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SOIL PROFILE AND ROOT PENETRATION AS INDICATORS OF APPLE PRODUCTION IN THE LAKE SHORE DISTRICT OF WESTERN NEW YORK

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INTRODUCTION

The principal apple-growing district of western New York is a belt 6 to 10 miles wide extending along the lake shore from Buffalo, on Lake Erie, to Oswego, on Lake Ontario, a distance of about 125 miles.

Previous to 1919 this constituted the most important barreled-apple district of the United States, but since that time there has been a decline in its relative importance owing to heavy competition and to decrease in production within the district.[1]

Decrease in production has been due to the age of many of the orchards, to periods of unfavorable weather, and to neglect during the past few years because of low prices and adverse economic conditions. As a result old orchards are dying out and are being cut down and few new plantings are being made.

During the summer of 1931 a study was made to determine, if possible, to what extent decline in production might be owing to soil conditions.[2] This study was confined to an area of about 22.5 square miles surrounding the village of Hilton, in Monroe County.

During the summer of 1932, in connection with a detailed soil survey made by the Bureau of Chemistry and Soils cooperating with the Department of Agronomy of Cornell University, this study was extended to cover the northern part of Monroe County from the ridge, or old beach line, to Lake Ontario. It includes a considerable portion of the best orchard soils, a large section in which the soils are of intermediate grade, and extensive sections entirely unsuited for orchard planting, thus offering opportunity for striking contrasts and comparisons.

[1] Folger, J. C., and Thomson, S. M. THE COMMERCIAL APPLE INDUSTRY OF NORTH AMERICA. p. 29–30. New York. 1921.

[2] Sweet, A. T., and Oskamp, J. SOILS IN RELATION TO FRUIT GROWING IN NEW YORK. PART I. A DETAILED SOIL SURVEY OF THE HILTON AREA, MONROE COUNTY. N.Y. (Cornell) Agr. Expt. Sta. Bul. 541, 16 p., illus. 1932.

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These detailed studies have been supplemented by observations and numerous field examinations of the soils throughout the apple-growing sections of this lake-shore district, and in all these sections a very definite relation was found to exist between the soil profile, the depth of rooting, condition of the orchards, and apple production.

CLIMATE

The importance of the lake-shore district for apple growing, as for the growing of other tree fruits, is owing largely to climatic conditions. Near the lake the tempering influence of this large body of water affords protection from the extremely low temperatures reached on the higher lands but a few miles from the shore.

As recorded by the United States Weather Bureau station at Rochester, the mean annual temperature is 47° F., and the absolute minimum is −14°. At Cortland, in Cortland County, about 50 miles inland and at a higher elevation, the minimum is −30° and at Cooperstown, about 100 miles from the lake, −33°.

The equalizing influence of the lake also prevents early blooming and injury from late spring frosts. At Rochester the average date of the last killing frost in spring is April 29, at Cooperstown it is May 5, and at Cortland May 15. Injury occurs at times, in the lake district, from cold cloudy weather in the spring, particularly at blossom time. Bees and other pollen-distributing insects do not work well under such conditions, and poor pollination results.

The normal annual precipitation for this district is about 32 inches. At Sodus it is 29 inches, at Lockport 30.97 inches, at Rochester 32.83 inches, at Brockport 33.08 inches, and at Oswego 35.21 inches. This is sufficient moisture, in a latitude of such low evaporation as this, for the production of good crops, provided soil and subsoil are favorable for its conservation.

On certain soils during periods of unusual drought apples and other crops suffer from lack of moisture. In orchards this is indicated by thin, pale foliage, by premature ripening, and by small-sized fruit. Under such conditions even the trees may be injured.

Injury from excessive moisture in the subsoil, especially during seasons of unusual precipitation is, however, believed to be much greater than that from lack of moisture during drought.

Apple growers of this district express the opinion that much injury was caused by excess precipitation during the years 1925, 1926, and 1927, and that this injury was so serious that orchards in many places have not yet fully recovered.

Weather records during this period show a precipitation as compared with the normal as follows: At Rochester, from 0.76 inches below the normal in 1925 to 0.82 inches above the normal in 1927; at Oswego, from 1.17 inches below the normal in 1926 to 2.16 inches above the normal in 1925; and at Lockport, from 1.32 inches above the normal in 1926 to 3.98 inches above the normal in 1927. The greatest increase above normal, that at Lockport, averaged only 2.46 inches a year for the 3 wet years.

Under favorable conditions of deep, well-drained soil and subsoil, especially where there is good surface drainage, it is doubtful that a small increase of moisture would be seriously harmful. On the other hand, where orchards are being grown on soils not naturally well suited for the purpose, or where the topography is flat without well-developed drainage ways and the underdrainage is poor, even a small increase may have been, and doubtless was, seriously harmful.

In Virginia, in the Ozarks, and in some other commercial apple-growing districts, where the rainfall is as great as in western New York but evaporation is higher and the soil is less retentive of moisture, serious injury results from drought.

In such districts trees of the same age and variety in the same orchard differ markedly in size. Trees in small depressions and on the lower gradual slopes, where the soil is deepest and has the greater moisture supply, have larger trunks than those on the steeper slopes where the soil is shallow and dry. Orchards 50 or 60 years old are unusual in such districts, and trees having trunks 6 feet in circumference are rarely seen. In the lake-shore district of western New York, in contrast, the trees of each orchard are nearly uniform in

FIGURE 1.—A typical old orchard in the lake-shore district of western New York.

size regardless of soil conditions. Many orchards are producing well at 50 years of age; some are still bearing well at 75 years of age, and there are said to be a number of bearing apple trees in Monroe County more than 100 years old. In many of these old orchards the average circumference of the trunk, 30 inches above the ground, is more than 6 feet; numerous trees have trunks more than 7 feet in circumference, and several measure more than 8 feet.

One highly productive old orchard of the lake-shore district, planted in 1865 on soils having good surface drainage and well-drained subsoils, has one tree with a trunk girth of 105 inches, which is said to have a record yield of 32 barrels of apples in 1 year. Roots in this orchard were found to penetrate the subsoil to a depth of about 8 feet (fig. 1).

From the age of these orchards, uniformity of growth, and size of the trees the conclusion is reached that orchards of this district are well supplied with moisture, have had an abundance of plant food, and have grown under rather favorable soil and climatic conditions.

In this district prevailing winds are from the northwest, and the trees of some orchards show this influence by a slight tendency to lean toward the southeast. A more pronounced tendency, however, is a twisting of the trunks of probably more than 75 percent of all the apple trees from left to right or clockwise.

This twisting of the trunks of trees is shown in several of the illustrations on the following pages. Occasionally a trunk may be found in which the twist is in the opposite direction. Trunks of pear and of other fruit trees and of forest trees of this district do not show this prevalence of twisting. When an occasional twisted trunk is found, the direction of twist is quite as often in the opposite direction as it is from left to right.

The cause of this prevalence in the direction of the twist of apple trees is not definitely known, but it is believed to be owing to the northwest winds and the tendency of the winds to shift from west to east. In well-spaced apple orchards this force exerts an almost constant pull in the direction of twist, while in pear orchards and in the native forests such force cannot be so readily applied.

VARIETIES OF APPLE TREES

In this district there is a general recognition of the advantage of using the better soils for orchard planting. These range in color from brown or light brown to reddish brown, and in texture from loam or silt loam to a light fine sandy loam. They are deep and have no tight or compact layers in the subsoil or substratum to a depth of several feet, and have good surface drainage and underdrainage.

Less attention has been given, however, to the adaptation of the soil to the different apple varieties. Heavy and less well drained soils are generally recognized as being better suited for the Rhode Island Greening and other green apples than for the Baldwin and other highly colored varieties. The McIntosh is thought to be somewhat more resistant to poor drainage conditions than are some other varieties.

Better coloring, especially early coloring, is obtained on well-drained soils of light texture than on heavy soils, or on those not well drained. The keeping quality of apples grown on soils of medium or heavy texture, however, is said by the managers of cold-storage plants to be superior to that of apples grown on sandy soils where time of ripening is earlier and the ripening process more rapid. The fruit has a better color in orchards in sod than in orchards under cultivation.

Early plantings in this region consisted largely of the Baldwin, Rhode Island Greening, and Twenty Ounce varieties. Of the trees planted in the Hilton area prior to 1899 these three varieties made up 83 percent.[3]

In orchards planted since that time the Baldwin and Greening make up an important part, but the more recent plantings also include a large percentage of McIntosh and a somewhat less number of the Cortland, Northern Spy, Delicious, Twenty Ounce, and Ben Davis.

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[3] La Mont, T. E. FACTORS AFFECTING THE INCOMES OF FRUIT FARMS IN THE HILTON AREA, MONROE COUNTY, N.Y. N.Y. (Cornell) Agr. Col. Agr. Econ. 1, 38 p., illus. 1931. [Mimeographed.]

In 1928 the Baldwin and Rhode Island Greening constituted 50 percent of the total number of bushels of apples produced in the Hilton area, Twenty Ounce 9 percent, and Ben Davis 8 percent. No other variety constituted more than 5 percent of the total number of bushels.

The adaptation of other tree fruits to soils is generally recognized. Sweet cherries are generally believed to require the sandier, best-drained soils. Next in order as to drainage are sour cherries, peaches, apples, pears, and quinces. For the last-named fruit, soils are used which are so poorly drained and wet that no other tree fruit can be grown on them.

