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A Study of the Phosphorus
Content at Different Depths of
the Brown Silt Loam Soil of the
Early Wisconsin Glaciation

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A STUDY OF THE PHOSPHORUS CONTENT AT DIFFERENT
DEPTHS OF THE BROWN SILT LOAM SOIL OF THE
EARLY WISCONSIN GLACIATION

by

Fred G. Allison

Thesis for the degree of Bachelor of Science in Agriculture

in the

College of Agriculture

of the

University of Illinois

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Fred G. Allison

ENTITLED A STUDY OF THE PHOSPHORUS CONTENT AT DIFFERENT

DEPTHS OF THE BROWN SILT LOAM OF THE EARLY WISCONSIN GLACIATION

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Bachelor of Science

Cyril G. Hopkins

HEAD OF DEPARTMENT OF Agronomy



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A STUDY OF THE PHOSPHORUS CONTENT AT DIFFERENT
DEPTHS OF THE BROWN SILT LOAM SOIL OF
THE EARLY WISCONSIN GLACIATION.

CONDITIONS SUGGESTING THE STUDY AND OBJECT.

How to maintain the productive capacity of our soils is a problem of vast importance and one which demands the serious consideration of the scientists, the economists, and of all the intelligent and thoughtful men of to-day. The study of this great problem from the soil fertility standpoint has up to date resulted in the drawing of some pretty definite conclusions. The fact has been well established that there are three plant food elements which are often present in our soils in insufficient quantities. These are nitrogen, phosphorus, and potassium and of the three phosphorus it seems, for most Illinois Soils, is by far the most important. Of potassium most of our soils have enough, of nitrogen we can secure a supply at a reasonable rate by means of legumes, but when our soils are deficient in phosphorus, as is very often the case, it seems that much of the supply must be obtained from off the farm in the form of bonemeal, rock phosphate, or similar fertilizers.

If maintaining or restoring the phosphorus content of our soil is to entail this outlay it is of primary importance to know how much of the phosphorus already in the soil is available for plant use. It is generally considered that a very large part of the food available for the use of the plants



lies in the surface soil, that is, in the soil which is ordinarily plowed, say seven inches in depth. It has been suggested that the phosphorus in the surface soil necessary for the crop production would, in the natural course of events, be replenished from that in the lower depths by some process, possibly being drawn up in capillary water or by plant roots. To just what extent such a process takes place, if at all, was unknown and it was for the purpose of throwing light on this question by determining, as nearly as possible, just exactly where the phosphorus is in the soil that this work was undertaken.

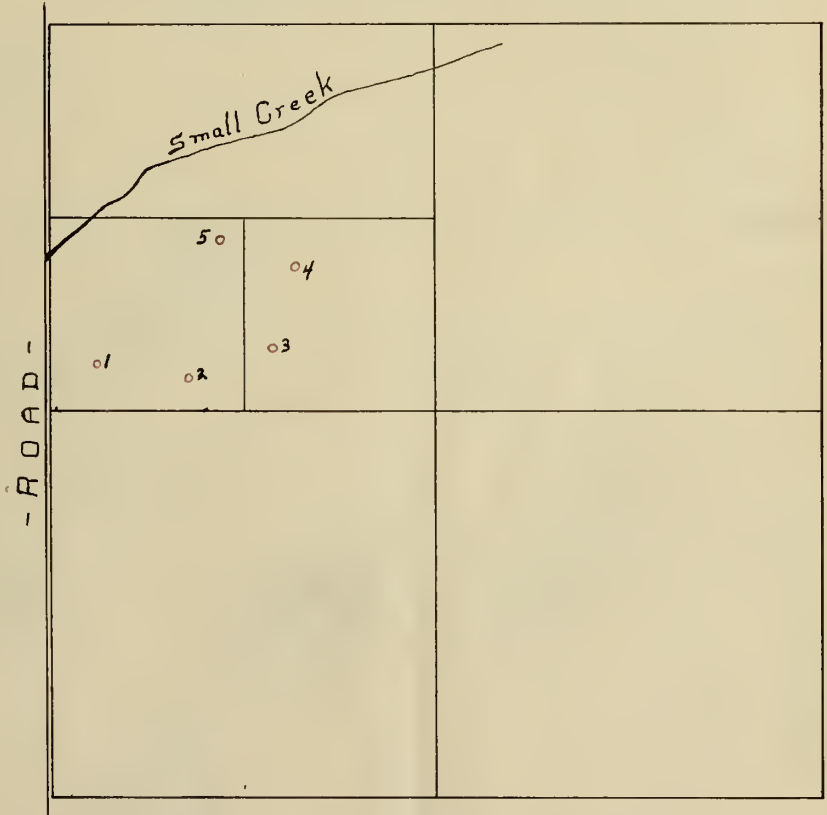
DESCRIPTION OF THE SOIL ANALYZED.

