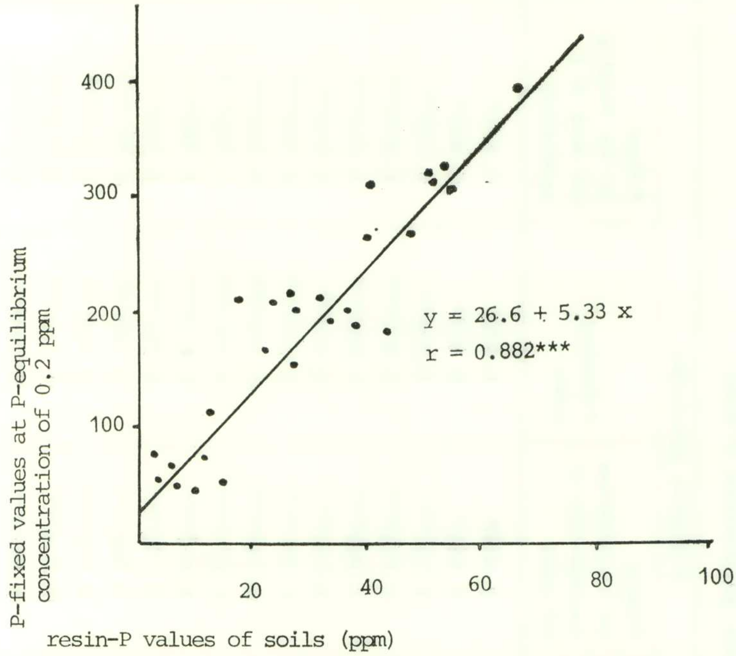


Fig. 4. Relationship between P-fixed values at P equilibrium concentration of 0.2 ppm and resin-P values of the soils.

TABLE 2

Coefficients of correlation between values of physical and chemical properties of soils and P-ficxation parameters of soils.

Values of physical and chemical properties of soils	P-fixation parameters			
	P-adsorption maxima	P-fixed (at P equilibrium concentration of 0,2 ppm)	P-fixation index	P-fixed (at the 5mqP/g soil level of P application)
clay %	0.425*	0.464*	0.402*	0.435*
silt %	0.420*	0.444*	0.412*	0.443*
pH	0.540**	0.527**	0.505**	0.525**
Org. matter %	0.699***	0.672***	0.693***	0.604***
$CaCO_3$ %	0.899***	0.892***	0.842***	0.852***
CEC me/100 g	0.535**	0.540**	0.502**	0.515**
Fe_2O_3 ppm	0.792***	0.761***	0.723***	0.737***
Al_2O_3 ppm	0.764***	0.742***	0.733***	0.741***
Olsen -P ppm	0.899***	0.874***	0.791***	0.762***
Resin-P ppm	0.882***	0.867***	0.832***	0.799***
0.2 M H_2SO_4 -P ppm	0.790***	0.776***	0.763***	0.745***
EUF-P ppm	0.796***	0.788***	0.780***	0.771***
Organic-P ppm	0.702***	0.701***	0.689***	0.667***
Total N ppm	0.755***	0.734***	0.712***	0.712***
P-BC ppm	0.857***	0.992***	0.746***	0.743***

*P 0.05, **P 0.01, ***P 0.001

High correlations were foud between the P fixation parameters of the soils and free oxides of Fe and Al, $CaCO_3$ in calcareous soils, organic matter, organic P, total N, available P (Olsen-P, resin-P, 0.2M H_2SO_4-P, EUF-P) and P-BC of soils (Table 2, Fig. 4). The P-fixation values were greater in soils with pH 5.8, smaller in soils with pH 7.0 and much smaller in soils with pH from 5.8 to 7.0. Soils derived from acid rocks fixed, generally, greater amounts of P, than soils derived from basic rocks.

