

THE ORGANIC PHOSPHORUS CONTENT OF SOME IOWA SOILS

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The form in which phosphorus occurs, as well as its function in soils has been the subject of much study. Many years ago it was suggested that part of the phosphorus in soils occurs in an organic form, but some investigators doubted the occurrence of sufficient amounts to be of any significance. Various methods of determining the mineral phosphorus compounds in soil have been suggested, but it is only comparatively recently that a method has been developed which serves to distinguish between organic and inorganic phosphorus, and to show that there is an appreciable amount of the former in most soils. Potter and Benton (6) first attempted to determine organic phosphorus in soil and they devised a method which proved quite satisfactory. Schollenberger (7) studied the problem later and modified the method slightly. His conclusions agreed with those of Potter and Benton, however, in showing that there is a rather large amount of soil phosphorus in the organic form. Very little work has been done as yet to show the relationship of organic phosphorus to other constituents of the soil and to the fertility of particular soil types. It would be very desirable to know the relation organic phosphorus bears to fertility. Is it more or less available to plants than inorganic phosphorus? Does organic phosphorus revert to the inorganic form and how rapidly? These, and many other questions remain to be answered when more is known about the organic phosphorus content of soils.

A review of the literature shows that as early as 1844 Mulder (1) noted the presence of phosphorus in organic soil material.

Schmoeger (2) studied the effect of igniting soil and of heating with water under pressure, and concluded that the increased solubility of phosphorus in hydrochloric acid after ignition was due to the destruction of insoluble organic phosphorus compounds. He concluded that the phosphorus was in the form of nuclein or similar compounds.

Hopkins and Pettit (3) noted that certain soils showed a uniform mineral composition in surface, subsurface, and subsoil, and suggested that the difference in phosphorus in surface and subsoil might be due to organic phosphorus. They suggested a method for calculating organic phosphorus.

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Stewart (4) discussed the solubility of soil phosphorus in hydrochloric acid and ammonia and concluded that the greater part at least of the ammonia-soluble phosphorus is organic.

Fraps (5) showed that inorganic phosphates were soluble in ammonia after ignition and extraction with hydrochloric acid. He concluded that no method previously advocated would distinguish between organic and inorganic phosphorus in ammonia extracts.

Potter and Beuton (6) originated a method for distinguishing between organic and inorganic phosphorus in ammonia extracts.

Schollenberger (7) developed further the method of Potter and Benton and he discussed the relationships between organic phosphorus and other constituents. He concluded that organic phosphorus and nitrogen exist in the same ratio at different depths.

EXPERIMENTAL

The object of this paper is to describe some preliminary experiments in a study of the organic phosphorus content of several Iowa soils.

The four soils used were selected so as to give as wide a range of conditions as possible and are described below.²

No. 1. Wabash silty clay loam. "A dark brown to black silty clay loam to a depth of 18 inches, becoming somewhat lighter in color at that point. A dark brown to lighter brown silty clay loam to silty clay or clay to a depth of 36 inches. The soil is level and often poorly drained." The organic matter content is very high. Both surface and subsoil are low in lime. This soil when properly drained and worked is capable of very high productivity. This soil in its native condition may, in spite of its poor drainage and low bacterial activity, be said to possess high latent fertility.

No. 2. Clinton silt loam. "The surface soil is a light brown to grayish-brown silt loam. This extends to a depth of 8 to 12 inches at which point it grades into a layer of yellowish-brown or yellowish-gray silty clay mottled with yellowish-brown. This intermediate layer is usually 4 to 8 inches in depth and changes abruptly into a yellowish-gray silty clay mottled with yellowish-brown and rusty brown. This subsoil is very plastic when wet and compact and hard when dry." The drainage is good, but the soil washes badly. The organic content of the soil is low. The phosphorus content is comparatively low and the soil reaction is acid.

No. 3. Hancock silty clay. "The surface soil is only 4 to 6 inches in depth, and the subsoil extends to 12 to 15 inches giving way below to a gray and brown mottled or drab plastic clay which extends to 3 feet or more." The soil is rather high in total phosphorus and low in organic matter.

No. 4. Jackson silt loam. "The surface soil is a light-brown, smooth, silt loam to a depth of 8 to 12 inches and passes into a yellowish-brown silty clay loam to silty clay. The subsoil is rather compact." The application of lime where the soil is acid and of phosphorus and organic matter gives good results. This particular soil was selected because of its low phosphorus and organic carbon content and because of its acidity and low fertility.