In order to have the work mean as much as possible it was desirable to secure soil which was representative of a considerable area and which had been subjected throughout a known history to approximately uniform conditions. A soil which satisfied these requirements was found upon the farm of Mr. Lafayette Funk of Bloomington, Illinois. The soil there is the brown silt loam of the Early Wisconsin Glaciation, a type which occurs over a very large area. The samples were secured in a large permanent pasture of about two hundred acres extent which has never been plowed or cultivated in any way. It is what we call a virgin soil. The pasture was originally covered with the once common prairie blue stem grass, but as the country was settled and the land more closely pastured this was forced out, with the exception of a few small areas,

by blue grass which grows there luxuriantly and furnishes excellent pasturage.

Knowing that the value of a soil analysis depends to a very large extent upon the fidelity with which the sample represents the soil in question, the attempt was made to secure truly representative samples. For this reason fences and all spots where stock may have stood and influenced the character of the soil to an abnormal degree by their droppings were carefully avoided. The samples were secured along the side of a gently sloping ridge in the end of the pasture away from the farm buildings. The five sets of samples which were analyzed were secured in the places shown in the following sketch. The numbers refer to the numbers of the sets.

Section 12,
Township 22,
Range 1 East
of the Third
Principal
Meridian



The samples were composited, each being made up of soil

secured from ten borings which were made in an irregular circle with a radius of twelve to sixteen feet. The soil was divided into four-inch strata and samples were taken to the depth of forty inches, except in the case of set two which extended to eighty inches, thus making ten composite samples in each forty-inch set. The two inch soil auger in use at the Illinois Experiment Station was employed in taking the samples and care was exercised to prevent mixing the soil from the different layers during the process.

In sets one, two, three and five the black topsoil extended to the depth of about eighteen inches, in set four it was a little deeper, about twenty inches. Underneath this the subsoil was a mottled yellow clayey silt. In set two a layer of gravel or glacial till was found between sixty four and seventy inches in depth and below this the material was quite sandy. Before grinding the soil for the analysis all stones and coarse material were removed by sifting, only the fine soil being used.

ANALYTICAL METHODS.

The first step in making a phosphorus determination is to get the material in solution. Various methods have been used in doing this and varying results have consequently been secured depending upon the completeness with which the entire quantity of phosphorus was dissolved. In the case of soils various standard solvents have been used and these results serve very well to show the comparative amounts in the soil. Further valuable interpretation of these results is however, apparently lacking and there remains some doubt as to just how much they do mean. For this reason it was decided that nothing short of total phosphorus determinations would be satisfactory for this study. The method which was decided upon is that which has recently been developed and put into use at the Illinois Experiment Station. It is as follows-

The soil for the analysis is ground very fine, ground a second time in the steel mill or in an agate mortar. Fifteen grams of sodium peroxid are weighed into a sliver crucible, about three grams of this removed to a watch glass, and the remainder thoroughly mixed by means of a glass rod with five grams of the finely ground soil which has been previously weighed out. The glass rod is then cleaned off by rubbing it against the peroxid on the watch glass, and this material is spread over the surface of the mixture in the crucible so as to form a complete covering. With subsoils having an insufficient amount of organic matter to carry on the fusion it was found advisable to mix about two tenths grams of Arrowroot

starch with the soil and peroxid so as to effect the fusion without applying heat from without. The mixture being prepared it is heated from above with the flame of a Bunsen burner until combustion commences. The flame is then removed and the crucible covered with a closely fitting lid until the action ceases.