In the western part of the county the growing of pears is confined almost entirely to heavy, imperfectly drained soils. Near Irondequoit Bay and the Genesee River, however, this fruit is grown rather extensively on well-drained sandy soils.

DRAINAGE

The northern part of Monroe County and a considerable portion of this apple-growing district occupies an old, nearly level lake plain with poor natural drainage.

Attention has been called to the injury believed to have been caused in the orchards of this district by excess precipitation in 1925, 1926, and 1927. In May 1931 examination was made of a number of orchards in the western part of Monroe County [4] to determine the soil and ground-water conditions. Borings with a soil auger were made, where possible, at regular intervals throughout the orchards and records kept of the character of soil and the height to which ground water rose in the holes.

Of 500 borings made between the middle of May and the first of June ground water came into more than 60 percent. In some it rose to a depth of only a few inches in the bottom of a hole 5 feet deep, but in many others it rose to within 2 feet or less of the surface a few minutes after the hole had been bored. In borings made during June, ground water was found less frequently than earlier in the season, collecting in 37 percent of more than 400 holes. Rainfall during this period was considerably above normal in May, but below normal in April and June.

In these borings a close relation was found between moisture conditions of the subsoil and the soil type. Dark-colored soils occupying slight depressions and flat areas were found to have the highest water table, free ground water coming into practically all soils of this kind, in many places rising to within a few inches of the surface. Brown soils having mottled gray and rust-brown layers in the upper subsoil and compact, nearly impervious layers in the deep subsoil showed better drainage conditions, ground water being found in about one half the borings made in such soils. In these soils the depth to free water was also found to be greater than in the dark-colored soils. Brown soils having subsoils free from mottling or but slightly mottled, and without compact or impervious layers in the deep subsoil, were found to have the best drainage conditions. In but few places was ground water found in such soils at a depth of 5 feet.

[4] OSKAMP, J., and BATJER, L. P. SOILS IN RELATION TO FRUIT GROWING IN NEW YORK. PART II. SIZE, PRODUCTION, AND ROOTING HABIT OF APPLE TREES ON DIFFERENT SOIL TYPES IN THE HILTON AND MORTON AREAS, MONROE COUNTY. N.Y. (Cornell) Agr. Expt. Sta. Bul. 550, 45 p., illus. 1932.

This examination indicated a saturated condition of subsoil in the orchards which is very unfavorable for tree growth and fruit production, especially if it occurs during the spring when growth should be most rapid.

Defective drainage is due (1) to the accumulation of water in small basinlike and depressed areas with no adequate outlet; (2) to smooth, flat areas in which heavy, nearly impervious clay or rock beds are reached at slight depths; and (3) to the occurrence of nearly impervious layers of gravelly, sandy, and clay till, which consists of an unassorted mass of small angular pieces of red sandstone, larger somewhat rounded boulders of various kinds, sand, silt, and clay, all of glacial origin. Fine sandy loam and fine sand of lacustrine origin are also in places so compact that they restrict moisture movement.

Poor drainage of low-lying and depressed areas results in dark-colored surface soils high in organic matter, and light-colored upper subsoils, from which the coloring matter has been leached. The light-colored layer is also sandier because a large part of the more soluble minerals has been leached out and the nearly insoluble silica remains.

Lack of drainage in some of the low-lying areas is due in part to character of the subsoil. Where this consists of mottled plastic sandy clay or of compact till, ground-water movement is very slow, and drainage either by means of tile or of open ditches is slow and difficult.

Lack of drainage in other places is often due to obstructions caused by roads, fences, field boundaries, and lines of trees crossing natural but not very well defined drainage ways. Cultivation of the fields has also caused the filling up of lower areas, thus checking the natural drainage.

Much might be done to improve the drainage of such areas by removing the obstructions and by the use of tile and of open ditches.

Provisions for drainage have thus far been almost entirely at the expense of the individual landowner. In many cases such measures cannot prove effective because deep master ditches are needed and can be constructed only through the cooperation of landowners or by the formation of drainage districts.

By such means poorly drained areas can be improved and prevented from becoming larger. Adjacent lands would also be benefited, but it is doubtful if any area of dark-colored poorly drained soil with light-gray upper subsoil in this district can be made sufficiently safe to justify its use for commercial orchard planting.

Owing to the uneven surface of the impervious subsoil material, poor drainage is not confined to low-lying or to flat areas. Soils from which the surface water quickly disappears after rainfall are not necessarily well drained. Poorly drained areas may occur on the tops of ridges or on the slopes. Soils which may seem to have a well-drained surface often have poorly drained subsoils. Ridges and uplands, where defective drainage is caused by the impervious condition of the subsoil, can be made suitable for orchard planting by providing good surface drainage only.

This unfavorable condition is made worse by the uneven surface of much of the lake-shore district. Slight depressions with intervening ridges and mounds are common. Smooth, uniform slopes are unusual. Run-off is seriously checked, and the water goes into the subsoil.

Ground-water conditions in soils intended for orchard planting where trees show signs of distress by their scant foliage or low production, can be determined by making test holes with a soil-sampling auger or a post-hole digger and by keeping a record of the height to which the ground water rises in the hole and the time required for it to disappear.

When young orchards are to be planted, good soils should be selected, the surface carefully smoothed, and adequate surface run-off provided. Orchards already planted should be given the best surface drainage possible.

SOIL GROUPS

For convenience of study, soils used for orchards in this district may be divided into three broad groups: (1) Soils with open subsoils. These are brown, light-brown, or reddish-brown soils with subsoils which do not restrict underdrainage. They occupy broad ridges, terraces, and well-drained uplands and have no gray and mottled layer in the upper subsoil or such a layer, if present, only slightly developed. (2) Soils with tight subsoils. These are brown to grayish-brown soils with subsoils that restrict underdrainage. They occupy parts of ridges, nearly smooth and flat areas, are imperfectly drained, and have the gray and mottled layer of the upper subsoil strongly developed. (3) Dark-colored soils with poorly drained subsoils. These are dark grayish-brown or nearly black soils which have the underdrainage restricted by saturation of the deep subsoil and occupy low, depressed, and basinlike areas. In the upper subsoil is a light-gray layer, grading below into a strongly mottled layer of gray and rust brown. The deep subsoil may consist of reddish-brown fine sand or fine sandy loam, of sandy clay, and in places of gravelly sandy till.

These groups do not include the marsh and muck lands or the recently deposited alluvial soils of the stream valleys. which are not suited for orchard planting.

In figure 2, *A*, is shown a profile of Alton gravelly fine sandy loam which is extensively developed along the ridge and in other places. It has a well-drained surface soil and open gravelly subsoil, and belongs to the soils of group 1. Figure 2, *B*, shows a profile of Poygan silty clay loam which has a highly granular surface soil, a strongly developed gray layer, and a hard cloddy structure in the upper part of the subsoil. The deep subsoil is compact till, near the surface of which is a heavy accumulation of lime. This is one of the imperfectly drained soils of group 2. Figure 2, *C*, shows a profile of Granby loam, a soil of group 3, which has a nearly black very granular surface soil and a light-gray layer below a depth of 11 inches with a sharp line of transition between.

The most striking feature of these analyses is is the heavy accumulation of lime in the deep subsoil. The soil of group 1, in the 60- to 84-inch layer, shows a lime content (expressed as CaO) of 8.06 percent; in group 2, in the 22- to 36-inch layer, it is 10.53 percent; and in group 3, in the 36- to 48-inch layer, it is 6.17 percent. This indicates an abundance of lime for any plants with roots sufficiently deep to reach it.

FIGURE 2, *A*, profile of Alton gravelly fine sandy loam; *B*, profile of Poygan silty clay loam; *C*, profile of Granby loam.

Table 1 gives the complete chemical analyses and pH values of one soil from each of the three soil groups.

TABLE 1.—*Chemical analyses and pH values of typical soils in each of the three orchard-soil groups*

Sample no.	Depth	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates	pH
BERRIEN FINE SANDY LOAM, GROUP 1, WELL-DRAINED SOILS																	
	In.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	
36612	0–4	75.68	0.63	9.12	2.89	0.05	1.07	0.71	1.48	1.33	0.17	0.17	6.37	99.67	0.184	-----	6.12
36613	4–12	77.63	.68	9.59	3.10	.05	.81	1.72	1.57	1.50	.13	.11	3.92	100.81	.094	-----	5.52
36614	12–30	76.05	.70	11.28	4.06	.10	.96	1.03	1.97	1.48	.17	.13	1.94	99.87	.013	-----	6.72
36615	30–60	66.98	.78	13.68	5.14	.13	2.97	1.80	2.74	1.48	.17	.11	4.41	100.39	.027	1.40	7.93
36616	60–84	56.51	.86	13.67	5.37	.09	8.06	2.45	2.88	1.22	.20	.12	8.94	100.37	.025	5.66	7.72
POYGAN SILTY CLAY LOAM, GROUP 2, IMPERFECTLY DRAINED SOILS																	
36617	0–5	74.36	0.73	9.93	3.58	0.10	1.07	0.82	1.79	1.70	0.17	0.14	5.85	100.24	0.180	-----	6.65
36618	5–13	75.38	.72	11.07	4.40	.15	.98	.93	1.76	1.55	.18	.09	2.82	100.03	.030	-----	6.33
36619	13–22	65.01	.81	15.86	6.35	.12	1.39	2.06	2.77	1.32	.19	.10	3.76	99.74	.030	-----	7.23
36620	22–36	52.45	.75	13.36	5.30	.10	10.53	2.79	2.58	1.11	.17	.11	11.03	100.28	.020	8.27	8.03
36621	36–42	64.55	.77	10.27	3.58	.08	7.31	2.26	2.00	1.62	.17	.09	7.25	99.95	.007	5.66	8.63
GRANBY LOAM, GROUP 3, POORLY DRAINED SOILS																	
36602	0–11	74.00	0.62	10.02	2.50	0.04	1.77	0.87	1.72	1.50	0.18	0.16	6.83	100.21	0.245	-----	7.65
36603	11–14	81.02	.48	9.30	2.10	.04	1.47	.80	1.65	1.53	.12	.08	1.04	99.63	.019	-----	8.12
36604	14–24	80.45	.48	9.64	2.28	.05	1.46	.84	1.65	1.45	.12	.07	1.03	99.52	.012	-----	8.33
36605	24–36	75.41	.61	11.00	3.03	.08	1.85	1.38	2.02	1.75	.16	.08	2.24	99.61	.015	0.88	8.79
36606	36–48	57.15	.89	13.94	6.85	.12	6.17	2.32	3.06	1.35	.21	.12	7.59	99.77	.032	4.49	8.20

