

SOME ASPECTS OF PHOSPHORUS BEHAVIOR IN SOILS

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Phosphorus is one of the ten elements necessary for the growth and development of plant tissue. Phosphorus, also, is one of the three or four of these ten elements that may be lacking in soil for the optimum plant growth. In fact, it is one of the first ones that is usually deficient in the soils of humid regions. The question of phosphorus and its replenishment in the soil, therefore, becomes one of paramount importance in agricultural practice.

There are two main sources of phosphorus that are used by farmers in replenishing the soil, in order to compensate for the loss of phosphorus removed by farm crops: (1) farm manures, and (2) commercial phosphatic fertilizers. The phosphatic fertilizers, in their turn, could be subdivided into two main groups, namely: (1) rock phosphate, and (2) acid phosphate. Rock phosphates are the natural phosphatic deposits quarried and ground into a very fine powder, 80 to 95 per cent of which usually passing through a 100-mesh sieve. Acid phosphate is the product obtained after natural phosphate is treated with a weak solution of sulfuric acid. Natural phosphate is but very slightly soluble in water, while acid phosphate, freshly prepared, is easily soluble in water. The subdivision, therefore, could be made on the basis of soluble and insoluble phosphatic fertilizers. Other minor sources of phosphorus for use as fertilizers would fall into either of these two main groups.

According to the American Fertilizer Handbook for 1920, there were produced and sold in the United States in 1918, in round figures, 2,500,000 metric tons of rock phosphate, estimated as being worth over \$8,000,000. At the same time 4,500,000 tons of acid phosphate were manufactured, being worth over \$76,000,000. Nearly all of this vast amount of phosphatic fertilizers was sold on a domestic market and used by American farmers as fertilizer.

It is interesting to note that according to these estimates, rock phosphate is worth \$3.20 a ton, while acid phosphate is priced at \$16.89 a ton. In spite of this difference in price, acid phosphate ordinarily contains

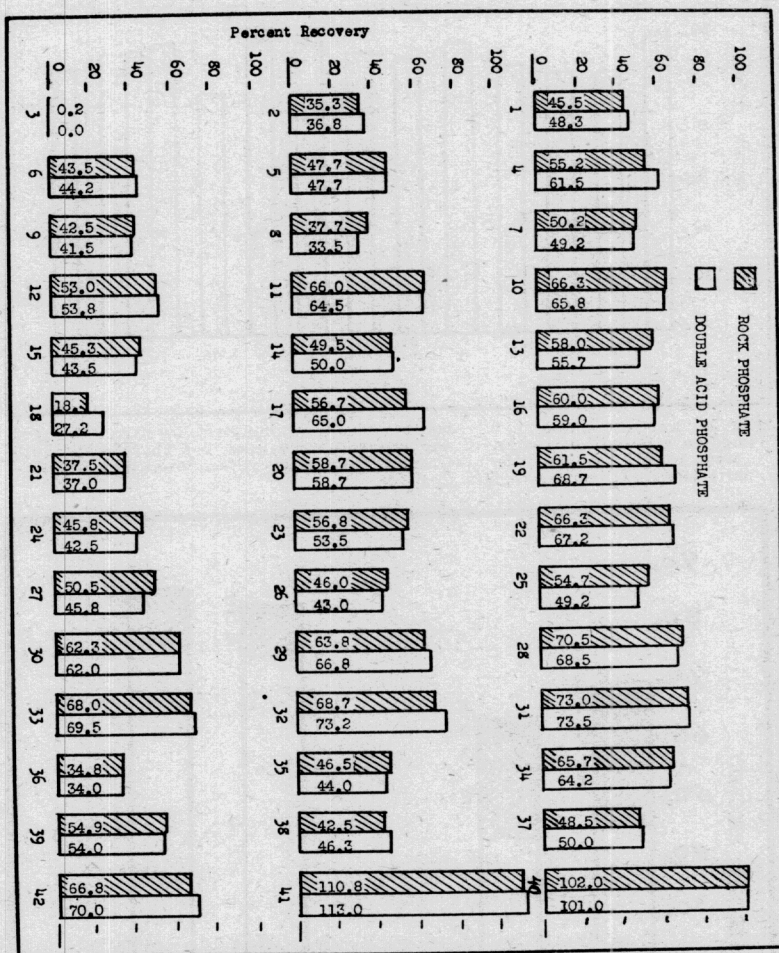


Fig. 1. Percent phosphorus recovery from Tennessee rock phosphate and double acid phosphate after different soils were treated with these substances in proportion of 4 mgs. of phosphorus per 25 gms. of soil; normal fifth nitric acid was used for extraction.

only one-half of the amount of phosphorus found in rock phosphate from which it is being prepared.