If the soil is not ground finely enough or if for any reason all the soil is not completely fused, heating the crucible to redness for a few minutes at this stage is often effective. Doing this, however, materially shortens the life of the crucible. The crucible is cooled while still covered and the cake of fused material is loosened by gently tapping the bottom. The material is placed in a large funnel and very cautiously transferred to a 500 cc. measuring flask with a stream of cold water. The crucible, cover and funnel are then washed and cleaned by the aid of a rubber-covered glass rod. The material in the flask is acidified with concentrated hydrochloric acid, diluted with water to about 250 cc. if necessary, boiled for about five minutes, cooled, filled to the mark and allowed to stand for four or five hours to allow the silica to settle out.

Exactly 200 cc. of the clear liquid are drawn out with a pipette, transferred to a 250 cc. beaker, evaporated to dryness on a steam bath and baked for five hours in an oven at 110°C . The material is taken up with about 20 cc. of concentrated hydrochloric acid and hot water, filtered through 9 cm. filters into 400 cc. beakers and washed with hot water until

free of chlorids. This process removes a large part of the silica which was in solution. The filtrate, including the washings, is evaporated on the steam bath to about 200 cc. and while still hot is precipitated with ammonium hydroxid, transferred to 11 cm. filters and washed about five times with hot water in order to get rid of a large part of the soluble salts. Holes are then made in the bottoms of the filters, the precipitate is dissolved in hydrochloric acid, returned again to the 400 cc. beakers, evaporated to dryness and baked for five hours at 110°C as before. The residue is taken up with concentrated hydrochloric acid and cold water, filtered through 9 cm. hard filters into 250 cc. beakers and washed until free of chlorids, thus completely removing the remaining silica.

The filtrate is evaporated to about 25 cc. , 2 cc. of concentrated nitric acid are added, the material is just neutralized with ammonium hydroxid and cleared up with a few drops of nitric acid, adding it slowly and applying heat gently if necessary but avoiding more than a few drops in excess. The solution is heated to 50° - 60°C and 15 cc. of the clear standard ammonium molybdate solution are added. The temperature is retained at this point for two hours, then the material is removed and allowed to stand over night. The precipitate is transferred to 9 cm. filters, washed with a cold dilute solution of nitric acid (10% is specified, but a weaker solution proves satisfactory), then with cold distilled water until free of acid. The filter and precipitate are returned to the beaker and standard potassium hydroxid is added in 10 cc. portions

until the precipitate is dissolved. The excess of potassium hydroxid is titrated against a solution of nitric acid of equal strength, using phenolphthalein as an indicator. The potassium hydroxid is of such strength that 1cc. is equivalent to one gram of P_2O_5 . Inasmuch as the sodium peroxid contains a small quantity of phosphorus each new portion of it was analyzed and the resulting factor deducted from subsequent determinations.

The above method was used with but slight variations for sets one to four inclusive. Before many fusions were completed the silver crucibles were found to be unequal to the demands upon them, the alternate heating and cooling together with the other strains speedily breaking them. Consequently iron crucibles were put into service and found to be more satisfactory because longer-lived. The amount of phosphorus in the iron removed at each fusion was so small as to deserve no consideration. While engaged upon the work information was obtained to the effect that the precipitate of ammonium phospho-molybdate was completely insoluble, or practically so, in a dilute solution of ammonium nitrate, a one-tenth per cent solution being strong enough to prevent it from dissolving. Instead, therefore, of washing the precipitate with nitric acid, ammonium nitrate solution was used with satisfactory results. With this change lacmoid was used as an indicator instead of phenolphthalein.

All analyses were made in duplicate and an analysis was considered satisfactory if the titrations of these duplicates

differed no more than 0.2 cc. Now in many instances after deducting the sodium peroxid factor the phosphorus in the soil corresponded to only 1.5 cc. or less , thus making the probable error in the neighborhood of 13%. This is rather a large limit of error and efforts were made to reduce it. In the first place the strength of the solutions used in the titrating was reduced so that 1 cc. was equivalent to 0.25 grams of phosphorus. A method was desired which would permit of the use of more than two grams of soil in the determination. The one described above would not do this because it was thought that the very large amount of precipitate obtained when ammonium hydroxid was added could not be satisfactorily washed.

