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A Survey of Ohio Orchard Soils Relative to Phosphorus Distribution and Acidity

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Wooster, Ohio

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A SURVEY OF OHIO ORCHARD SOILS RELATIVE TO PHOSPHORUS DISTRIBUTION AND ACIDITY

J. H. GOURLEY AND R. M. SMOCK[1]

INTRODUCTION

The primary purpose of this orchard survey was to determine the available phosphorus content and the soil acidity of orchards whose previous soil treatment was known.

As a special feature of the survey, attention was given to the downward distribution of available phosphorus following treatments with this element. It is a well established fact that, when phosphorus-supplying fertilizers are applied to a soil, a large portion of the phosphorus is "fixed" or "reverted" into insoluble forms in a comparatively short time; and, as a result, there is very little percolation or leaching of the soluble forms. Since the preponderance of evidence in orchard experiments has failed to show that the use of phosphorus has benefited fruit trees in any direct way, the study of phosphorus distribution was made in the hope of shedding some light on the reason why fruit trees seldom respond to phosphorus fertilization. The survey of soil acidity was made with the intent of indicating the range of soil reaction in which fruit trees are grown in Ohio.

THE ROLE OF PHOSPHORUS IN THE ORCHARD

A review of the literature on orchard experiments reveals that most investigators find little or no direct benefit to fruit trees resulting from the use of phosphorus. However, a few investigators have shown some direct benefit from the use of this element, either alone or in combination with nitrogen and potassium. None of the investigators who disclaimed any direct benefit from phosphorus applications would discount its value in an indirect way. The value of phosphorus in the development of cover crops and in stimulating the sod growth is unquestioned.

One explanation of the lack of response of fruit trees to phosphorus may be that fruit trees have a comparatively low phosphorus requirement. Thompson (5) stated that fruit trees use phosphorus more nearly in the proportion found in the soil than do field crops.

[1]Grateful acknowledgment is hereby made of the splendid cooperation extended by the orchard and vineyard owners mentioned in this publication.

A second possible contributing cause is that fruit trees have an extensive horizontal and vertical root spread as compared with the field crop plants; this may account for their ability to secure sufficient phosphorus from the natural supply in the soil.

A third suggestion is the known fixation of phosphorus into insoluble forms, with little resulting leaching or percolation to the region of root absorption.

Bear and Salter (2) found that, after 15 years of phosphorus fertilization, apparently all of the applied phosphorus in excess of the crop needs was still present in the surface soil, never having diffused into the subsoil. They concluded that practically all of the applied phosphorus was fixed in the top 6⅔ inches of soil.

RELATION OF SOIL ACIDITY TO FRUIT TREE RESPONSES

The simplest method of indicating soil reaction is to designate whether a soil is "acid" or "alkaline". The total acidity of a soil (measured by titration) is expressed as the "lime requirement". The term "pH" which expresses the logarithm of the reciprocal of the hydrogen-ion concentration is perhaps the most specific means of indicating soil reaction. In general, the pH correlates fairly well with the lime requirement of a soil, even though it is not a measure of total acidity.

A pH value of 7.0 indicates a state of neutrality—a condition neither acid nor alkaline. A pH value of 6.0 indicates a state of slight acidity. Thus, all soils having a pH value below 7.0 are acid; whereas those above 7.0 are alkaline. A soil having a reaction of 5.0 is considered very acid; one with a pH of 9.0 is very alkaline.

Effect of soil reaction on fruit tree responses.—The bulk of the evidence points to the fact that most of the fruit trees are not so sensitive to soil reaction as are many of the field crop plants. Chandler (3) stated that, although there is no conclusive evidence, apple trees do not seem to show any response to the addition of lime. From work done in New Hampshire, Gourley (4) reported that apple trees did not respond to the use of lime. That lime will greatly benefit the cover crop or soil cover that is to be grown on an acid soil and thus indirectly benefit the trees is well known.

THE SURVEY

THE SOIL ACIDITY TEST

Method of sampling.—A soil auger was used to obtain soil from the top 5 inches of earth. At each tree from which samples were taken, three borings were made around the tree and the earth from

the combined borings was well mixed and tested as a composite sample. For the most part, the samples were taken within the "fertilizer ring" or in the areas affected by the fertilizer treatment. However, to make some comparisons with soil unaffected by the fertilizer treatment, some samples were taken out in the "land" some little distance from the tree.

The acidity test.—The La Motte-Morgan Soil Testing Set was used for the pH determinations. The test involves the percolation of different indicators (i. e., brom-cresol-green, chlor-phenol-red, brom-thymol-blue, and phenol-red) through the soil sample and the production of a specific color change, the resultant color being compared with a standard color chart.

THE AVAILABLE PHOSPHORUS TEST

Method of sampling.—The refuse, debris, sod, or decaying plant residues were first scraped away from the soil surface. A hole was dug with a tiling spade, an attempt being made to have the sides as nearly vertical as possible. The soil was cut out from the soil profile by means of a two-edged knife at one-inch levels from the surface down to 4 inches and from 4 inches down to 10 inches at 2-inch levels.