It is a mooted question among soil workers as to which of the two phosphatic fertilizers is better and the more economical to apply to the soil for crop production and

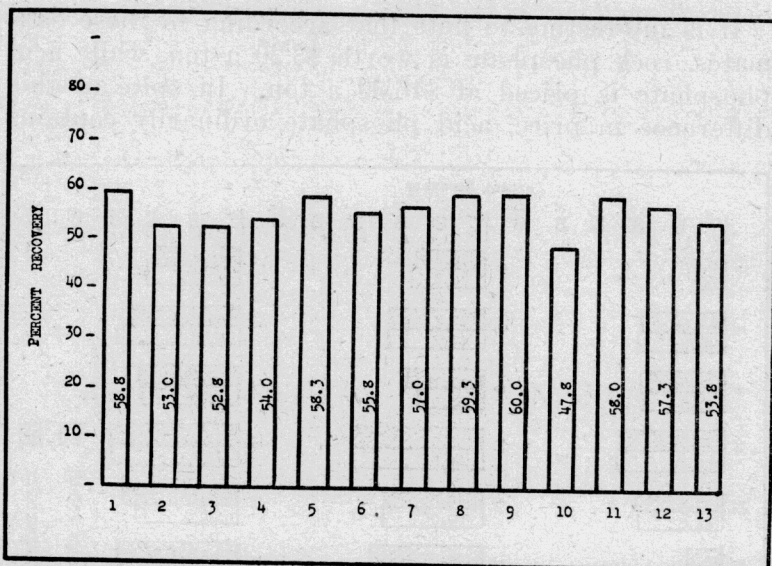


Fig. 2. Percent phosphorus recovery from phosphatic fertilizer treated brown silt loam. 4 mgs. of phosphorus were used for 25 gms. of soil. Nos. 1, 2, 3, etc. at the bottom of the figure refer to numbers opposite the fertilizer materials in table 3.

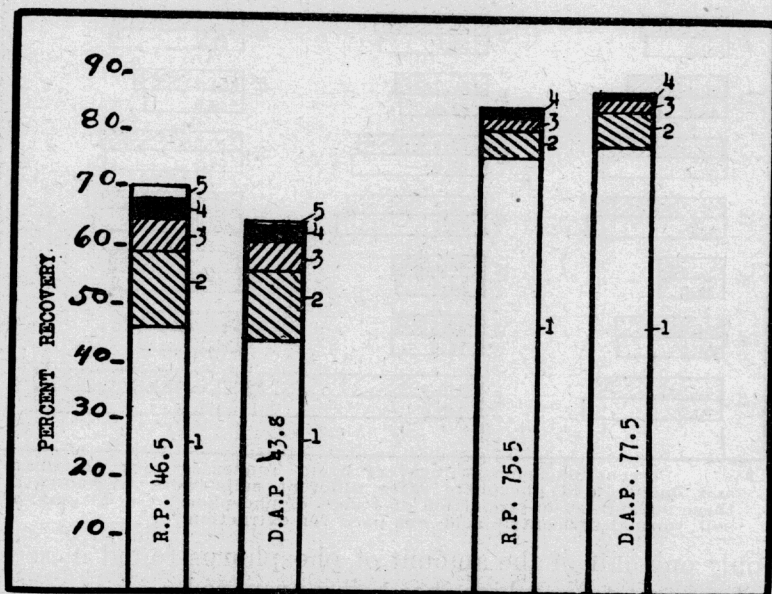


Fig. 3. Percent of phosphorus recovery from 25 gms. of brown silt loam and brown gray silt loam treated with 4 mgs. of phosphorus of either Tennessee rock phosphate, R. P., or double acid phosphate, D. A. P. Five consecutive extractions were made with HNO_3 N/5. First extraction data represented at the base line. Subsequent extractions are placed above, in order named.

the maintenance of soil fertility. Notwithstanding the great amount of work that has been done in various parts of the world, the question is far from being solved. The results are often conflicting and not strictly comparable.