In the soil of group 1 the nearly insoluble silica (SiO_2) decreases from near the surface downward, and the more soluble iron (Fe_2O_3) and alumina (Al_2O_3) show a corresponding increase. In the soil of group 2 the silica (SiO_2) is least abundant in the 22- to 36-inch layer, and the iron (Fe_2O_3) and alumina (Al_2O_3) show an almost regular curve with maximum concentration in the 13- to 22-inch layer, the highest concentration of lime (CaO) being in the 22- to 36-inch layer. In the soil of group 3 the silica (SiO_2) is concentrated in the 11- to 14-inch layer, and the iron (Fe_2O_3) and alumina (Al_2O_3), on the other hand, are lowest in the white leached 11- to 14-inch layer and have their maximum concentration in the 36- to 48-inch layer, in this case probably owing to heavy parent material at this depth.

Table 2 gives the mechanical analyses of one soil from each of the three groups.

As shown in table 2, fine sand predominates in all layers in the soil of group 1 (Berrien loamy fine sand) and silt and clay are fairly uniformly distributed. In the soil of group 2 (Poygan silty clay loam) silt and clay predominate, and a very heavy concentration of clay, much of which is colloidal clay, is found between depths of 13 and 36 inches. Very fine sand predominates in the soil of group 3 (Granby loam), with silt ranking next. Between depths of 11 and 24 inches there is only a trace of clay, this being practically all colloidal clay. The heavy silt and clay in the 36- to 48-inch layer is slightly weathered parent material.

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TABLE 2.—*Mechanical analyses of typical soils in each of the three orchard-soil groups*

BERRIEN LOAMY FINE SAND, GROUP 1

Sample no.	Depth	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay	Colloid [1]
	Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
36626	0–4	3.5	10.8	21.0	35.0	10.3	11.4	7.9	5.6
36627	4–15	4.7	12.8	20.5	36.0	9.8	9.9	6.2	4.3
36628	15–40	4.0	11.9	23.3	47.2	6.1	4.1	3.5	2.4
36629	40–70	2.4	9.0	16.4	51.6	14.6	3.0	2.9	2.0
36630	70–104	2.0	7.4	17.1	39.2	25.7	5.8	2.8	2.2
POYGAN SILTY CLAY LOAM, GROUP 2									
36617	0–5	1.3	2.6	3.2	5.7	18.5	50.1	18.5	16.2
36618	5–13	2.1	3.0	2.9	5.4	21.1	48.5	16.8	11.8
36619	13–22	.1	.4	.6	1.3	5.1	36.3	56.2	40.0
36620	22–36	1.3	1.0	.4	.8	1.6	42.8	52.2	33.1
36621	36–42	2.3	3.6	3.6	8.6	18.2	46.7	17.1	7.4
GRANBY LOAM, GROUP 3									
36602	0–11	0.3	2.3	4.9	11.1	37.0	29.0	15.3	7.8
36603	11–14	.4	6.0	13.9	22.8	32.2	17.8	6.7	6.7
36604	14–24	.6	5.5	10.7	16.1	38.3	21.4	7.5	6.4
36605	24–36	.1	.4	.7	3.0	43.8	41.1	10.8	9.4
36606	36–48	.0	.3	.3	1.1	4.0	37.8	56.4	36.0

[1] Colloid (included with clay) represents particles less than 0.002 millimeter in diameter.

In a study of the soils of the Hilton area,[5] the soils of the first group were classed as favorable, the second group as marginal, and the third group as unfit. In a comparison in production of the different groups it was found that in an area of 13,582 acres, 23 percent was used for orchards. Of the land planted to orchards, 57 percent was regarded as favorable, 39 percent marginal, and 4 percent unfit.

On the favorable soils, during the period 1928–30, 25 orchards with a total of 3,466 trees, ranging from 55 to 61 years of age, had an average yield of 7.25 bushels a tree, and on the marginal soils 12 orchards with a total of 1,445 trees averaged only 2.6 bushels a tree. Following is a comparison of the average yield of orchards ranging from 18 to 21 years of age, during the same period: On the favorable soils 15 orchards with a total of 1,858 trees had an average yield of 3.16 bushels a tree, and on the marginal soils 16 orchards with a total of 1,914 trees averaged only 1.5 bushels.

Appearance of the trees on the better soils is shown in figure 3, *A;* of the unproductive trees near the edge of the Granby soils, which are poorly drained soils, in figure 3, *B;* and of the dead and missing trees grown on the top of a low ridge in a small area of Poygan silty clay loam surrounded by a good stand of trees grown on the slopes of Hilton gravelly loam in figure 3, *C.* Contrasts of this kind are to be found in a very large percentage of the orchards of this district where the use of poor soils has increased the cost of planting and maintaining the orchards and lowered their average production.

[5] OSKAMP, J., and BATJER, L. P. Op. cit.

FIGURE 3, *A*, a high-producing orchard of the Baldwin and Rhode Island Greening varieties on a soil of group 1; *B*, an unproductive tree near the edge of a group 3 soil; *C*, dead and missing trees where surface drainage is poor surrounded by a nearly perfect stand of productive trees where the surface drainage is good.

In the following pages, brief descriptions of the more important soils of this apple-growing district are given.

GROUP 1, SOILS WITH OPEN SUBSOILS

Soils of group 1, which may be called the well-drained or best-drained soils, have a rather wide range in character of parent material from which they developed. These soils have weathered from beach and terrace deposits of sandy and gravelly material, from old lake deposits of fine sand, silt, and clay, and to some extent from glacial till.

In the Hilton area it was found[6] that roots in soils of this group extend to a depth of more than 8 feet, and that these soils are considered among the best of the district for apple growing.

ALTON SOILS

Along the old beach line or ridge which extends almost continuously across Monroe County and the entire length of this apple-growing district, marking the southern limit of the area studied, is a dark-brown sandy and gravelly soil called Alton gravelly sandy loam. At a depth ranging from 6 to 10 inches this soil grades into a yellowish-brown light gravelly sandy loam or fine sandy loam which is underlain below a depth of 18 inches by thin beds of light-brown sand, fine sand, and small sharp gravel. The deep subsoil, below a depth of 30 inches, consists of sand and water-worn gravel which, below a depth ranging from 30 to 36 inches, has an abundance of lime, effervescing freely with acid, but is cemented only in small local spots.

Northeast of Morton, in the western part of Monroe County, is a low broad ridge on which there is an almost continuous planting of apple and peach orchards. This is generally recognized as one of the most highly productive orchard sections of the county. These soils belong to the same series as those on the higher better-drained parts of the ridge. Smaller areas of Alton soils are found throughout the district.

Roots of apple trees planted on this soil penetrate the subsoil to a depth of many feet. On account of the coarse texture and open structure these soils require heavy fertilization, especially with manure, but owing to good underdrainage they are excellent orchard soils.

DUNKIRK SOILS

In the northern half of the belt between the ridge and the lake, west of Genesee River, and in places east of Irondequoit Bay are numerous areas of light-brown silty soil, with no gravel, or nearly free from it. The subsoil is heavier than the surface soil. It consists of silty clay, which in places is light red or pink, and in other places olive-brown. It is stratified with thin layers of silt, fine sandy loam, and fine sand. The gray and mottled upper subsoil layer is variable, thin, and slightly developed in places, and thick and strongly developed in other locations. Some of the oldest and highest producing orchards of this district have been grown on this soil (Dunkirk silt loam).

[6] OSKAMP, J., and BATJER, L. P. Op. cit.

BERRIEN SOILS

Closely associated with the soils of the Dunkirk series are loamy fine sands and light fine sandy loams of the Berrien series which have almost the same value for apple-orchard purposes. These soils have developed largely from water-laid material. The surface soil and the upper part of the subsoil is well drained, but drainage in the deeper part of the subsoil is restricted to some extent by layers of silty clay. Mottling of light gray and rust brown occurs in a deep zone of the subsoil, but this seems to indicate a less harmful condition in soils of this kind than in soils of heavier texture, in which the zone of mottling is near the surface.

PETOSKEY SOILS

In the vicinity of Genesee River and Irondequoit Bay are extensive areas of brown loamy fine sand, which are nearly free from compact or heavy layers and from mottling of gray and rust brown. They have, however, in many places thin irregular layers of slightly cemented reddish-brown sand. This soil (Petoskey loamy fine sand) is used extensively for gardening, for use in greenhouses, for growing peaches, and to less extent for apple orchards.