One hole was dug at each tree tested, one to 2 feet inside the drip of the tree in order to obtain soil affected by the fertilizer treatment. As indicated in the data, a few samples were taken out in the "land" between the rows some distance from the tree drip. The soil was well broken up and mixed before the tests were made.

The phosphorus test.—The La Motte-Truog Test for "available" phosphorus was used. This test, devised by Emil Truog (6) of the Wisconsin Agricultural Experiment Station, attempts to measure the available phosphorus content in pounds per acre.

The available phosphorus is extracted from a known amount of soil by 0.002 normal sulfuric acid buffered to a pH of 3.0 by ammonium sulfate. The buffering makes possible a solvent of optimum intensity and flocculates the soil to aid in filtration. After extraction (accomplished by shaking the soil and extracting medium for one minute, followed by filtration), the clear extract is shaken well with three drops of ammonium molybdate-sulfuric acid solution. The final step is the addition of a small amount of stannous chloride; after the addition of which, a blue color develops. The intensity of the blue measures the amount of available phosphorus per acre and is determined by comparison with a standard color chart.

PRESENTATION OF DATA

ORCHARD J, OHIO AGRICULTURAL EXPERIMENT STATION, WOOSTER

Phosphorus.—This orchard was planted in 1922, and comparative fertilizer tests were started in 1928 to determine the effect of various elements on the keeping quality of fruit. The orchard is at present in a mixed clover-alfalfa sod. Phosphorus was applied broadcast in the rows when the orchard was seeded down in 1929; this doubtless accounts for the phosphorus content appearing higher than one would expect, even in the check plots of this orchard. It also should be noted in the data that the soil has a relatively high phosphorus content to a depth of nearly 8 inches. This is probably due to the fact that the orchard was in cultivation for one year after the experiment was started (1928), not having been seeded down until 1929.

In 1931 the "normal nitrate" treatment referred to in the data consisted of 2½ pounds of sodium nitrate, an additional quarter of a pound of nitrate being added each year. The superphosphate treatments were the same as the nitrate in pounds per tree. In 1931 the potash treatment was 1¼ pounds per tree, an additional eighth of a pound being added each year.

The soil in this orchard is a Wooster silt loam. The orchard is tile drained and lies on a gentle northeastern slope. Samples were collected from June 25 through July 1, 1931.

The most striking thing to note is the marked fixation of phosphorus in the first inch of soil. Table 1. The actual amount of phosphorus indicated in the surface soil of the check plot should be discounted somewhat, since phosphorus was broadcast in the orchard at the time the seeding of the sod was done.

Soil reaction.—The marked decrease in acidity as a result of the "triple nitrate" treatment is evident in the change of pH from approximately 4.6 or 4.7 (check plot) to approximately 6.0. All treated plots seem to run consistently less acid than the check plot, although the difference is slight.

H. A. HABER AND SONS VINEYARD, VERMILION, OHIO

A fertilizer experiment has been in progress in this vineyard since 1927. The experiment is being carried on under the auspices of the Ohio Agricultural Experiment Station. The vineyard is kept cultivated throughout the season, but a rye cover crop is sown in the fall and turned under the following spring.

TABLE 1.—Orchard J, Ohio Agricultural Experiment Station, Wooster, Ohio

Plot	Treatment	Available Phosphorus, pounds per acre						pH				
		Soil depth	Tree 1	Tree 5	Tree 9	Tree 14	Tree 18	Tree 1	Tree 5	Tree 9	Tree 14	Tree 18
		In.										
1	Triple Nitrate: ¾ lb. nitrate per year of tree's age.	0–2	60	60	55	60	55	6.1	6.2	5.4	6.2	6.2
		2–4	25	45	45	45	30					
		4–6	25	30	30	30	25					
		6–8	25	25	20	25	25					
		8–10	15	15	15	20	20					
3	Normal Nitrate: ¼ lb. nitrate per year of tree's age.	0–2	55	55	45	47	45	4.8	4.9	4.8	5.0	5.0
		2–4	35	35	40	40	35					
		4–6	30	25	25	25	25					
		6–8	25	20	25	25	20					
		8–10	20	15	15	15	15					
5	Complete Fertilizer: ¼ lb. nitrate and superphosphate and ⅛ lb. muriate of potash per year of tree's age.	0–2	100	110	115	87	63	4.8	4.7	4.8	4.9	4.8
		2–4	50	50	50	45	25					
		4–6	25	30	30	40	25					
		6–8	25	25	25	25	20					
		8–10	20	15	20	15	15					
			Tree 2	Tree 6	Tree 8	Tree 14	Tree 19	Tree 2	Tree 6	Tree 8	Tree 14	Tree 19
9	Superphosphate plus Nitrate: ¼ lb. each of nitrate and superphosphate per year of tree's age.	0–1	125	130	85	100	125	5.0	5.0	5.1	5.1	5.1
		1–2	65	85	60	40	60					
		2–4	50	50	40	40	50					
		3–5				30	60					
		4–6	40	35	35	25	60					
		6–8	25	25	25	25	25					
		8–10	20	20	15	20	15					
			Tree 1	Tree 5	Tree 9	Tree 14	Tree 19	Tree 1	Tree 5	Tree 9	Tree 14	Tree 19
13	Potash plus Nitrate: ¼ lb. nitrate and ⅛ lb. muriate of potash per year of tree's age.	0–1	55	60	55	35	35	5.0	5.0	5.1	5.1	5.0
		1–2	50	55	35	30	30					
		2–3	35	30	30	25	25					
		3–4	30	25	25	20	25					
		4–6	25	25	25	20	20					
		6–8	25	20	20	20	15					
		8–10	15	15	15	15	15					
15	Normal Nitrate: ¼ lb. nitrate per year of tree's age.	0–1	50	55	60	45	35	4.8	4.7	5.0	4.8	4.8
		1–2	40	45	45	40	30					
		2–3	30	30	35	30	35					
		3–4	25	30	25	25	25					
		4–6	25	25	25	25	25					
		6–8	20	20	25	25	20					
		8–10	15	15	15	25	15					
17	No fertilizer.	0–1	50	55	50	40	40	4.6	4.6	4.7	4.6	4.7
		1–2	45	40	45	35	35					
		2–3	30	30	30	30	30					
		3–4	30	25	25	25	30					
		4–6	25	20	20	20	25					
		6–8	20	20	15	15	20					
		8–10	15	15	10	10	15					