Phosphorus fixation in acid soils is primarily due to the formation of iron and aluminium compounds (19). The effect of pH and free oxides of Fe and Al of the soils studied on their fixation capacity, is indicated by soils 5 and 6. Soil 5 with pH 5,45 (Table 1), 0.08 % Fe_2O_3 and 0.01 Al_2O_3, fixed 72 ppm P, while soils 6, with pH 4.45, 0.71% Fe_2O_3 and 0.4% Al_2O_3, fixed 163 ppm P (Fig. 1).

In calcareous and alkaline soils, the fixation of P is due to the formation of a whole series of insoluble calcium phosphate compounds (19). The influence of $CaCo_3$ content is shown in soils 19 and 21. Soil 19, with 22.3% $CaCO_3$, fixed 322 ppm P, while soil 21, with 3.0% $CaCO_3$, fixed 214 ppm P. (Fig. 1).

Direct correlations between soil organic matter content, organic P and total N and P-fixation are reported in the literature (8, 20). They, propably, reflect increases in finaly dirided sesquioxides with increasing levels of organic matter (18).

ΠΕΡΙΛΗΨΗ

Παράμετροι δέσμευσης φωσφόρου ἀντιπροσωπευτικῶν ἐδαφῶν καὶ ἡ σχέση τους μὲ τὶς ἰδιότητες τοῦ ἐδάφους

Μελετήθηκαν οἱ παράμετροι δέσμευσης P 27 ἀντιπροσωπευτικῶν ἐδαφῶν. Οἱ ποσότητες P ποὺ ἀπαιτήθηκαν γιὰ νὰ δώσουν μιὰ συγκέντρωση 0,2 ppm P στὸ διάλυμα ἰσορροπίας (P ποὺ δεσμεύτηκε) κυμαίνονταν ἀπὸ 65-350 ppm P μὲ μιὰ μέση τιμὴ 191 ppm. Οἱ ἰσόθερμες προσρόφησης ὅλων τῶν ἐδαφῶν βρέθηκε νὰ ἐκφράζουν στὴν ἐξίσωση τοῦ Langmuir καὶ τὰ μέγιστα προσρόφησης P τῶν ἐδαφῶν κυμαίνονταν ἀπὸ 79-425 ppm μὲ μιὰ μέση τιμὴ 232 ppm P. Γιὰ τὴν αὔξηση τῆς ἀναλυτικῆς τιμῆς (Olsen -P) κατὰ 1 mg P_2O_5/100g ἐδάφους ἀπαιτήθηκαν κατὰ μέσο ὅρο 5,1 mg P_2O_5/100g ἐδάφους. Οἱ παράμετροι δέσμευσης P τῶν ἐδαφῶν συσχετίζονταν στενὰ μὲ τὴν ὀργανικὴ οὐσία, τὰ ἐπίπεδα $CaCO_3$ στὰ ἀσβεστοῦχα ἐδάφη, τὰ ἐλεύθερα ὀξείδια τοῦ Fe καὶ Al, τὸ διαθέσιμο P καὶ τὴ ρυθμιστικὴ ἱκανότητα σὲ P τῶν ἐδαφῶν. Γενικά, ἐδάφη ποὺ προέκυψαν ἀπὸ ὄξινα πετρώματα δέσμευσαν μεγαλύτερες ποσότητες P, ἀπ' ὅ,τι τὰ ἐδάφη ποὺ προέκυψαν ἀπὸ βασικὰ πετρώματα.

LITERATURE

1. R. C. Beckwith, Sorbed phosphate at standard supernatant concentration as an estimate of phosphorus needs of soils. Aust. J. Exp. Agrip. Anim. Husb. 5: 52-58. 1965
2. K. A. Bondorj, Studies on the phosphoric acid content of soil. VI. Solubility of soil phosphoric acid in dilute sulfuric acid. Tidsskr. Planteavl. 55:185-210.1952
3. R. H. Cooke and J. Hislop. Use of anion-exchange resin for the assessment of available soil phosphate. Soil Sci. 96:308-312. 1963
4. R. L. Fox, External phosphorus requirements of crops. In «Chemistry in Soil Environment». ASA Special Publication Number: 40. 1981
5. R. L. Fox and E. J. Kamprath. Phosphate sorption isotherms for evaluatin the phosphate requirements of soils. Soil Sci. Soc. Amer. Proc. 34:902-907. 1970
6. R. L. Fox, R. K. Nishimoto, R.S. Thompson and R. S. Pena de la.