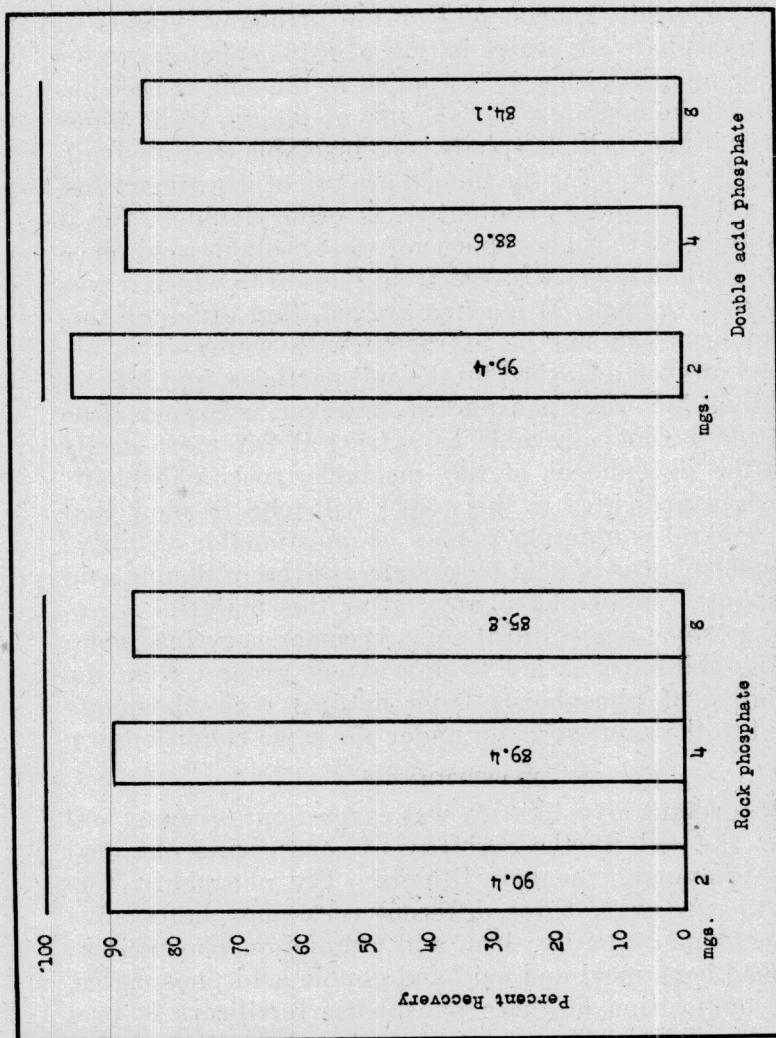


Fig. 4. Percent recovery of phosphorus from 25 gms. of coarse quartz sand treated with 2.4 and 8 mg. of phosphorus in the form of either Tennessee rock phosphate or double acid phosphate. Normal fifth nitric acid was used for extraction.

It was thought advisable, therefore, to compare these two forms of phosphatic fertilizers in their behavior after they are applied in various types of soil, and also to study some of the factors that influence their behavior.

It would be of fundamental importance to know: What becomes of phosphorus when phosphatic fertilizer is applied to the soil? What reactions take place? To what extent is phosphorus "available" when "water soluble" acid phosphate is incorporated with the moist soil mass?

As generally known, one of the strongest claims of acid phosphate advocates is that acid phosphate is water soluble and that when it is applied to the soil, it becomes available immediately for the use of plants, while phosphorus in the rock phosphate is so insoluble that its availability is too low for the immediate use of growing crops. The validity of this contention is often doubted, for it was observed that phosphorus of water soluble acid phosphate could not be extracted from the soil to which it was previously added. It is often argued, that although this phosphorus can not be extracted with water, it is absorbed or even adsorbed by the soil particles, and loosely held thereby. This phosphorus, however, is in such state that plant roots are able to extract it far more easily than the phosphorus of the insoluble rock phosphate. The data presented in this paper will tend to show that this general contention is also of questionable validity; that phosphorus of acid phosphate or even of double acid phosphate (super phosphate), after this material is applied to some agricultural soils, becomes very insoluble; and its solubility is not to any extent greater than the solubility of phosphorus from natural rock phosphate added to the same soil and under the same conditions.