The mechanical distribution of available phosphorus secured by cultivation and the increase in the content of phosphorus as a result of the use of manure are rather remarkable. This is in accord with the statement of Spurway (4) that either manure supplied phosphorus in an unusually available form or else it exerted a solvent action on the unavailable soil phosphorus. However, an annual application of 3 tons of manure per acre would add considerable phosphorus; in fact, almost as much as did the use of 300 pounds of superphosphate. The manure plot is the only one in the series that has given increased grape yields in this fertilizer experiment (3). As is usually the case, the use of lime with the phosphorus application (Plot 12) increased the amount of available phosphorus considerably over that in plots treated with superphosphate but no lime.

TABLE 2.—H. A. Haber and Sons Vineyard, Vermilion, Ohio

Soil depth In.	Plot 1 NPK	Plot 1 NPK	Plot 2 Check	Plot 2 Check	Plot 3 NP	Plot 3 NP	Plot 11 Manure	Plot 11 Manure	Plot 12 NPK and lime	Plot 12 NPK and lime
	Available Phosphorus, pounds per acre									
0-1	85	80	30	35	80	75	80	80	110	110
1-2	75	75	30	35	75	75	75	75	110	110
2-3	75	75	30	30	75	70	65	75	80	90
3-4	60	75	25	25	60	70	75	75	85	85
4-6	50	60	25	25	50	25	50	60	25	50
6-8	25	25	15	15	25	20	50	50	20	25
8-10	20	20	10	10	15	15	20	20	15	25
	pH									
	4.4	4.3	4.6	4.5	4.4	4.4	4.4	4.4	7.0	7.1

This vineyard has rye cover crop-cultivation culture, is tile drained, and is level. The surface soil is brown with a mottled gray subsoil which is very impervious. The average depth of the surface soil is about 7 inches. Samples were taken July 23 and 24, 1931.

Fertilizer treatments on the different plots were as follows:

Plot 1. 192 lb. sulfate of ammonia, 300 lb. superphosphate, and 32 lb. muriate of potash
Plot 2. No fertilizer
Plot 3. 192 lb. sulfate of ammonia and 300 lb. superphosphate
Plot 5. 192 lb. sulfate of ammonia
Plot 6. 150 lb. nitrate of soda
Plot 7. 300 lb. nitrate of soda
Plot 9. 384 lb. sulfate of ammonia
Plot 11. 3 tons of manure per acre per year
Plot 12. Same as Plot 1, plus 1000 lb. lime per year

W. C. YULE ORCHARD, DANBURY, OHIO

This is a cultivated peach orchard on the Sandusky Bay Peninsula where a fertilizer experiment was carried on from 1922 to 1927. The purpose of this study was to discover the residual effects of the phosphatic fertilizer after an interval of 4 years.

At the time of the experiment, alfalfa cover crop-cultivation culture was employed. Since the termination of the experiment, the volunteer weed crop has been disced down each spring. The orchard is practically level; the soil is a Randolph silt loam, and the depth of the surface soil is about 8 inches. Drainage is natural and fair.

It will be noted that the soil is almost alkaline, although the effects of the use of ammonium sulfate can be noted in some plots (Nos. 10 and 11). The soil is of limestone origin, with numerous outcrops of limestone in the immediate vicinity. The calcareous nature of this soil would probably account for the high available phosphorus content in the check plot.