LUCAS SOILS

Of the Lucas soils, only Lucas silty clay loam was recognized in Monroe County. This soil is a gray or dark-gray silty clay loam. The surface soil is granular and has a thin, shallow gray layer. The entire subsoil breaks into very hard, blocky clods which effervesce freely with acid below a depth of 30 inches. This soil is used to some extent for apple orchards, and where examined, the roots were found to penetrate the soil to a depth of more than 9 feet, principally by following downward along cleavage planes.

Lucas silty clay loam is used to some extent for apple orchards, but owing to difficulty in handling it and to the slow growth of trees, it is not the most desirable soil for this purpose.

GROUP 2, SOILS WITH TIGHT SUBSOILS

Soils of group 2 have a surface soil of slightly different color from the soils of group 1. In places the soils are light brown or grayish brown and in others dark gray, dark grayish brown, or reddish brown. The deep subsoil is tight or compact silty clay, or compact silt, fine sandy loam, fine sand, or gravelly sandy till. The gray layer is strongly developed, with abundant mottling of rust brown in the lower part of the layer. Most soils in this group have smooth, nearly flat surfaces and are not well drained.

COLLAMER SOILS

The soils of the Collamer series differ from those of the Dunkirk series, with which they are closely associated, principally in having a less well drained surface soil, a more compact deep subsoil, and a more strongly developed gray and mottled layer. These soils have developed on nearly level surfaces from the weathering of old lake-laid material where underdrainage is restricted by heavy or compact layers. These layers in places are not only nearly impervious but are cross-bedded, twisted, bent, and distorted, causing pocketing and the formation of false or suspended water tables. On soils of this kind, however, many high-producing orchards have been grown. Greater care to provide good surface drainage is necessary, and on such soils orchards deteriorate, when neglected, more rapidly than on naturally better drained soils.

HILTON SOILS

In the northern part of Monroe County, but most extensively developed midway between the ridge and the lake, are many long low ridges of reddish-brown gravelly fine sandy loam and gravelly loam soils of the Hilton series. The deep subsoil is reddish-brown very compact till. In some places this deep subsoil has been reworked by water and is more or less stratified. When the moist soil is bored into with a soil auger the compact subsoil seems loose and friable, but when examined with pick and shovel it is found to be so hard that it cannot be broken easily. When dry this subsoil is so hard that it seems to be cemented, although such is not the case. At a depth of about 30 inches it contains, in most places, enough lime to effervesce freely with acid. Its imperviousness is owing to compaction of soil particles rather than to cementation.

Where this layer of compact till is exposed in roadside cuts, moisture after rainfall may be seen to follow along its surface after penetrating the upper subsoil layer. Since the surface relief is very uneven, it causes the formation of wet and imperfectly drained areas on till slopes, shallow basins with impervious subsoil around the source of small drainage ways, and in many places poorly drained flats on the tops of till ridges.

In the Hilton soils the gray and mottled layer is moderately developed. These soils were originally classed with the Ontario soils but have recently been separated. In a few areas of fine sandy soil the gray layer is not developed and the subsoil is more friable than typical, but on account of their small extent these soils have been included with Hilton fine sandy loam.

There are in the lake-shore district, principally south of the ridge, important areas of till soils, the subsoils of which are not compact. In such areas trees root deeper than on the Hilton soils, but climatic conditions here are less favorable than on the soils nearer the shore of the lake.

Compactness of a subsoil can best be determined by digging into it when dry or when only slightly moist. If it is so hard that it can be loosened only by the use of a pick or crowbar, it may be regarded as compact, and tree roots will penetrate it but slightly. Soils on which orchards are to be planted should be thoroughly examined by digging several pits, to a depth of at least 6 feet, and the character of the subsoil thus determined. If the soil is found to be 30 inches deep before a compact layer is reached, an orchard may be grown on it, but good surface drainage will be necessary. Yields will be less certain, however, and production lower, over a period of years, than where the soil has a deep open subsoil of twice that depth or more.

The Hilton soils have been used extensively for apple orchards since the early plantings were made, probably because it was believed that these soils were well drained. On these till ridges some good orchards are to be found, but production in many is below the average for this district.

In a comparison of yields from orchards grown on till soils, including both well-drained and imperfectly drained soils, in the Hilton and Morton areas, with yields from orchards grown on soils developed from water-laid material represented principally by the Dunkirk and Collamer series, it was found[7] that in orchards of the old-age group grown on soils developed from water-laid material 24 orchards with a total of 3,265 trees had an average yield of 6.7 bushels a tree, but on the till soils 13 orchards with a total of 1,646 trees averaged only 3.85 bushels. In the young-age group, on soils developed from water-laid material, 14 orchards, with a total of 1,797 trees, averaged 2.8 bushels a tree, but on the till soils 17 orchards, with a total of 1,975 trees, averaged only 1.8 bushels.

Adjacent to the ridges occupied by the typical Hilton soils, and in places surrounding them, are gravelly soils of slightly darker gray color, in which the gray layer is more strongly developed. These soils are recognized as imperfectly drained phases of Hilton gravelly fine sandy loam and Hilton gravelly loam. They have less gravel on the surface, a more level topography, and poorer surface drainage. The subsoil is very compact and in places very gravelly, a larger part of it having been reworked and stratified than in the subsoil of the ridges. These soils are used rather extensively for orchards but are believed to be less well suited for this purpose than are the typical Hilton soils.

South of the main till ridges, in the district studied, are a number of low ridges and broad areas in which a thin layer of till rests, at depths ranging from 30 inches to more than 6 feet, on residual soil derived from dull-red shale and in places on reworked and stratified till. This soil has been classified as a shallow phase of Hilton gravelly loam and has been used for orchards with a fair degree of success.

SCHLEGEL SOILS

In the eastern part of the county, occupying the same relative position north of the ridge as the shallow phase of Hilton gravelly loam, are areas of shallow till soils over an uneven shaly limestone. These areas are also used for apple orchards but are not highly productive. These soils are identified as Schlegel gravelly loam.

POYGAN SOILS

Within the till ridges, especially where surface drainage is poor, are small flat and basinlike areas in which both surface drainage and underdrainage are imperfect. Many of these areas, within orchards, can be outlined by the poor condition of the trees or by missing trees. The soil is dark grayish-brown silty clay loam or silty clay of the Poygan series, underlain by a plastic clay which breaks into large, hard, irregular clods. This material, in turn, is underlain at an average depth of about 30 inches by compact till. The upper part of this till layer is more or less mottled with gray and rust brown, the clods have a dark-brown staining on the surface, and there is usually a heavy accumulation of lime in light-gray masses immediately above the till layer.

[7] OSKAMP, J., and BATJER, L. P. Op. cit.

SCHOHARIE AND LOCKPORT SOILS

Other soils belonging to group 2 having tight or imperfectly drained subsoils are the Schoharie silty clay loam, a dull-red heavy silty clay loam, and the Lockport silty clay loam, developed largely from the weathering of dull-red shale. Both soils have been used to some extent for orchard planting, but results have been unsatisfactory.

GROUP 3, DARK-COLORED POORLY DRAINED SOILS

GRANBY SOILS

Soils of group 3 have a dark grayish-brown or nearly black surface soil, a light-gray or nearly white subsoil highly mottled with rust brown in the lower part of the layer, and a deep subsoil which is somewhat variable. In much of this district, the subsoil consists of

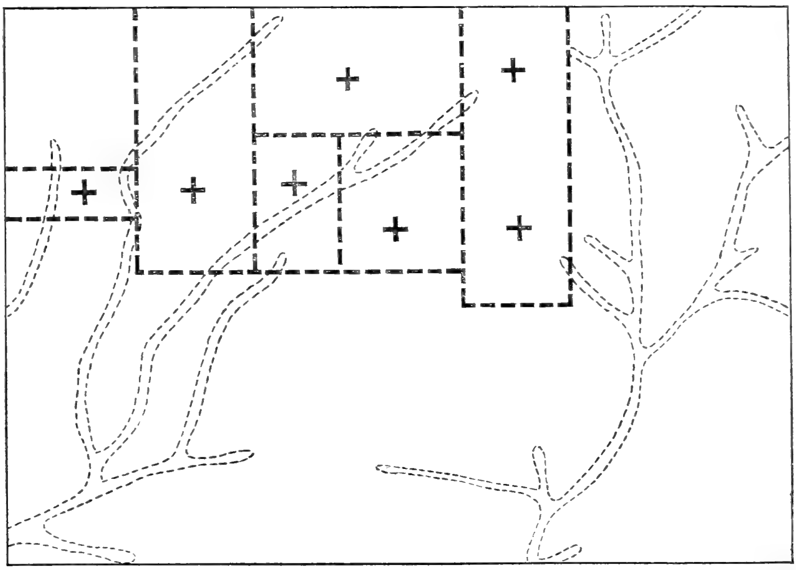

FIGURE 4.—Small section of soil map of the Hilton area showing how the dark-colored soils, indicated within the dotted lines, extend into apple orchards, indicated by +.

light-brown or reddish-brown fine sandy loam or fine sand. In places, however, rust-brown fine sandy clay is reached at slight depths, and in some places till is found in the deep subsoil. In much of this district these soils are alkaline from the surface downward.