²Quotations are taken from Soil Survey Reports of Iowa: Soil No. 1, Wright County Soils (in press); Soil No. 2, Johnson County Soils (in press); Soil No. 3, Pottawattamie County Soils; Soil Survey Report No. 2; Soil No. 4, Henry County Soils; Soil Survey Report No. 15.

- No. 1. High organic carbon, phosphorus, and nitrogen, high latent fertility.
 No. 2. Low nitrogen and organic carbon, relatively high total phosphorus.
 No. 3. High total phosphorus and low organic carbon, high nitrogen.
 No. 4. Low phosphorus, carbon and nitrogen, low fertility.

The analytical data given in table 1 with the exception of those giving organic phosphorus are taken from the analyses made in connection with the work of the Iowa Soil Survey.³ The organic phosphorus results were obtained by the method developed by Schollenberger with some slight modifications. This method involves the preliminary extraction of the soil with 1 per cent HCl followed by the extraction of the phosphorus by eight hours shaking with 4 per cent ammonia. After the extraction with HCl, the soil was washed free

TABLE 1
Analyses of soils

SOIL STRATUM	ORGANIC CARBON	NITROGEN	PHOSPHORUS	ORGANIC PHOSPHORUS
	<i>lbs. per acre</i>	<i>lbs. per acre</i>	<i>lbs. per acre</i>	<i>lbs. per acre</i>
Soil 1:				
Surface.....	129,354	9,500	1,563	393.46
Subsurface.....	178,542	9,760	2,398	482.40
Subsoil.....	116,298	6,180	2,304	690.36
Soil 2:				
Surface.....	20,256	1,500	1,428	72.22
Subsurface.....	12,448	1,000	2,560	
Subsoil.....	18,509	1,320	3,072	233.82
Soil 3:				
Surface.....	52,428	4,380	1,900	289.40
Subsurface.....	73,016	6,800	3,120	422.80
Subsoil.....	63,834	6,600	4,260	623.40
Soil 4:				
Surface.....	26,880	2,376	830	289.40
Subsurface.....	21,960	2,123	1,278	267.40
Subsoil.....	23,280	2,433	2,124	345.18

from chlorides, dried and ground to pass thru a 100-mesh sieve. 75 gm. were shaken with 750 cc. of 4 per cent ammonia. The soil suspension was set aside to settle then filtered through porcelain filters under 45 pounds pressure. This method of separation is open to some objection because it has been found that part of the organic matter does not pass through the filter. However, there was no difficulty experienced in the filtration. Soil no. 1 with the highest organic matter content filtered more slowly, but in every sample all but a few cubic centimeters filtered through. If there were any great discrepancy in results due to the filtration it should show up in soil no. 1. Here, however,

³The soil survey of Iowa is carried out by the Soils Section of the Iowa Agricultural Experiment Station in cooperation with the Bureau of Soils of the United States Department of Agriculture.

there was found a high percentage of organic phosphorus. Fraps (8) found with pure humic acid as much as 10 per cent loss in filtration. Schollenberger in comparing total phosphorus in an original ammonia soil extract with one filtered through unglazed porcelain found 6.6 per cent loss. Granting a loss of 10 per cent, the differences in percentages of organic phosphorus in the soil types used was so great that the value of the comparisons is not lost. In following up this preliminary work, however, a method of separation will be used which will eliminate this factor of loss.

Total phosphorus was determined from a 100 cc. portion of the filtrate. Inorganic phosphorus was determined from an equal aliquot. Organic

TABLE 2
Ratios of various constituents

SOIL STRATUM	NITROGEN-CARBON RATIO	ORGANIC PHOSPHORUS-TOTAL PHOSPHORUS RATIO	ORGANIC PHOSPHORUS-ORGANIC CARBON RATIO	ORGANIC PHOSPHORUS-NITROGEN RATIO
Soil 1:				
Surface.....	1-13.6	1- 3.98	1-328.7	1-24.1
Subsurface.....	1-18.3	1- 4.97	1-370.1	1-20.2
Subsoil.....	1-18.6	1- 3.34	1-168.4	1- 8.9
Soil 2:				
Surface.....	1-13.5	1-19.84	1-280.4	1-20.7
Subsurface.....	1-12.4			
Subsoil.....	1-14.0	1-13.15	1- 79.2	1- 5.6
Soil 3:				
Surface.....	1-11.9	1- 6.57	1-181.1	1-15.1
Subsurface.....	1-10.7	1- 7.40	1-172.6	1-16.0
Subsoil.....	1- 9.6	1- 6.84	1-102.3	1-10.5
Soil 4:				
Surface.....	1-11.3	1- 2.87	1- 92.8	1- 8.2
Subsurface.....	1-10.3	1- 4.80	1- 82.1	1- 7.9
Subsoil.....	1- 9.5	1- 6.17	1- 67.7	1- 7.0

phosphorus was obtained by taking the difference. All determinations were run in duplicate. It will be noted that in some cases rather large proportions of the total phosphorus were in organic form.