A study of the data will reveal the mechanical distribution of phosphorus obtained as a result of cultivation. The remarkable residuum of phosphorus should be observed on the plots which were treated with phosphatic fertilizers.

TABLE 3.—W. C. Yule Orchard, Danbury, Ohio

Soil depth In.	Plot 7 NK	Plot 7 NK	Plot 8 NPK	Plot 8 NPK	Plot 10 Tankage and bone meal	Plot 10 Tankage and bone meal	Plot 11 Check	Plot 11 Check
	Available Phosphorus, pounds per acre							
0–1	75	75	150	150	70	75	75	60
1–2	75	75	150	150	70	75	75	60
2–3	75	75	150	150	65	75	75	55
3–4	70	70	125	125	60	65	70	50
4–6	70	65	125	125	50	60	65	35
6–8	40	60	100	100	30	60	50	30
8–10	50	40	75	75	55	60	50	20
	pH							
	7.0	7.0	6.8	7.0	5.8	5.6	5.8	5.8

It might be inferred that cultivation has increased the amount of available phosphorus, even to a depth of 10 inches, on the plots treated with this element. This apparent distribution should be discounted somewhat, since, in discing the orchard, ridges have been thrown up along the tree row and samples taken here would indicate a greater mechanical distribution than would otherwise occur.

Furthermore, the use of nitrate of potash has increased the content of available phosphorus. Spurway (5) also mentioned this effect of potash.

The fertilizer treatment since the termination of the experiment (1927) has consisted of uniform applications of sulfate of ammonia. The previous treatments of plots tested during the experiment were as follows (Amounts per tree are given):

Plot 7. Nitrate of potash
Plot 8. 3 lb. sulfate of ammonia, 4½ lb. superphosphate, and 1½ lb. muriate of potash
Plot 10. 7 lb. tankage and 5 lb. bone meal
Plot 11. No fertilizer

FARNSWORTH ORCHARD COMPANY, WATERVILLE, OHIO

This is a large orchard in the Maumee Valley, south of Toledo. The orchard is practically level and is tile drained.

At the time of the fertilizer experiment (1923-1926), this section of the orchard was in blue-grass sod. At present it is clean cultivated until June first and a weed cover crop is disced down the following spring. Samples were taken July 28 and 29. The fertilizer treatments during the experiment were as follows (Amounts per tree given):

Plot 7. 5 lb. superphosphate
Plot 8. 5 lb. superphosphate and 3.9 lb. nitrate of soda
Plot 10. No fertilizer
Plot 13. 2½ lb. muriate of potash
Plot 14. 2½ lb. muriate of potash and 3.9 lb. nitrate
Plot 16. 3.9 lb. nitrate of soda, 5 lb. superphosphate, and 2 lb. muriate of potash
Plot 17. 4 lb. sulfate of ammonia, 8 lb. superphosphate, and 3 lb. muriate of potash
Plot 19. 16 lb. superphosphate and 5 lb. muriate of potash
Plot 20. 16 lb. superphosphate, 3 lb. sulfate of ammonia, and 5 lb. muriate of potash

Since the termination of the experiment, sulfate of ammonia and quantities of manure have been used. The phosphorus-treated plots in the fertilizer experiment had no better yields than did the check plots. This is a calcareous soil, and the data indicate the lack of acidity, although the use of sulfate of ammonia under the trees has probably increased the acidity somewhat.

It is interesting to note the naturally occurring abundance of available phosphorus. This condition is associated with the basicity of the soil; also, the manure has perhaps been supplying

some available phosphorus in recent years. There is a much greater quantity of available phosphorus at a depth of 10 inches on the check plot than in the uppermost inch of most soils. The mechanical distribution of the phosphorus, due to cultivation, is also noticeable in this orchard.

The use of only 5 or 8 pounds of superphosphate per tree in the fertilizer experiment did not leave a very significant residuum of available phosphorus, but the use of 16 pounds per tree left a remarkable residuum in the cultivated layer.

TABLE 4.—Farnsworth Orchard, Waterville, Ohio

Soil depth In.	Plot 7 P	Plot 8 NP	Plot 10 Check	Plot 13 K	Plot 14 NK	Plot 16 NPK	Plot 17 NPK	Plot 19 NP	Plot 19 NP	Plot 20 NPK
	Available Phosphorus, pounds per acre									
0-1	160	160	150	150	110	160	160	200	200	200
1-2	160	160	150	150	110	150	160	175	200	200
2-3	160	160	150	150	110	125	150	200	175	175
3-4	125	150	125	130	100	150	150	180	160	175
4-6	100	100	65	100	80	75	75	150	150	150
6-8	60	75	70	65	50	60	60	50	125	125
8-10	60	60	50	50	40	50	50	50	75	75
	pH									
	6.6	6.8	7.0	.....	6.8	7.0	6.0	6.2	6.6	6.1

It is very doubtful if there is any distribution of phosphorus in this orchard below the level affected by cultivation. However, one might expect more percolation of available phosphorus in this orchard soil than in many others, due to its loose texture.