Soils of this kind, which belong principally to the Granby series, are entirely unsuited for orchards. Because of their occurrence in small bodies in association with better soils they have, however, been used for this purpose rather extensively. In many orchards, they are confined to a few narrow strips or to small isolated spots, but in varying amounts they occur in nearly every orchard of the district.

On such soils many trees have grown to large size but have, as a rule, become unproductive and died prematurely.

A plot of the trees in almost any orchard of this district will show that the sick and missing trees were planted on soils of this kind,

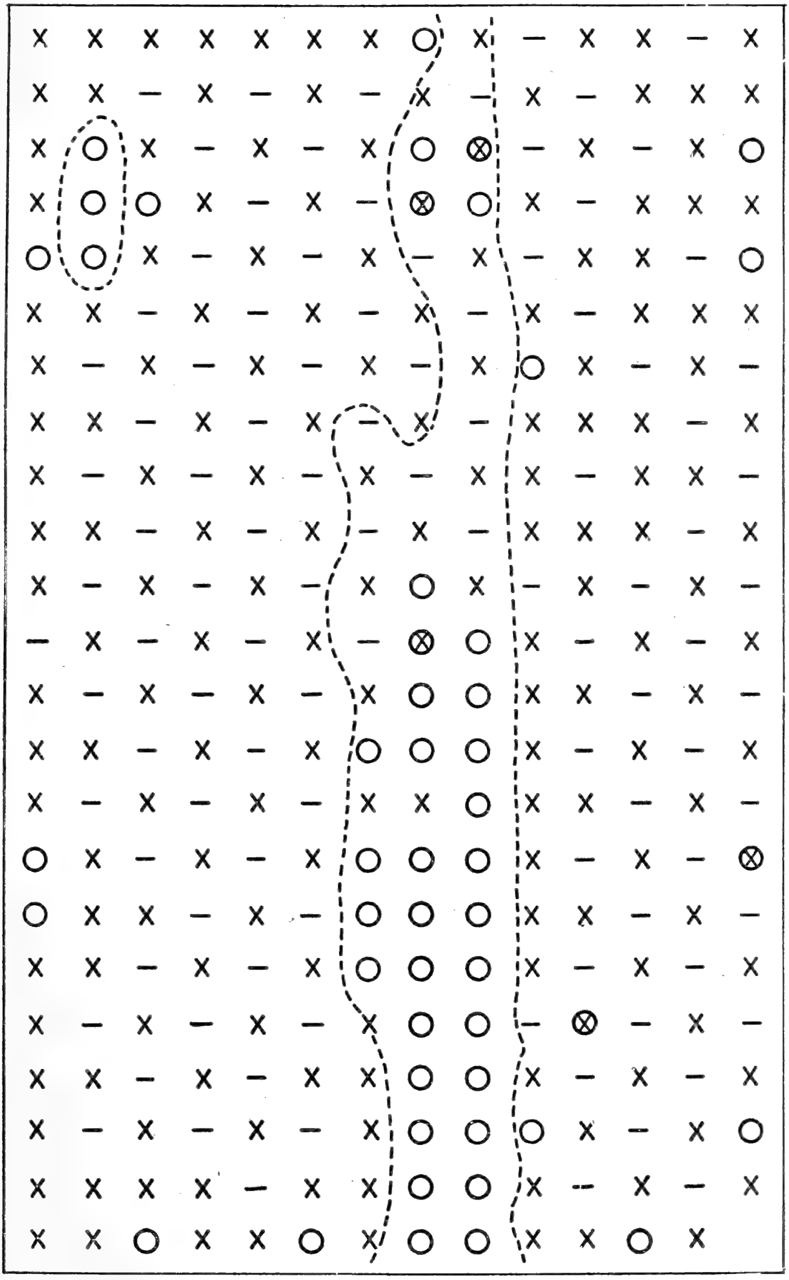

FIGURE 5.—Plot of trees in an old high-producing orchard showing large number of dead trees on dark-colored poorly drained Granby soils, indicated within the dotted lines. × indicates productive trees; ○, dead trees; ⊗, sick trees; —, trees cut out for better spacing.

and that the trees which have persisted and have been productive are on soils that are lighter brown in color and better drained.

The way in which these dark-colored soils finger out into nearly all parts of an area and extend into or across orchards is shown in a tracing of a small part of the soil map of the Hilton area (fig. 4).

In figure 5 is shown the plot of an old high-producing orchard of Baldwin and Greening trees planted on Dunkirk silt loam but with a narrow strip of Granby silt loam extending across it. On the Granby soils, enclosed by dotted lines, nearly all the trees have died or have been cut out. Some trees around the edge of this strip are also unproductive.

SOIL PROFILE AND ROOT PENETRATION

In the commercial apple-growing districts of Virginia, there are a few orchards, 65 years old or older, with trunks 5 to 6 feet in circumference. Where examined, these orchards were found to be on deep well-drained friable soils favorable for deep rooting and for moisture conservation.

In the apple-growing districts of the Ozarks, examinations have shown [8] that trees planted on soils with open subsoils grow larger, produce better, and live longer than trees planted on soils with tight subsoils.

To determine the depth and extent of rooting in the soils of the lake-shore district of western New York, excavations were made and the number, size, and position of the roots were plotted.

For this purpose representative trees were selected, and excavations 30 inches wide, 8 feet long, and as deep as roots could be found were made, the center of the closer side being 16 feet from the trunk of the tree. If possible the excavations were made where roots from other trees would not enter them.

As the excavation was extended downward, the side wall adjacent to the tree was smoothed with a shovel. This was then laid off into 1-foot squares which were further divided into 6-inch blocks. The size and position of the roots cut off in the side wall were then plotted for a length of 6 feet, leaving 1 foot of space at either end of the excavation for working room. Lines were also marked on the wall and corresponding lines were drawn on a graph representing as nearly as possible the soil horizons or soil layers as seen in the freshly cut wall, these being indicated largely by the color of the soil.

In this way a number of graphs were made of roots of trees growing on the more important soil types of each group. A few of these, believed to be representative of subsoil conditions and root penetration as found in this district, are shown in this circular.

Attention has already been called to the relation between the dark-colored poorly drained soils and missing or unproductive trees. The nearly black color and granular structure of these soils at the surface is well shown in figure 2, *C*. No orchards were found which had been planted entirely on soils of this group, and where any considerable part of an orchard had been so planted it was found that nearly all the trees had died. Occasionally, however, an isolated tree was found in an area of this kind or along its edge.

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[8] SWEET, A. T. SUBSOIL AN IMPORTANT FACTOR IN THE GROWTH OF APPLE TREES IN THE OZARKS. U.S Dept. Agr. Circ. 95, 12 p., illus. 1929.

Figure 6 shows the root development of a Baldwin apple tree[9] 47 years old, with a trunk circumference of 72 inches, grown on Granby loam. Roots near the surface are very abundant and are fairly so to a depth of 5 feet. More than one half of these roots, however, both large and small, are dead. Maximum penetration was to a depth of about 5 feet, and the dead and live roots seem to be rather uniformly distributed.

The condition of the roots of this tree is fairly representative of that found wherever trees in this district have been planted on these dark-colored poorly drained soils. In many places, however, where

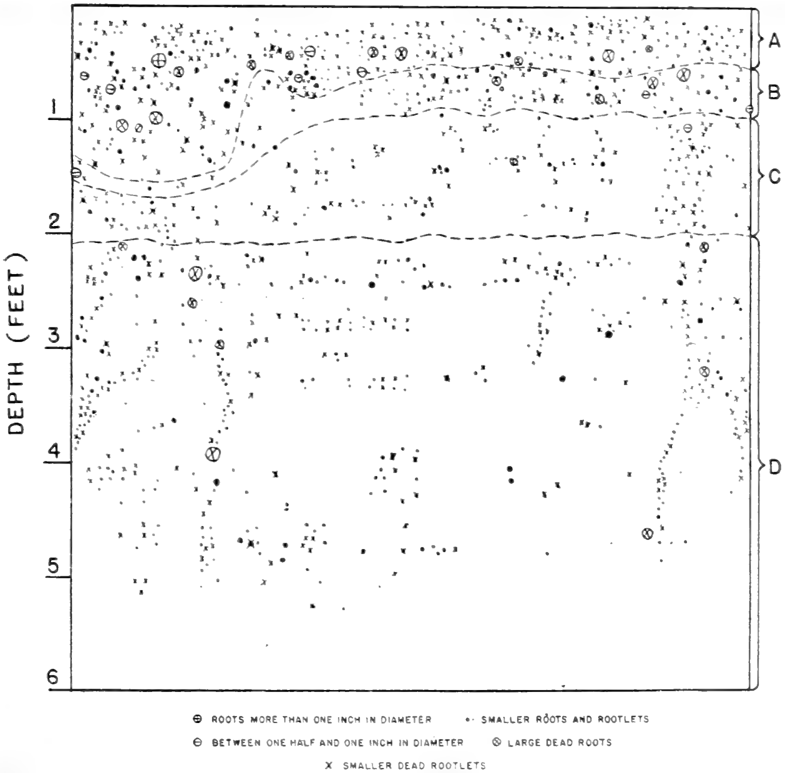

FIGURE 6.—Root development of a Baldwin apple tree 47 years old on Granby loam, a poorly drained soil of group 3: *A*, very dark grayish-brown silt loam; *B*, light-gray almost white fine sandy loam; *C*, rust-brown and gray mottled clay loam; and *D*, reddish-brown thinly stratified fine sandy loam.

the subsoil is almost continuously saturated, but few roots extend to a depth of more than 30 inches.