EXPERIMENTAL

The present investigation was carried out on many soil types, the soils in the majority of cases being obtained from Champaign county, Illinois. The phosphatic fertilizers used were three different rock phosphates; five slags; ground apatite; iron and aluminium phosphates; steamed bone meal and acid and double acid phosphates. The composition of these phosphatic fertilizers is presented in Table 1.

The comparative work on different soils was carried out with Tennessee rock phosphate, as a representative of insoluble rock phosphate, and with double acid phosphate, as easily soluble phosphatic fertilizer.

The general procedure of the experiment was as follows: 25 grams of mineral soil or 12.5 grams of organic soil (peat) were placed in a 350 c. c. glass bottle, thoroughly mixed with a given amount of fertilizing material, moistened with distilled water, and let stand for seven days at room temperature. At the end of this period, it was taken with 250 c. c. of fifth normal nitric acid and shaken for three hours in a shaking machine. Then it was filtered on a dry filter paper. 200 c. c. aliquot of clear solution was taken for determination of phosphorus. Volumetric method of analysis was followed in this work. The average of two determinations is given in the tables.

It is recommended often in the studies of weak acid extractions to make the acids somewhat stronger than fifth normal so that after the soil bases are neutralized the remaining acidity will be equal to fifth normal. Such an arrangement, of course, would give the phosphatic compounds in different soils the same chance for equal solubility. This procedure, however, introduces a very objectionable feature for the comparative study of different soils. The solvent necessarily would be different for nearly every soil, and the results could hardly be comparable. It seems as though we should accept soils as such; accept the conditions under which any given soil has to function, and make our observations, preserving these conditions intact.

If we take two field soils and subject them to the same cultural and climatic conditions, we may safely expect the resultant soil solutions to be practically the same. Yet the ultimate character of these two soil solutions may be widely different depending on the physical and chemical character of these respective soils.

There are given two soils; one is abundantly supplied with carbonates, while the other is very deficient in them. The solvent action of acids formed in the soils will go very largely to neutralize the carbonates in the first soil, and will be available as a free acid in the second soil. Naturally there will be more phosphorus available for crops in the second soil than in the first. The field observations at various experiment stations show that soils

excessively supplied with lime do not respond very well to the application of phosphates. This well known fact among soil workers seems to justify the procedure here adopted.

In time, the biological activities of these soils will also add to the modification of their soil solution, but this phase does not enter into the realm of the present study.

The comparative work was done on soils of different geological and morphological formations. Prairie soils were represented by three soils of brown silt loam, two of clay loam, and one each of drab clay loam, brown gray silt loam of tight clay, and brown sandy loam. Timber soils were represented by one sample each of the yellow gray silt loam on gravel, yellow silt loam (eroded) and yellow gray sandy loam. Terrace soils were represented by brown sandy loam. Mixed loam was used as a bottom land type formed along rivers; deep peat was a representative of swamp lands.

In each soil type the soils of three different depths were used for the comparative tests with the phosphatic fertilizers: (1) the plowed layer of 6 2/3 inches in depth, (2) the second layer from 6 2/3 inches to 20 inches, and (3) the layer from 20 to 40 inches. The second and the third layers, of course, differ from the first one in their physical and chemical properties, and the descriptive name of soils for each layer is given here in order to facilitate interpretation of the presented data. All soils in this experiment were ordinary stock samples collected in Champaign county for the soil survey analyses.

These fourteen soils of three layers each, or forty-two soil samples in all, were treated with either Tennessee rock phosphate or double acid phosphate in such amounts that in each case 4 mgs. of phosphorus were applied for 25 grams of mineral soil and for 12.5 gms. of peat of the first two layers. The results presented in Table 2 show the percent of applied phosphorus that was extracted with nitric acid fifth normal. In each case the amount of phosphorus extracted from the untreated soil was subtracted from the amount of phosphorus extracted from the treated soil. It constitutes a net gain due to the treatment, and it assumes that the amount of soil phos-

phorus extracted from the treated soil is the same under these conditions as the amount of phosphorus extracted from the untreated soil.