J. F. McCOSH ORCHARD, VINCENT, OHIO

A fertilizer experiment was conducted in this orchard from 1912 to 1917 by the Ohio Station, with the intent of rejuvenating the trees. Ballou and Lewis (1) report that phosphorus gave no direct benefit to the trees but that it did aid the cover crop and the sod remarkably.

Since the termination of the experiment, sulfate of ammonia has been used only a few times. At the present time the orchard is in a sparse sod.

It will be noted in the data that there is a noticeable residual effect following the application of 5 pounds of superphosphate per tree, even after an interval of 14 years. The residual effect is most apparent after the use of a complete fertilizer. The graphs also indicate the low available phosphorus content of this orchard soil.

The soil is extremely acid (i. e., 4.1 to 4.3).

TABLE 5.—J. F. McCosh Orchard, Vincent, Ohio

Soil depth In.	Plot 8 NP	Plot 11 Check	Plot 12 NP	Plot 12 NP	Plot 14 Check	Plot 15 NPK	Plot 16 NPK
	Available Phosphorus, pounds per acre						
0–1	25	20	30	20	25	35	40
1–2	25	15	20	15	20	15	20
2–3	15	10	15	10	15	15	15
3–4	10	10	10	10	10	10	15
4–6	10	10	10	10	10	10	10
6–8	10	10	10	10	10	10	10
8–10	8	8	8	10	8	10	8
	pH						
	4.1	4.1	4.2	4.2	4.3	4.1	4.3

Sod culture is practiced. The orchard is practically level; drainage is natural and only fair. The average depth of the surface soil is about 8 inches. Samples were taken August 6. Since the cessation of the experiment (1917), one or two applications of nitrate of soda or sulfate of ammonia have been used. Treatment per tree during the experiment was as follows:

Plot 8. 5 lb. nitrate of soda and 5 lb. superphosphate
Plot 11. No fertilizer
Plot 12. 5 lb. nitrate of soda and 5 lb. superphosphate
Plot 14. No fertilizer
Plot 15. 5 lb. nitrate of soda and 5 lb. superphosphate
Plot 16. Same as Plot 15 and 5 lb. muriate of potash

M. H. DYAR ORCHARD, LOWELL, OHIO

A fertilizer experiment was conducted in this orchard from 1912 to 1917. Ballou and Lewis (1) reported no direct benefit from the use of phosphorus, except that it did stimulate sod growth. This southern Ohio orchard is located on the top of a hill, but the orchard itself is practically level, with a slight slope to the east.

Since the termination of the experiment, annual applications of sulfate of ammonia have been used.

The orchard was in sod at the time of the experiment and has continued so up to the present.

Even after an interval of 14 years there is still a marked residual effect from phosphorus application (Table 6). Furthermore, 5 pounds of superphosphate per tree did not give nearly the marked residuum that 10 pounds did. Such a remarkable residuum is noteworthy since a heavy sod has been exhausting this supply of phosphorus during the intervening years.

No significant residue appears below a depth of 3 inches, indicating that practically all of the phosphorus was fixed in the surface 3 inches.

The high degree of acidity occurring in this soil will also be noted in the data. The pH value outside of the fertilizer ring was somewhat lower (more acid) than in the soil in the fertilized area, indicating that the continuous use of sulfate of ammonia has increased acidity slightly.

TABLE 6.—M. H. Dyar Orchard, Lowell, Ohio

Soil depth In.	Plot A NPK	Plot B P	Plot C NPK	Plot D NPK	Plot E NPK	Plot F Check	Plot G See above
	Available Phosphorus, pounds per acre						
0-1	30	45	80	30	.....	25	30
1-2	25	25	25	25	.....	20	25
2-3	20	20	20	20	.....	15	.....
3-4	20	15	15	15	.....	15	.....
4-6	15	15	15	15	.....	15	.....
6-8	15	10	10	10	.....	10	.....
8-10	10	10	10	10	.....	10	.....
	pH						
	4.2	4.2	4.2	4.2	4.2	4.2	4.2

The surface soil is yellowish brown; the subsoil is yellow. The average depth of the surface soil approximates 10 inches. Drainage is natural and good. Samples were taken August 4 and 5. Since the termination of the experiment (1917), there have been uniform applications of sulfate of ammonia. During the experiment, treatments per tree were as follows:

Plot A. 5 lb. nitrate of soda, 10 lb. superphosphate, and 2½ lb. muriate of potash
Plot B. 10 lb. superphosphate
Plot C. 10 lb. nitrate of soda, 10 lb. superphosphate, and 2½ lb. muriate of potash
Plot D. 2½ lb. nitrate of soda, 5 lb. superphosphate, and 2½ lb. muriate of potash
Plot E. 5 lb. nitrate of soda, 5 lb. superphosphate, and 2½ lb. muriate of potash
Plot F. No fertilizer
Plot G. 10 lb. tankage, 10 lb. bone meal, and 5 lb. muriate of potash