A considerable part of the soils of the second group has developed from ice-laid material or till, a portion of which has been reworked and somewhat stratified by water. Figures 7 and 8 show the depth of rooting in soils of this kind.

In figure 7 is shown the root development of a Baldwin tree 50 years old, with a trunk girth of 59 inches, planted on Hilton gravelly loam. The orchard has received good care, and production has been moderate but uncertain.

[9] In these studies of root penetration Baldwin apple trees have been used to a greater extent than other varieties because they make up the larger part of the older orchards. An examination of other varieties, however, shows approximately the same depth of penetration in corresponding soils.

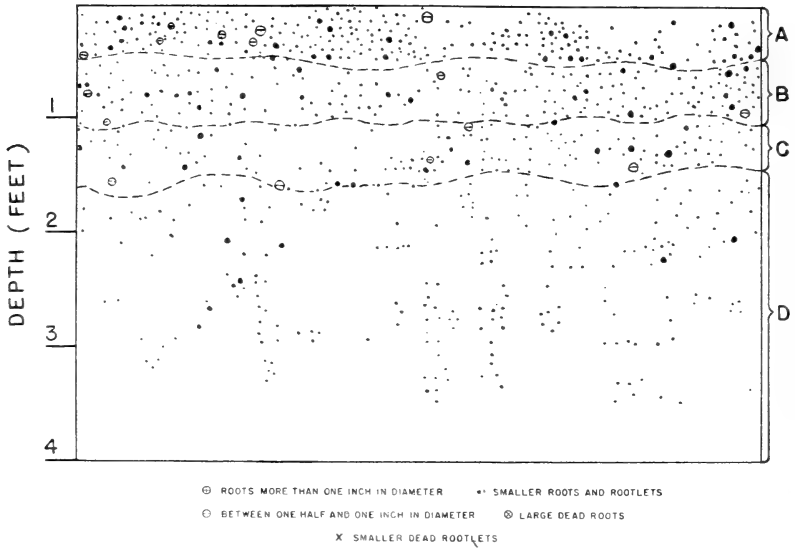

FIGURE 7.—Root penetration of a Baldwin apple tree 50 years old, 59 inches in circumference, on Hilton gravelly loam, a till soil of group 2: *A*, dark reddish-brown gravelly loam; *B*, light-brown gravelly loam; *C*, gray and brown mottled loam; and *D*, compact reddish-brown sandy till.

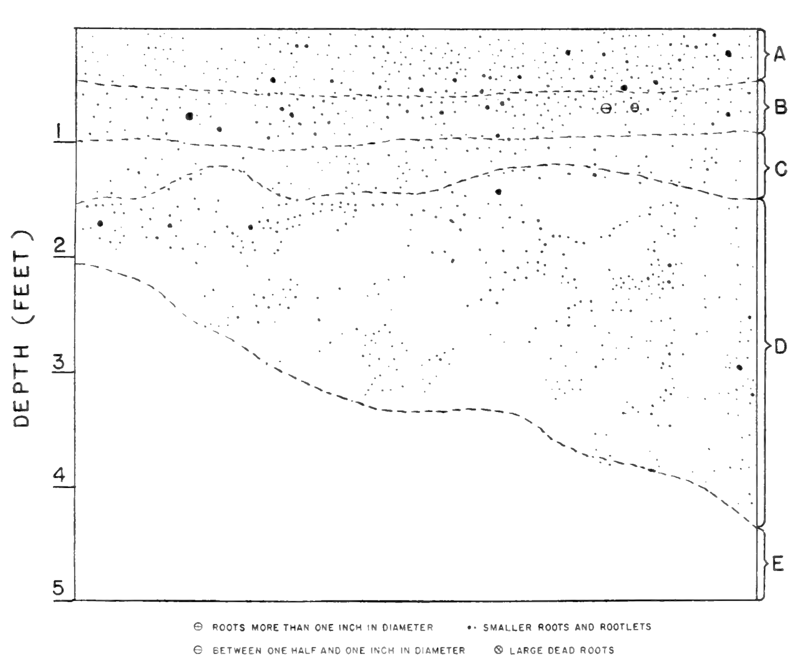

FIGURE 8.—Root penetration of a Baldwin apple tree 50 years old, with a trunk girth of 52 inches, planted on Hilton gravelly loam: *A*, dark-brown gravelly loam; *B*, light-brown gravelly loam; *C*, grayish-brown mottled gravelly loam; *D*, compact sandy clay; and *E*, very compact sandy till.

Figure 8 shows the depth and extent of rooting of a Baldwin tree about 50 years old, with a trunk girth of 52 inches, planted on a reddish-brown very gravelly loam with compact sandy till subsoil, the Hilton gravelly loam. The trunk is small for a tree of that age, in this district, and production has been poor and uncertain. At one end of the excavation the roots extended to a depth of nearly 4 feet, but at the other end no roots were found deeper than 2 feet.

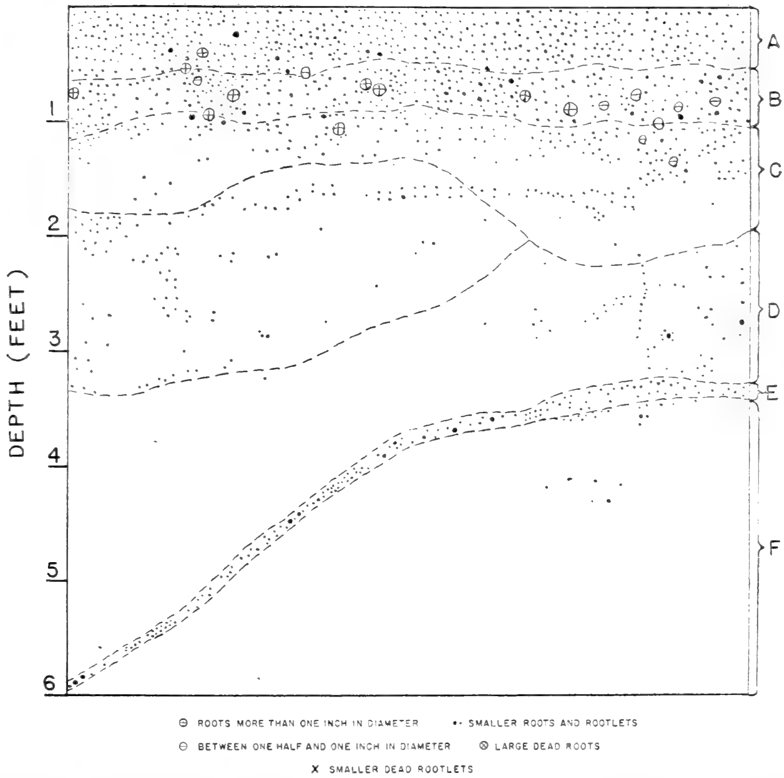

FIGURE 9.—Root penetration of a Baldwin apple tree grown on a soil of group 2 developed from water-laid material: *A*, brown silt loam; *B*, light-brown silt loam; *C*, gray and brown mottled silt loam, with a mass of grayish-brown sandy clay on the left; *D*, light-brown compact fine sandy loam; *E*, reddish-brown clay; and *F*, grayish-brown very compact fine sandy loam.

Depths of root penetration shown in figures 7 and 8 are fairly representative of the root penetration of a number of trees examined on soils of this kind.

The average depth of rooting as shown in figure 7 is about 3 feet; the rooting is sparse in the lower part of the soil section, where roots come in contact with the compact layer of till. The surface of the till, as shown in figure 8, is in places very uneven.

In the level imperfectly drained soils which surround the till ridges, the Hilton gravelly loam and Hilton gravelly fine sandy loam, imperfectly drained phase, the depth of rooting has been found to be about as deep as on the till soils on the ridges but with roots slightly less abundant.

The water-laid soils of group 2, particularly the Collamer soils, show wider variations in subsoil conditions than are found in the soils of till origin.

In figure 9 is shown the root development of a Baldwin tree 71 years old having a trunk 92 inches in circumference and grown on Collamer silt loam, a soil of group 2 developed from water-laid material.

Heavy rooting near the surface and an abundance of large roots will be noted. In the *C* and *D* layers the rooting is light. In the thin layer of reddish-brown clay it is heavy, and in the grayish-brown very compact fine sandy loam roots are almost entirely lacking. Maximum root penetration is about 6 feet but is scant below 3 feet. In this orchard surface drainage is good, the soil has been heavily manured, and the orchard has been productive.