Examination of the results in Table 2 and of the accompanying Fig. 1 reveals the rather striking fact that the degree of recovery of phosphorus from nearly every soil studied is practically the same, regardless of the source of the phosphatic material. Water soluble double acid phosphate, after it is incorporated into the soil mass and moistened, becomes soluble in fifth normal nitric acid, only to the same extent as the Tennessee rock phosphate. There are some relatively small differences in solubility in some individual cases. On the whole, however, these differences are very important, as one can judge from the application of Student's Method of biometric analysis. Using 42 soil trials in which the mean deviation is only $-.37$, and the standard deviation 3.256 , the ratio of the former to the latter, or Z , is only $.113$. This value is too small to be significant. The smallest value of Z used in Student's tables is $.1$ and such value gives chances from 10 to 12 times as small as those considered at all significant in calculations of probability.

Different soil types allow the recovery of different amounts of phosphorus. In this respect, the variations are very great. Thus, the soil of the third layer of one brown silt loam (Sample 3, Table 2) did not allow any recovery; while the surface layer of peat showed a complete recovery. Indeed, the amount of phosphorus recovered from peat of the second layer was greater than the amount applied. The differences are from 11 to 13 per cent, and seem to be larger than could be ascribed to the experimental error. In the majority of cases the recovery of phosphorus varied between 40 and 60 per cent. On the whole, the recovery was somewhat greater in the surface layer than in the subsurface. The third layer, or the subsoil, gave the smallest recovery of phosphorus in all cases.

In order to ascertain whether or not other phosphatic fertilizers would follow the same general mode of behavior observed on the Tennessee rock phosphate and double acid phosphate, an experiment was repeated on

another brown silt loam, using various phosphatic fertilizers. As one notices from Table 1, these phosphorus-carrying substances varied in their phosphorus content very considerably. The amount of each substance used, however, was in every case equivalent to 4 mgs. of phosphorus, as calculated from their analyses. 25 gms. of soil were used in every case. Amounts of phosphorus extracted with fifth normal nitric acid, as well as percent of phosphorus recovery, are given in Table 3, and are shown graphically in Figure 2. The results show that, with the exception of iron phosphate and two or three brands of slag, the per cent of recovery is practically the same. Acid phosphate gave no larger recovery than the majority of the so-called insoluble phosphatic fertilizers. These figures are rather interesting, especially if one considers them in parallel to the data presented in Table 4, which has the amount and the percent of phosphorus recovery from the same amount of fertilizing material alone (without the soil), when the extraction was made either with distilled water or with normal fifth nitric acid.

The data in Table 4 show that phosphorus in acid phosphate is recovered with distilled water to the extent of 85 per cent, and from double acid phosphate to the extent of 90 per cent. None of the other phosphates had solubility in water amounting to six per cent; some of them, as apatite and one of the slags, were extremely insoluble in water.

When the same materials were extracted with fifth normal nitric acid under the same conditions, i. e., without mixing them with the soil, the per cent of recovery was around 100 percent in nearly every case. See Table 4.

It is evident that there is something in the soil that prevented this phosphorus recovery. Undoubtedly some of the acid, after it is added to the soil, reacts with some of the soil bases, forming nitrates. This would be true especially of carbonates of calcium and magnesium. Such a reaction taking place would decrease the concentration of the acid, causing a decrease in the amount of phosphorus extracted. Anticipating such action in some soils that are more or less supplied with carbon-

ates, an aliquot of clear extracted solution was taken and titrated against a standard alkali (.1484 normal), using Methyl-red-Para-nitro-phenol for the indicator. The figures for relative titrations are given in Tables 2, 3, and 4 (last column). They show that fertilizing materials alone do not reduce the concentration of nitric acid to any appreciable extent. (Table 4.) The fertilizing materials after they are applied to brown silt loam, as recorded in Table 3, reduce the acid concentration rather uniformly to about 90 percent of its original strength. This in no way accounts for the reduction of phosphorus recovery to about 50 or 60 percent of its recovery from fertilizing materials themselves. The titrations recorded in Table 2 explain the failure of phosphorus recovery in only a very limited number of cases. The soil number "3", or the subsoil layer of brown silt loam, contained a large amount of carbonates, which used practically all of the acid present, thus making the phosphorus extraction impossible. Perhaps samples Nos. 21 and 24 also behaved in a similar way. With these three exceptions, however, the reduction in the acid concentration fails entirely to explain the behavior of phosphorus in all these soils. The lack of such correlation is very apparent, if one compares the surface soil with its subsurface and the subsoil layers in regard to the phosphorus extraction and the concentration of nitric acid at the end of the extraction.