MAHONING COUNTY EXPERIMENT FARM, CANFIELD, OHIO

This orchard lies on almost level ground. The average depth of the surface soil approximates 8 inches. The surface soil is brownish yellow and the subsoil is yellow. The orchard is tile

TABLE 7.—Mahoning County Experiment Farm, Canfield, Ohio

Soil depth In.	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
	Available Phosphorus, pounds per acre				
0–1	75	100	25	95	25
1–2	50	50	20	40	15
2–3	25	25	20	.....	.....
3–4	25	20	20	.....	.....
4–6	15	15	15	.....	.....
6–8	10	10	10	.....	.....
8–10	10	10	10	.....	.....
	pH				
	4.5	4.6	4.2	4.6	4.6

drained. Samples were collected August 1, 1931. Sample 1 was taken in the variety orchard; the others were taken in the fertility and culture orchard. The fertilizer and cultural treatments of the various samples were as follows:

Sample	Plot	Culture	Fertilizer
1.....	.....	Blue-grass sod	Normal nitrate; 200 lb. superphosphate broadcast each year.
2.....	1	Blue-grass sod	160 lb. nitrate over entire surface of ground with an added ½ lb. under drip of trees. 200 lb. superphosphate broadcast each year.
3.....	2	Blue-grass sod	No fertilizer.
4.....	3	Blue-grass sod	200 lb. superphosphate broadcast each year.
5.....	4	Blue-grass sod	Same as Sample 2, minus the superphosphate.

WASHINGTON COUNTY EXPERIMENT FARM, MARIETTA, OHIO

This orchard is situated on the crest of a hill. Drainage is fair and natural. The surface soil is yellowish-brown and the subsoil is red. Average depth of surface soil approximates 10 inches. Part of the orchard is in permanent sod and part was reseeded in the spring of 1931. Samples 1, 2, 3, and 4 were taken from the permanent sod section; Samples 5 and 6 were taken from the section plowed and reseeded in the spring of 1931. Samples were taken August 5, 1931. The phosphate which was applied to the orchard was put on broadcast and did not serve as a tree treatment. Fertilizer treatments were as follows:

Sample 1. 160 lb. nitrate broadcast, plus 1 lb. nitrate under tree per year of age. No phosphorus
Sample 2. No fertilizer
Sample 3. Normal nitrate under trees; 160 lb. superphosphate broadcast each year
Sample 4. Same as 3
Sample 5. Same as 3, plus 1½ tons lime spring 1931
Sample 6. Same as 5

TABLE 8.—Washington County Experiment Farm, Marietta, Ohio

Soil depth In.	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
	Available Phosphorus, pounds per acre					
0-1	25	25	60	80	50	50
1-2	20	20	20	20	50	25
2-3	15	15	15	15	50	15
3-4	15	15	10	15	25	15
4-6	15	15	10	10	15	10
6-8	10	10	10	10	10	10
8-10	10	10	10	10	10	10
	pH					
	4.7	4.4	4.8	4.7	4.9	5.0

THORNECREST ORCHARD, WOOSTER, OHIO

This is a hill orchard on a northeastern slope. Drainage is natural and good. The surface soil is brown and the subsoil is brownish-yellow. The average depth of the surface soil approximates 8 inches. The orchard is in blue grass and clover. Some trees are mulched. Samples were taken July 10, 1931. Fertilizer treatment is as follows: 200 pounds of superphosphate per acre are broadcast each year. Normal nitrate per tree was used until 1931, when sulfate of ammonia was employed. Samples 1, 2, 3, and 4 were taken under the drip of the trees as usual and indicate that some of the broadcast phosphate had fallen under the drip of the tree. Sample 5 was taken in the "land" where the phosphate had been broadcast.

TABLE 9.—Thornecrest Orchard, Wooster, Ohio

Soil depth In.	Sample 1*	Sample 2	Sample 3	Sample 4	Sample 5
	Available Phosphorus, pounds per acre				
0-1	70	150	160	150	150
1-2	65	100	150	50	90
2-3	60	75	80	25	75
3-4	55	45	55	30	50
4-6	60	25	30	25	40
6-8	70	20	25	20	20
8-10	75	25	20	15	15
	pH				
	4.8	4.6	4.6	4.7	.....

*The explanation of the data in Sample 1 is not clear. It is possible that mechanical mixture of the soil had been effected here in recent years.