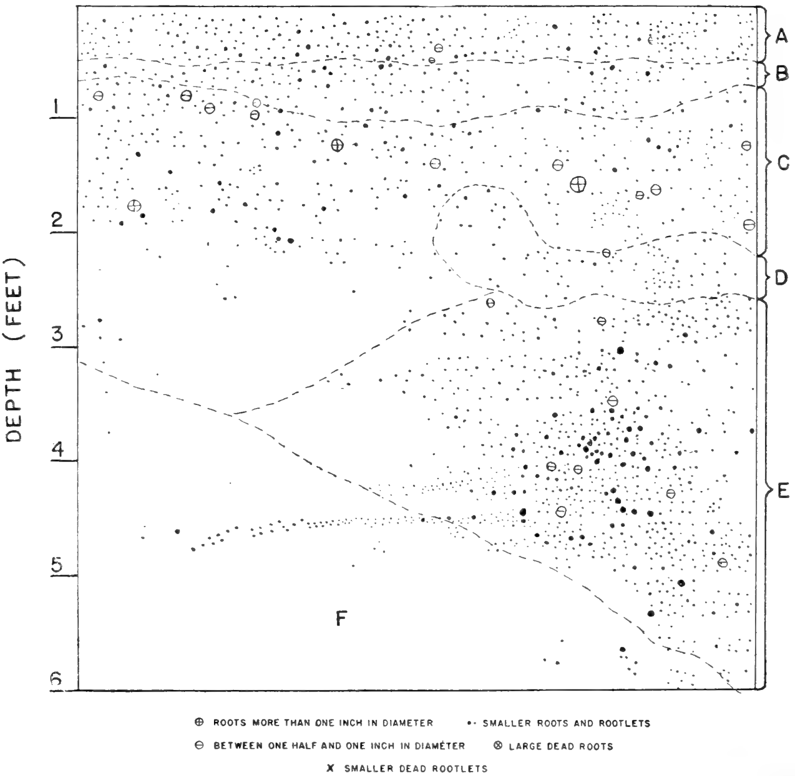

FIGURE 10.—Root penetration of a Baldwin apple tree grown on a heavy phase of Collamer silt loam: *A*, dark grayish-brown heavy silt loam; *B*, light-brown silt loam; *C*, dull reddish-brown silty clay slightly mottled with gray in the upper part; *D*, an irregular mass of olive-brown silt; *E*, brown clay; and *F*, olive-brown compact silt and very fine sandy loam reached at a depth of 3 feet at one end of the excavation and at 6 feet at the other.

In figure 10 is shown the root development of a Baldwin apple tree 75 years old, with a trunk girth of 86 inches, grown on a heavy type of Collamer silt loam. The gray layer is not very strongly developed, and the impervious subsoil is rather deep.

Figure 11, *A*, shows a Baldwin apple tree 71 years old, 92 inches in circumference, grown on Collamer silt loam; and figure 11, *B*, shows

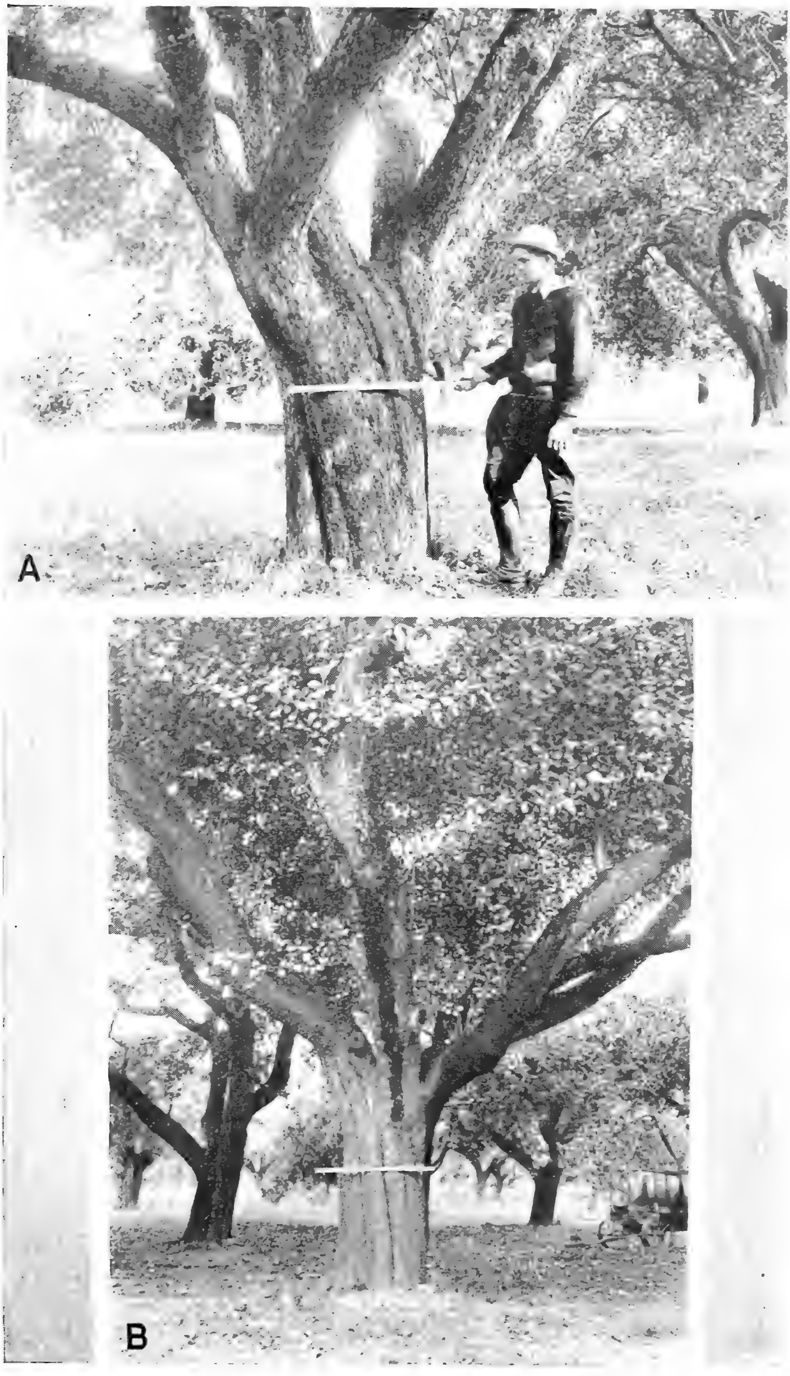

FIGURE 11.—*A*, Baldwin apple tree 92 inches in circumference, the root penetration of which is shown in figure 9; *B*, Baldwin apple tree 86 inches in circumference, the root penetration of which is shown in figure 10.

a Baldwin apple tree 75 years old, 86 inches in circumference, grown on a heavy type of the same soil. The root penetration of these trees is shown in figures 9 and 10, respectively.

Roots are very abundant in the heavier soils but almost entirely wanting in the compact silt and very fine sand. At a depth of about $4\frac{1}{2}$ feet a number of small roots have followed a thin layer of clay into the compact silt and very fine sand. With this exception they have penetrated the compact material scarcely at all.

In places soils of the Collamer series of group 2 differ from the Dunkirk series of group 1 principally in the more strongly developed gray and mottled layer of the upper subsoil.

FIGURE 12.—A deep roadside cut near Seabreeze showing the twisted and crumpled subsoil layers found in places in the soils of group 2.

Although soils of the Collamer series have been developed from water-laid and stratified material, the layers in the deep subsoil as seen in these excavations and in figure 12 are in many places distorted and twisted.

The cause of this distortion of water-laid material is not definitely known. It may have been caused by the thrust of the ice mass, by the melting of ice flows, by slumping of the material on slopes, or by some other agency.

Soils of group 1 have good underdrainage so that the subsoil is never saturated for long periods of time. Compact layers which tend to check or stop root penetration are not reached at slight depths and are but slightly developed. The deep penetration of roots in such soils is well shown in figures 13 and 14.

In figure 13 is shown the root development of a Baldwin apple tree 35 years old, with a trunk girth of 67 inches, grown on Petoskey loamy fine sand. The soil of this orchard has been deeply cultivated and has received heavy applications of manure. The scarcity of roots in the surface layer and their abundance and larger size in the *B*, *C*, and *D* layers can be noted. The roots extend to a depth of 10 feet.