Peat, or samples Nos. 40, 41, and 42, afford an interesting observation. The carbonates of the surface layer reduce the acid concentration to about one-sixth of its original strength. In spite of that, the phosphorus recovery was practically complete. In the subsoil layer, number 42, the acid concentration was over four times as great as in the surface layer, yet the phosphorus recovery was reduced to 70 percent. Again, with the acid in the subsurface layer, number 41, slightly weaker than that in the subsoil layer, the recovery was complete. There was even some stimulating effect noticed on the soil phosphorus.

Very little or no correlation could be traced if one compares, in this respect, the surface, subsurface or the sub-

soil layers by themselves. Noticing the fact that the sub-soil layer of the peat soil contained a considerable amount of clay particles or mineral matter, it suggests for itself that the mineral portion of the soil forces phosphorus to react in the way here observed. It would seem probable that some double salts of phosphorus with iron or aluminum or with both are formed that are less soluble than the calcium, iron and aluminum phosphates. The presence of silica in the form of silicic acid perhaps has considerable influence on the formation of these complex combinations. However, the presence of bases commonly found in the soil is evidently essential for their formation. The silica of the quartz sand, which was rather coarse in texture, prevented some phosphorus from recovery, as one notices from Figure 4, in which data of another experiment are shown where different amounts of phosphorus were added to 25 gms. of quartz sand and later extracted with fifth normal nitric acid. The influence of silica (with or without certain bases) on the behavior of phosphorus is under further investigation.

In conclusion, I wish to emphasize the fact that the phosphorus, which fifth normal nitric acid fails to extract from a given soil, exists in the soil in such a complex combination that even subsequent extractions with fresh nitric acid of the same strength fail to bring the phosphorus in solution. Two soils, brown silt loam and brown gray silt loam, were treated with either Tennessee rock phosphate or double acid phosphate. The extractions with nitric acid were filtered and washed four times with warm distilled water. The residue was treated with fresh nitric acid, and the procedure was repeated five times. The results are presented in Table 5 and show that but a relatively small amount of phosphorus was extracted from those soils after the first extraction, and the amount was decreasing with every subsequent extraction.

The time at my disposal here precludes the possibility of discussing the various factors that influence the behavior of phosphorus in soil. This will be published elsewhere later in a report. The presented paper, being its integral part, will be reproduced in its essential features.

CONCLUSIONS

The foregoing data, it seems, justifies the following conclusions:

1. When phosphorus in the form of phosphatic fertilizers is applied to ordinary mineral soils, it becomes considerably less soluble in fifth normal nitric acid than phosphorus of the same material before application.

2. Peat soil, as an exception, does not depress the recovery of phosphorus under the same conditions.

3. After phosphatic fertilizers are applied to the soil, the recovery of phosphorus from soil treated with double acid phosphate is not any greater than the recovery of phosphorus from the same soil treated with natural rock phosphate, using fifth normal nitric acid for the solvent in each case.

4. After the first extraction with fifth normal HNO_3 , the subsequent extractions with fresh acid fail to extract a considerable amount of additional phosphorus. Five consecutive extractions fail to recover the entire amount of phosphorus applied either in the form of rock phosphate or double acid phosphate.

TABLE 1.

Phosphorus content of phosphatic fertilizers used.

	Percent Phosphorus	Amount of material containing 4 mgs. of Phos.
Tennessee Rock Phosphate.....	13.8	.0290 gms.
Double Acid Phosphate.....	19.94	.0201 "
Slag A	8.40	.0476 "
Slag B	9.30	.0430 "
Slag C	5.79	.0691 "
Slag D	6.61	.0605 "
Birmingham Slag	8.55	.0468 "
Blue Rock	13.05	.0306 "
Florida Soft Rock.....	14.77	.0271 "
Apatite	12.36	.0324 "
Iron Phosphate	16.36	.0244 "
Aluminum Phosphate	17.09	.0234 "
Acid Phosphate	9.54	.0419 "
Steamed Bone Meal	14.81	.0270 "

TABLE 2.

Percent phosphorus recovery from Tennessee rock phosphate and double acid phosphate after different soils were treated with these substances in proportion of 4 mgs. of phosphorus per 25 gms. of soil; fifth normal nitric acid was used for extraction.