CLERMONT COUNTY EXPERIMENT FARM, BATAVIA, OHIO

This orchard lies on comparatively level ground. The land is tiled and drainage is fair. The soil is light to dark brown. Samples were collected August 27, 1931. Cultural practices on the different plots from which samples were taken were as follows:

Sample 1. Legumes planted in the spring of 1931
Samples 2 and 3. Permanent blue-grass sod

Fertilizer practices in plots where samples were taken were as follows:

Sample 1. Normal sulfate of ammonia; superphosphate broadcast 8 or 10 years ago; 3½ tons of lime in the spring of 1931
Sample 2. Double normal sulfate of ammonia; superphosphate broadcast 8 or 10 years ago; 3½ tons of lime in the spring of 1931
Sample 3. No nitrogen treatment; superphosphate and lime as above

TABLE 10.—Clermont County Experiment Farm, Batavia, Ohio

Soil depth In.	Sample 1	Sample 2	Sample 3
Available Phosphorus, pounds per acre			
0-1	60	35	25
1-2	30	25	15
pH			
	5.8	4.8	5.8

R. W. RODGERS ORCHARD, READING, OHIO

This orchard is situated on rolling ground. The color of the surface soil is brown. The orchard is tile drained. Samples were collected August 26, 1931. The apple orchards were in blue-grass sod, which was disced up in the spring of 1931. The peach orchard (Sample 3 taken here) has rye cover crop-cultivation culture. Fertilizer treatment was as follows: Normal sulfate of ammonia used each year on the trees. Samples 1 and 3 had phosphate broadcast between the rows 5 years ago. It is noteworthy that the available phosphorus is retained in the surface 2 inches to a very great extent.

TABLE 11.—R. W. Rodgers, Reading, Ohio

Soil depth In.	Sample 1	Sample 2	Sample 3
Available Phosphorus, pounds per acre			
0-1	60	25	70
1-2	50	20	65
pH			
	6.2	6.4	6.0

OHIO ORCHARD COMPANY, MILFORD CENTER, OHIO

This orchard lies on slightly rolling land, although most of it is practically level. The soil color is brown. Drainage is only fair, and parts of the orchard are tiled. Cover crop-tillage culture is practiced. Sweet clover, millet, and red and alsike clovers mixed are used as cover crops. Samples were collected August 29, 1931. Fertilizer treatments were as follows:

Samples 1, 2, and 3. Normal sulfate of ammonia; 400 lb. superphosphate broadcast twice during the past 3 years

TABLE 12.—Ohio Orchard Company, Milford Center, Ohio

Soil depth In.	Sample 1	Sample 2	Sample 3
Available Phosphorus, pounds per acre			
0-1	65	60	50
1-2	60	55	.....
pH			
	4.6	4.3	.....

DISCUSSION

Conditions vary so widely from point to point that the actual value of such a summary can only be suggestive. To get the best estimate of the existing situation, one should make a rather specialized study of each orchard visited in the survey. However, a general summary of results obtained in cultivated and non-cultivated orchards is presented.

Figures 1 and 2 can give at best but a rough picture of conditions as regards the available phosphorus content in Ohio orchard soils. Care was taken in the selection of orchards to be used in the plotting of the summary graphs. Only orchards in which actual fertilizer experiments had been conducted with proper controls were

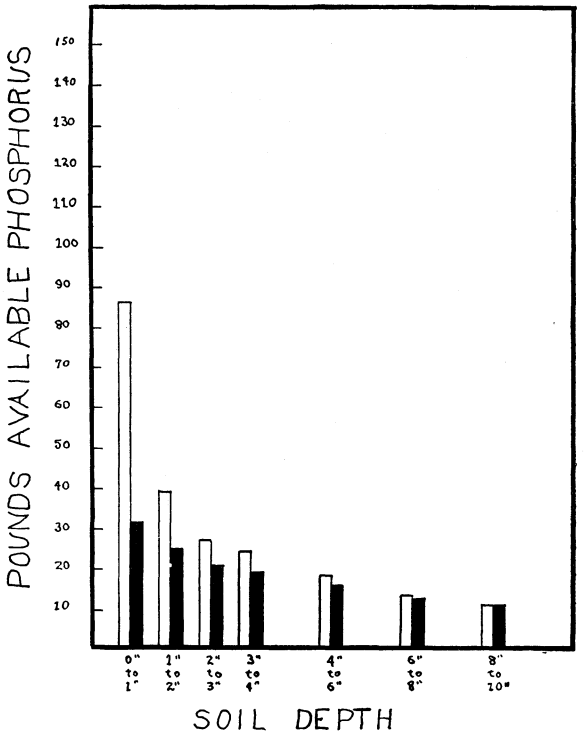

Fig. 1.—General summary of sod orchards

Solid bar = No superphosphate applied
Open bar = Superphosphate applied

Summary of results obtained in several sod orchards in which known amounts of superphosphate were applied. Note localization of available phosphorus in upper few inches and its lack of penetration.

used in these summaries; for example, the data included in Figure 2 concerning cultivated orchards were taken from summaries of results obtained in the Yule and Farnsworth orchards and the Haber vineyard, all in north and northwestern Ohio. The summary of data obtained in sod orchards (as represented in Figures 1 and 3) includes the following orchards: Orchard J, Wooster; I. P. Lewis

orchard[2]; Washington County Experiment Farm orchard; and the Mahoning County Experiment Farm orchard, all in northeastern Ohio. The results obtained in the Dyar and McCosh (Benedict) orchards were not included in the graphs concerning sod orchards, since the program of fertilization had been discontinued for a long time.