Comparative external phosphorus requirements of plant growing in tropical soils. Int Congr. Soil Sci Trans. 10th (Moscow) 4:232-239. 1974

7. R. L. Fox and P. G. Searle. Phosphate adsorption by soils of the Tropics. ASA Special Publication Number 34 p 97-119. 1978
8. G. Hinga, Phosphate sorption capacity in relation to properties of several types of Kenya soils East. Africa Agr. For. J. 38:400-404. 1973
9. M. L. Jackson, Soil Chemical Analysis. Costable and Co Ltd, London. 1948
10. A. S. R. Juo and R. L. Fox. Phosphate sorption characteristics of some Bench-Mark soils of West Africa. Soil Sci. 124:370-376. 1977
11. O. P. Mehra and M. L. Jackson, Iron oxide renoval from soils and clays by a dithionite-citrate system buffered with sodium bicarbonate. Proc. 7th Natl. Conf. Clays. 1959 5:317-327. 1960
12. K. Nemeth, The availability of nutrients in the soils as determined by electro-ultrafiltration (EUF). Adv. Agr. 31, 155-188. 1979
13. S. R. Olsen, C. V. Cole. F. S. Watanabe and L. A. Dean. Estimation of available phosphorus in soils by extraction with sodium-bicarbonate. USDA. Circ. 939. 1954
14. S. R. Olsen and F. S. Watanabe. A method to determine a phosphorus adsorption maximum of soils as measured by the Langmuir isotherm. Soil Sci. Soc. Amer. Proc. 21:144-149. 1957
15. S. R. Olsen and W. D. Kemper. Movement of nutrients to plant roots. Adv. Agron. 20:91-151. 1968
16. P. G. Ozanne and T. C. Shaw, Advantages to the recently developed phosphate sorption tests over the older extractant methods of soil phosphates. Int. Soil. Sci. Cong. Trans. 9th (Adelaide) 2:273-380. 1968
17. S. S. S. Rajan, Phosphorus adsorption characteristics of Hawaiian soils and their relationships to equilibrium phosphorus concentrations required for maximum growth of millet. Plant Soil. 39:519-532. 1973
18. P. A. Sanchez and Uehara. Management conciderations for acid soils with high phosphorus fixation capacity. ASA-CSSA-SSSA. In «The Role of Phosphorus in Agriculture». 1980
19. E. C. Sarple, R. J. Soper and E. J. Racz. Reactions of phosphate fertilizers in soils. ASA-CSSA-SSSA. In «The Role of Phosphorus in Agriculture». 1980
20. W. M. A. Saunders, Phosphate retention in New Zealand soils and its relationship to free oxides, organic matter and soil properties. N. Z. J. Agr. Res. 8:30-37. 1965
21. A. D. Simonis, The determination of fundamental characteristics of soils as related to their phosphate suplying power to plants in some representative soils. Proc. Athens Acad. V, 51, 337-358. 1976
22. A. D. Simonis and K. Nemeth. Comparative study of EUF and other me-

thods of soil for the determination of available phosphorus in soils from Northern Greece. Paper presented on the 2nd Internationsl Symposium on EUF. 1984

23. A. D. Simonis, Phosphorus soil tests and their suitability for the assessment of available phosphorus of soils. Proc. Athens Acad. (In Press).

24. R. P. White and Doll, E. C. Phosphorus and potassium fertilizers affets soil test levels. Michigan State Research Report. 127. 1971