DISCUSSION OF RESULTS

Table 2 gives the calculations of the nitrogen-carbon, organic phosphorus-total phosphorus, organic phosphorus-organic carbon, and organic phosphorus-nitrogen ratios. By examining this table it may be seen that the nitrogen-carbon ratio is wider in soil no. 1 than in any of the other soils. This is as might be expected since soil no. 1 contains much more organic matter than any of the other soils. There has been less cropping on this soil than on the average upland soils of this section, drainage is poor and aeration deficient; hence organic matter has accumulated. Soil no. 4 shows the narrowest ratio;

and although it is very little different from no. 3, more decomposition and greater loss of easily decomposed organic matter has evidently occurred in this type.

When the ratio of organic phosphorus to total phosphorus is observed some interesting comparisons will be noted. For instance, the soil having the highest latent fertility (soil no. 1) and the soil having the lowest latent fertility (soil no. 4), show the highest ratios of organic phosphorus to total phosphorus. However, it is not fair to compare these two soils from the phosphorus standpoint alone since soil no. 1 is well supplied with nitrogen and has nearly twice as much total phosphorus. The significant part of the comparison is that a soil like no. 4 which is comparatively low in fertility and with so low a total phosphorus content should have 34 per cent of its phosphorus in organic form. This seems to indicate that organic phosphorus is perhaps less available than inorganic and remains in organic form rather tenaciously. In soil no. 4 if organic phosphorus were readily changed to inorganic it would hardly be expected that so large a percentage of organic phosphorus would be found. Following this line of reasoning it would be expected that soil no. 2 with only 5 per cent organic phosphorus would show a greater response to nitrogen than to phosphorus, since it has only 1500 pounds of nitrogen and has a comparatively high amount (1428 pounds) of total phosphorus of which only 5 per cent is organic.

Table 2 shows that with the exception of soil no. 4 the ratio of organic to total phosphorus is fairly constant at all depths. Soil no. 4 has evidently lost more of its inorganic phosphorus.

The organic phosphorus-nitrogen ratio shows a very striking contrast to the organic phosphorus-total phosphorus ratio. There is a wider ratio in the surface soils in all cases than in the subsoils in the former. This indicates that the nitrogen accumulated at the surface and made soluble has been leached out more rapidly than has the organic phosphorus. This of course is not surprising.

It may readily be seen from table 2 that the ratios of organic phosphorus to organic carbon are so different that no one ratio will serve for calculating organic phosphorus from organic carbon in different soil types. There is a range in ratios in surface soils from 1 to 328.7 in soil 1, to 1 to 92.8 in soil 4. However, if a large number of determinations had been made on each type it is possible, though not probable, that a more satisfactory and uniform ratio might have been secured.

Table 3 shows the amounts in all soils at different depths based on 2,000,000 pounds for surface, subsurface and subsoil. It is interesting to observe that organic phosphorus is rather uniform in subsurface and subsoil in all cases. Unfortunately the subsurface determination of soil no. 2 was lost.

The only explanation which can be suggested for this is that the organic phosphorus in the soil, or the phosphorus called organic, seems to remain as such and is rather uniformly distributed throughout the soil with the exception

of the surface where the amount has been increased by decaying plant residues.

No attempt has been made to draw any conclusions from these few analyses. This paper is merely a preliminary report on the problem. The results are interesting and indicative of the need of further study of organic phosphorus, but they will not permit of definite conclusions.

TABLE 3

Organic phosphorus in soil on basis of 2,000,000 pounds of soil for surface, for subsurface, and for subsoil

SOIL STRATUM		ORGANIC PHOSPHORUS
		<i>lbs.</i>
Soil 1:		
Surface.....		393.46
Subsurface.....		241.20
Subsoil.....		230.12
Soil 2:		
Surface.....		72.22
Subsurface.....		
Subsoil.....		77.94
Soil 3:		
Surface.....		289.40
Subsurface.....		211.40
Subsoil.....		211.70
Soil 4:		
Surface.....		289.40
Subsurface.....		133.70
Subsoil.....		115.09

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