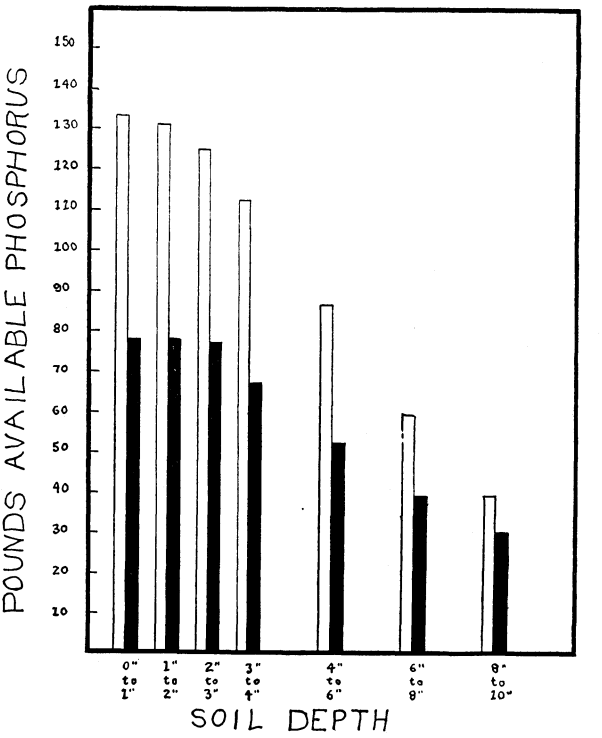

Fig. 2.—General summary of cultivated orchards

Solid bar = No superphosphate applied
Open bar = Superphosphate applied

Summary of results obtained in cultivated orchards in which known amounts of superphosphate were applied. Note mechanical distribution effected by cultivation.

In a consideration of the results on sod orchards, it should be noted that the results obtained in Orchard J at the Ohio Station were included in this summary. There was a mechanical distribution of phosphorus to some little depth, due to one year of cultivation.

[2]Not recorded in bulletin as the data are very similar to others used.

Figure 2 summarizes the results obtained in cultivated orchards in which fertilizer experiments have been made or are in progress. The mechanical distribution of available phosphorus in the first 6 or 8 inches is notable. It might be inferred from this figure that cultivation brings the applied phosphorus closer to the roots than could possibly occur under the sod system of culture.

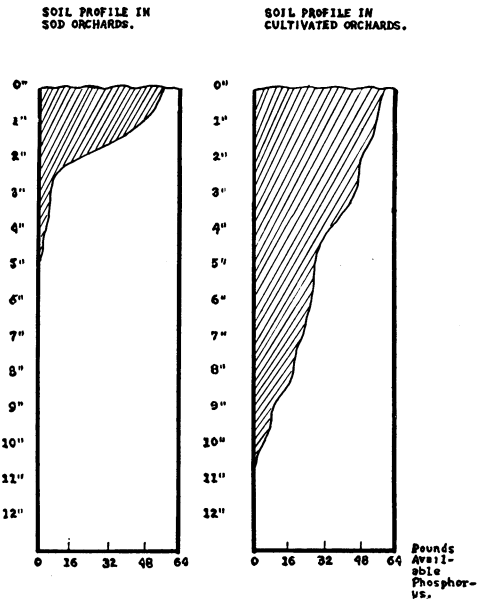

Fig. 3.—Penetration of phosphorus in sod and cultivated orchards

Shaded area represents available phosphorus resultant from applications of superphosphate. It represents amounts above what normally occurs in the soil, or merely the amounts present as a direct result of applications. Note localization and lack of penetration in sod orchards and the mechanical distribution effected by cultivation in tilled orchards.

One should remember, however, that cultivation tends toward a deeper root system. It is very doubtful if a significant increase in available phosphorus results from an application of phosphorus in cultivated orchards below the level affected by tillage. This assumption is in agreement with the findings of Bear and Salter (2).

An apparent discrepancy appearing in Figure 2 should be accounted for. It would appear from a comparison of the figures concerning sod and cultivated orchards that the latter had considerably more available phosphorus. It should be noted that two of the orchards (i. e., Yule and Farnsworth) included in the summary of cultivated orchards occur in calcareous soils with a very high natural phosphorus content. The value of the figures lies mainly in their indication of the distribution of available phosphorus in the two different cultural systems.

SUMMARY

I. This survey of 27 Ohio orchard soils, 12 of which are here reported, indicates that the available phosphorus content is low in the acid soils of eastern and southern Ohio.

II. The amount of available phosphorus is relatively high in the less acid soils of the State (i. e., in the northwestern portion).

III. When phosphorus is applied to sod orchards, there is little, if any, percolation of available phosphorus below a depth of 3 inches.

IV. Cultivation effects a mechanical distribution of available phosphorus to the depth of tillage.

V. The low pH, or high degree of acidity, existing in many Ohio orchard soils would explain in large part the frequent failure of leguminous or, in extreme cases, even non-leguminous cover crops in those sections. In order to grow satisfactory cover crops or other orchard covers on such acid soils adequate applications of lime must be made.

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