The attempt was made to fuse 4 grams of soil, transfer to a beaker and filter directly in an alkaline solution, retaining the phosphorus, as was supposed, as iron phosphate on the filter and disposing of much of the silica as soluble sodium silicate. The idea of so easily solving the problem was, however, given up when it was learned in the Experiment Station laboratory, where the process was also being studied, that a variable quantity of phosphorus also passed through the filters with the silica in some unknown form.

At last the following process was hit upon and found to be satisfactory.- Four grams of soil are fused with twelve grams of the peroxid, transferred to a beaker with water, acidified with hydrochloric acid and precipitated with ammonia. The precipitate is transferred to 18 cm. filters, washed with hot water to dispose of soluble salts and returned to the

beakers with hydrochloric acid. It is then twice evaporated to dryness, baked and filtered to remove the silica, and the phosphorus is determined as in the method above. Using this method and the dilute solution for titrating mentioned above the probable error was materially reduced. Set five was analyzed according to this method and while the results are similar to the previous ones the greater accuracy of the work gives them additional value.

Hygroscopic moisture determinations were made with the soils analyzed and the calculations were based upon dry matter, the results being expressed in parts per million. The results of the analyses are shown in the following tables.

TOTAL PHOSPHORUS IN SOILS.

Set No. 1.

Number of soil.	Depth (inches)	Parts per million.
1	0-4	584.
2	4-8	518.
3	8-12	547.
4	12-16	481.
5	16-20	363.
6	20-24	316.
7	24-28	320.
8	28-32	288.
9	32-36	331.
10	36-40	342.

TOTAL PHOSPHORUS IN SOILS.

Set No. 2.

Number of soil.	Depth (inches)	Parts per million.
1	0- 4	550.
2	4- 8	567.
3	8-12	479.
4	12-16	443.
5	16-20	419.
6	20-24	365.
7	24-28	346.
8	28-32	350.
9	32-36	334.
10	36-40	321.
11	40-44	348.
12	44-48	352.
13	48-52	347.
14	52-56	355.
15	56-60	360.
16	60-64	338.
17	64-68	345.
18	68-72	357.
19	72-76	342.
20	76-80	354.

TOTAL PHOSPHORUS IN SOILS.

Set No. 3.

Number of soil	Depth (inches)	Parts per million.
1	0- 4	541.
2	4- 8	556.
3	8-12	482.
4	12-16	429.
5	16-20	399.
6	20-24	376.
7	24-28	353.
8	28-32	337.
9	32-36	340.
10	36-40	362.

TOTAL PHOSPHORUS IN SOILS.

Set No. 4.

Number of soil.	Depth (inches)	Parts per million.
1	0- 4	557.
2	4- 8	534.
3	8-12	519.
4	12-16	478.
5	16-20	434.
6	20-24	403.
7	24-28	362.
8	28-32	340.
9	32-36	347.
10	36-40	353.

Set No. 5.

Number of soil.	Depth (inches)	Parts per million.
1	0- 4	543.
2	4- 8	547.
3	8-12	504.
4	12-16	447.
5	16-20	413.
6	20-24	378.
7	24-28	342.
8	28-32	351.
9	32-36	352.
10	36-40	356.

TOTAL PHOSPHORUS IN SOILS.

Average of five sets.

Depth (inches)	Parts per million.
0- 4	556.
4- 8	554.
8-12	506.
12-16	456.
16-20	406.
20-24	368.
24-28	345.
28-32	353.
32-36	341.
36-40	347.