Description of soils.		Soil Survey Numbers.	Percent Phosphorus Recovery			Deviation Squared.	Alkali required per 10 c.c. ex- tracted solution.
			From Rock Phosphate.	From Double Acid Phos- phate.	Deviation — or +		
PRAIRIE SOILS.							
1	Brown silt loam.....	7729	45.5	48.3	-2.8	7.84	11.4
2	Brown silt loam passing into yellow clayey silt	7730	35.3	36.8	-1.5	2.25	11.4
3	Yellow clayey silt with till	7731	0.2	0.0	+0.2	.04	0.2
4	Brown silt loam.....	7741	55.2	61.5	-6.3	39.70	10.6
5	Brown silt loam with some yellow	7742	47.7	47.7	0.0	.....	10.7
6	Yellow clayey silt with some brown	7743	43.5	44.2	-0.7	.49	11.3
7	Brown silt loam.....	7765	50.2	49.2	+1.0	1.00	11.3
8	Brown silt loam with some yellow.....	7766	37.7	33.5	+4.2	17.64	11.2
9	Yellow clayey silt, more silty with depth....	7767	42.5	41.5	+1.0	1.00	11.0
10	Black clay loam to dark brown	7840	66.3	65.8	+0.5	.25	12.4
11	Drab to black clay loam	7841	66.0	64.5	+1.5	2.25	12.6
12	Yellow to brownish yel- low and drab clay...	7842	53.0	53.8	-0.8	.64	11.9
13	Black clay loam with some sand	7825	58.0	55.7	+2.3	5.29	12.2
14	Black clay loam, some gravel and sand....	7826	49.5	50.0	-0.5	.25	12.1
15	Drab to olive colored clayey silt	7827	45.3	43.5	+1.8	3.24	11.8
16	Drab clay loam, dark..	7843	60.0	59.0	+1.0	1.00	10.0
17	Drab clay loam, lighter at 12".....	7844	56.7	65.0	-8.3	68.90	10.2
18	Drab silty clay, pebbles and lime	7845	18.0	27.2	-9.2	84.64	10.5
19	Brown gray silt loam on tight clay.....	7801	61.5	68.7	-7.2	51.84	9.3
20	Gray silt loam.....	7802	58.7	58.7	+0.0	.....	8.9
21	Yellow to grayish clayey silt	7803	37.5	37.0	+0.5	.25	4.7
22	Brown sandy loam....	7849	66.3	67.2	-0.9	.81	9.8
23	Brown sandy loam, some sand	7850	56.8	53.5	+3.3	10.89	10.1
24	Yellow sand, some silt.	7851	45.8	42.5	+3.3	10.89	4.2
TIMBER SOILS.							
25	Yellow gray silt loam on gravel	7816	54.7	49.2	+5.5	30.25	12.0
26	Yellow silt loam.....	7817	46.0	43.0	+3.0	9.00	11.9
27	Yellow clayey silt, some gravel	7818	50.5	45.8	+4.7	22.09	11.8
28	Yellow silt loam, brown- ish, gravelly	7858	70.5	68.5	+2.0	4.00	10.6
29	Yellow silt loam to yellow sandy loam..	7859	63.8	66.8	-3.0	9.00	11.4
30	Yellow silt to gravelly sandy silt	7860	62.3	62.0	+0.3	.09	11.7
31	Yellow gray sandy loam, some brown...	7855	73.0	73.5	-0.5	.25	12.0
32	Yellow sandy loam, some gray	7856	68.7	73.2	-4.5	20.25	12.1
33	Yellow sand, little silt..	7857	68.0	69.5	-1.5	2.25	12.1

TABLE 2—Concluded.

Description of soils.	Soil Survey Numbers.	percent Phosphorus Recovery			Deviation Squared.	Alkali required per 10 c.c. extracted solution.
		From Rock Phosphate.	From Double Acid Phosphate.	Deviation + or -		
TERRACE SOILS.						
34 Brown sandy loam.....	7852	65.7	64.2	+1.5	2.25	12.0
35 Brown sandy loam, variable	7853	46.5	44.0	+2.5	6.25	12.1
36 Yellow sand, some clayey sand	7854	34.8	34.0	+0.8	.64	12.0
RIVER AND BOTTOM SOILS.						
37 Brown mixed loam.....	7861	48.5	50.0	-1.5	2.25	9.90
38 Brown mixed loam.....	7862	42.5	46.3	-3.8	14.44	10.5
39 Yellowish brown loam, some sand	7863	54.9	54.0	+0.9	.81	11.3
40 Black decomposed peat, shells	7870	102.0	101.0	+1.0	1.00	2.1
41 Black peat	7871	110.8	113.0	-2.2	4.84	7.0
43 Black to brown peat, drab clay at 30".....	7872	66.8	70.0	-3.2	10.24	8.8
Algebraic sum				-15.6	451.	
Mean deviation.....				-.37		

$$\text{Standard deviation} = \sqrt{\frac{\sum ED^2}{N} - M^2} = \sqrt{\frac{451}{42} - .137} = 3.256$$

$$Z = \text{ratio of mean deviation to standard deviation} = \frac{.37}{3.256} = .113$$

TABLE 3.

Recovery of phosphorus from different phosphatic fertilizers applied to Brown Silt Loam. In each case 4 mgs. of phosphorus was applied per 25 gms. of soil.

	Mgs. Phosphorus extracted	Percent Phosphorus extracted	Alkali required per 10 c.c. of extracted solution
Tennessee Rock Phosphate.....	2.35	58.8	11.6
Slag A	2.12	53.0	11.4
Slag B	2.11	52.8	11.4
Slag C	2.16	54.0	11.4
Slag D	2.33	58.3	11.4
Birmingham Slag	2.23	55.8	11.5
Blue Rock	2.28	57.0	11.6
Florida Soft Rock.....	2.37	59.3	11.6
Apatite	2.40	60.0	11.6
Iron Phosphate	1.91	47.8	11.7
Aluminum Phosphate	2.32	58.0	11.6
Acid Phosphate	2.29	57.3	11.6
Steamed Bone-meal	2.15	53.8	11.6
Soil, alone			11.7
Acid, alone			12.7*

* 10 c.c. of distilled water was used to wet the soil after fertilizer was added to it. In order to make the results comparable, 10 c.c. of water was added to 250 c.c. of acid before titration.

TABLE 4.

Phosphorus extracted with distilled water and fifth normal nitric acid from different phosphatic fertilizers. 250 c.c. of either acid or water were used on fertilizer which contained per sample 4 mgs. of phosphorus.

	Water Soluble		Fifth normal HNO ₃ Soluble		
	Mgs. Phos. ex-tracted	Percent Phos-phorus re-covery	Mgs. Phos. ex-tracted	Percent Phos-phorus re-covery	Alkali required per 10 cc. extracted solution
Tennessee rock phosphate...	.08	2.0	3.94	98.6	13.0
Double acid phosphate.....	3.60	90.0	4.19	105.0	13.0
Slag A	0.0	0.0	3.89	97.3	12.9
Slag B .....	.03	.8	3.98	99.5	12.9
Slag C .....	.23	5.8	4.05	101.0	12.8
Slag D .....	.06	1.5	4.02	100.5	12.8
Birmingham Slag .....	.09	2.3	3.96	99.0	12.9
Blue Rock .....	.16	4.0	4.02	100.0	13.1
Florida Soft Rock.....	.09	2.3	3.98	99.5	13.0
Apatite .....	.01	0.3	4.08	102.0	13.0
Iron phosphate .....	.15	3.8	3.72	93.0	13.1
Aluminum phosphate .....	.22	5.5	4.07	101.8	13.1
Acid phosphate	3.40	85.0	3.88	97.0	13.1
Steamed bone meal .....	.20	5.0	4.01	100.2	13.0
Acid alone					13.1

TABLE 5.

Recovery of phosphorus from 25 gms. of Brown Silt Loam and Brown Gray Silt Loam treated with 4 mgs. of phosphorus of either Tennessee Rock Phosphate or Double Acid Phosphate. Five consecutive extractions were made with fifth normal nitric acid.

	Brown Silt Loam		Brown-gray Silt Loam	
	with Rock Phosphate	with Double Acid Phosphate	with Rock Phosphate	with Double Acid Phosphate
First extraction in Mgs. P.....	1.86	1.75	3.02	3.10
Second " " " ".....	.47	.46	.25	.24
Third " " " ".....	.24	.21	.09	.10
Fourth " " " ".....	.13	.12	.02	.05
Fifth " " " ".....	.09	.02	.00	.01
Total " " " ".....	2.79	2.56	3.38	3.50
Percent of phosphorus recovery in first extraction.....	46.5	43.8	75.5	77.5
Percent of phosphorus recovery in all five extractions.....	69.8	64.0	84.5	87.5