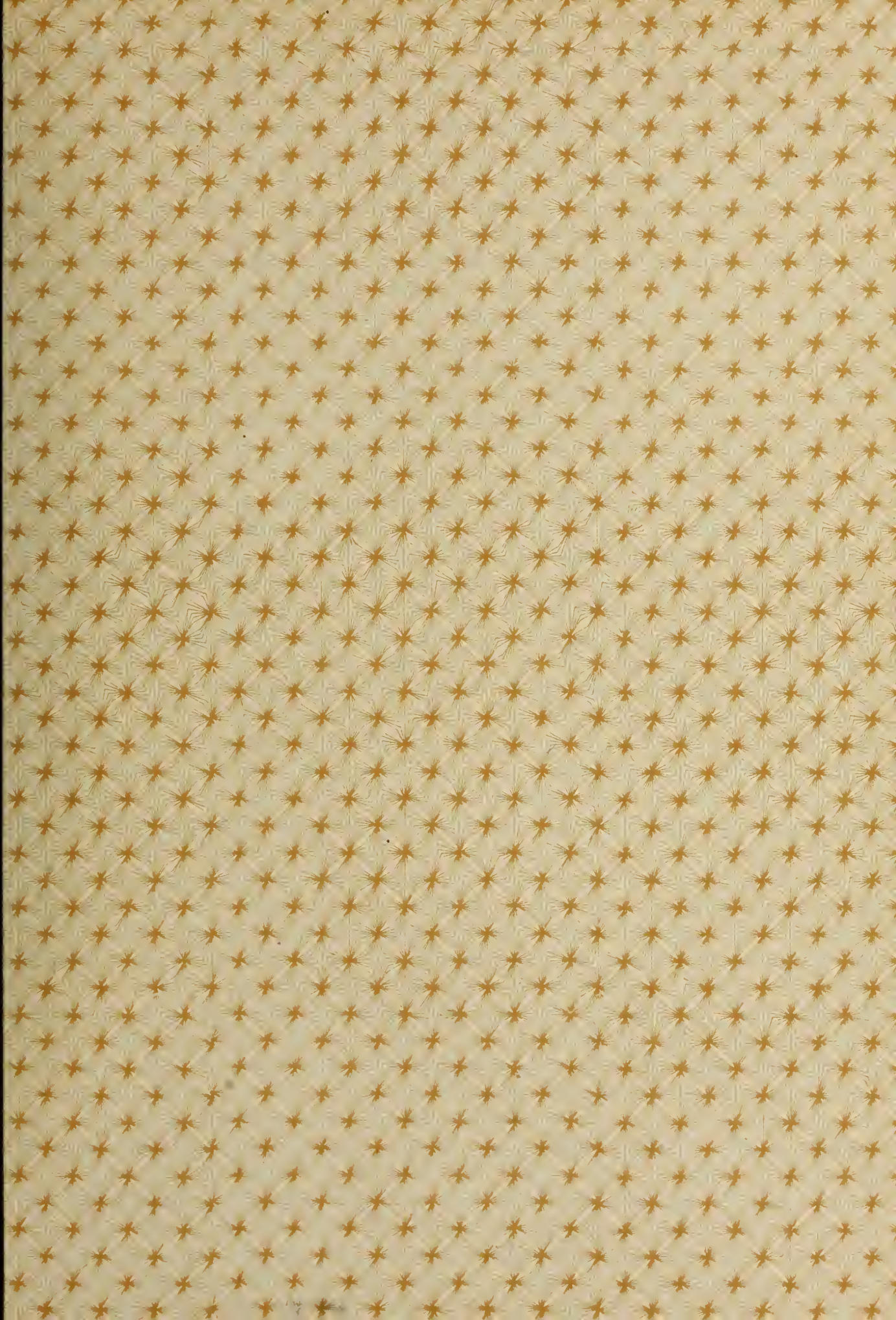
CONCLUSIONS.

Greater difficulty was experienced with the procedure than had been anticipated and consequently fewer results were obtained. The writer feels that the data are insufficient to warrant the deducing of many or far reaching conclusions. Observing the data presented above, however, it appears that the quantity of phosphorus in the soil gradually decreases down to 20 or 24 inches and below that depth is practically constant. There seems also to be a relation between the depth at which the decrease in quantity ceases and the lower limit of the range of the principal mass of plant roots (in this case chiefly of grasses). Our attention is further called to

the fact that the quantity of phosphorus in the soil below this point is always smaller than the quantity above. This might, in a way, be considered incompatible with the theory that it is only the phosphorus within the range of plant roots that is available, for if that were true then we would expect to find, sometimes at least, the amount below this range greater than that above.

This possible explanation of how the existing conditions may have come about is suggested. The surface of most of our soils are being constantly lowered by particles of earth being carried away in surface drainage waters and by various other means. The soil removed in this way may contain a less quantity of phosphorus than does the subsoil, and thus there would be an accumulation of phosphorus near the surface. This proportion is not proved, yet it seems to be the most plausible one which has been suggested. Further study of the problem, using different soils and perhaps better methods, is highly desirable.





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