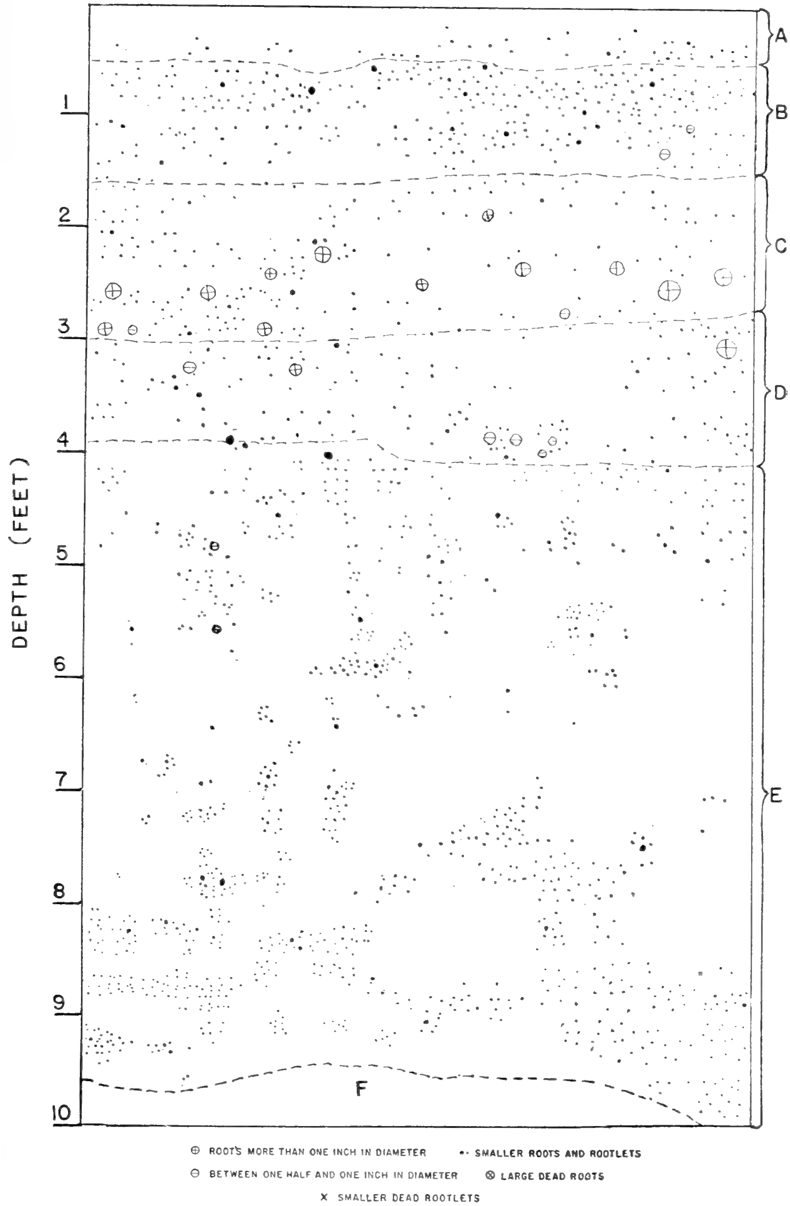

FIGURE 13.—Root penetration of a Baldwin apple tree 35 years old on Petoskey loamy fine sand, a soil of group 1: *A*, brown loamy fine sand; *B*, light-brown loamy fine sand; *C*, yellowish-brown fine sand; *D*, grayish-brown fine sand; *E*, light grayish-brown fine sand; and *F*, gray fine sand.

In figure 14 is shown the root development of a Baldwin tree 54 years old, with a trunk girth of 80 inches, grown on Dunkirk silt loam, a soil of group 1. The roots are well distributed but are most abundant near the surface and in the thin layers of clay near the bottom. They are least abundant in the lower part of the very fine sandy

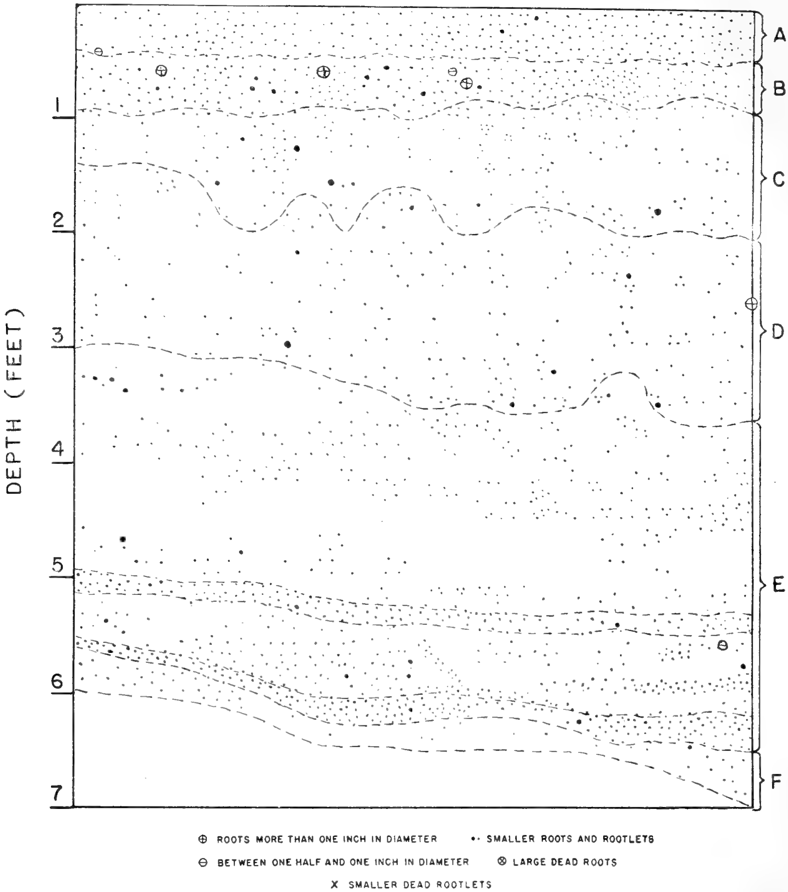

FIGURE 14.—Root penetration of a Baldwin apple tree on Dunkirk silt loam, a soil of group 1: *A*, brown silt loam; *B*, light-brown silt loam; *C*, gray and rust-brown silt loam; *D*, light-brown silt with lenses of red clay, *E*, light-brown very fine sandy loam with thin layers of light-red and olive-brown clay; and *F*, compact very fine sand.

loam layer and stop abruptly at the surface of the compact very fine sand layer at a depth ranging from 6 to 7 feet.

Figure 15 shows the root development of a Baldwin tree 55 years old, with a trunk girth of 100 inches, growing on Dunkirk silt loam. The heavy and well-distributed rooting will be noted, also an almost total absence of roots in layer *E* of compact very fine sandy loam. Roots which extend into the lower part of the profile are evidently the branches of larger roots which penetrate this compact layer nearer the tree trunk. Roots were found to a depth of more than 9 feet.

Figure 16 shows a Baldwin apple tree with a trunk of 100 inches in circumference, the root development of which is shown in figures 15 and 17.

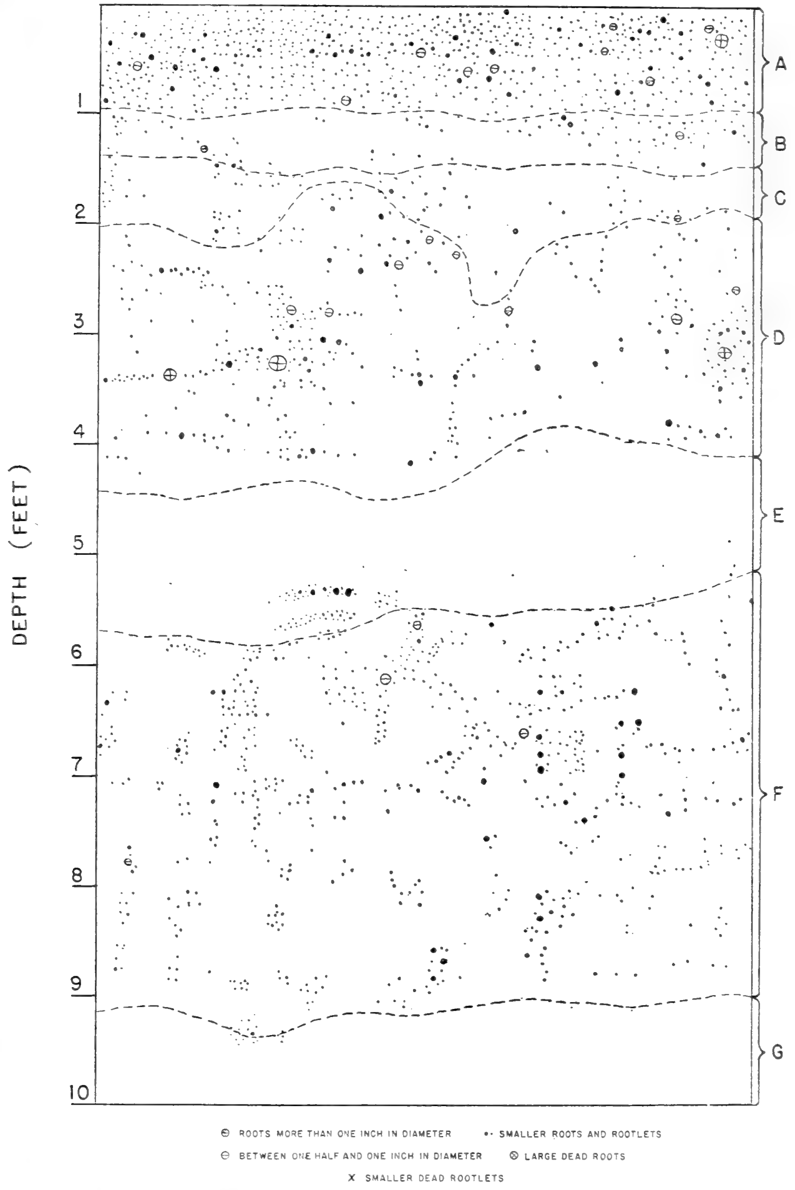

FIGURE 15.—Root development of a Baldwin apple tree on Dunkirk silt loam, in the subsoil of which is a thin layer of compact very fine sandy loam: *A*, brown silt loam; *B*, light-brown silt loam; *C*, gray and rust-brown mottled silt loam; *D*, dull-red stratified clay; *E*, grayish-brown compact very fine sandy loam; *F*, dull-red and olive-brown stratified clay; and *G*, compact sand and gravel.

In order to see how completely the roots permeate the soil mass, a strip 1 foot wide extending from the top to the bottom of the excavation used in figure 15 was selected. On this strip of side wall the soil was carefully picked from the roots and rootlets to a thickness of about 2 inches. These were then sketched as shown in figure 17.

The enormous extent of the roots of a large apple tree in a soil of this kind is much greater than is often realized. A conservative estimate indicates that the roots of this tree thoroughly permeate and draw moisture and some plant food from at least 14,400 cubic feet of soil, enough to cover, to a depth of 1 foot, one third of an acre. The function of these deep roots is not definitely known, but records show that trees which root deeply not only produce well but also are consistent producers under varying seasonal conditions. In the Hilton area it was found that roots in the deep subsoil seem to have a stabilizing influence on orchard performance and practically all deep-rooted orchards were found to be productive.

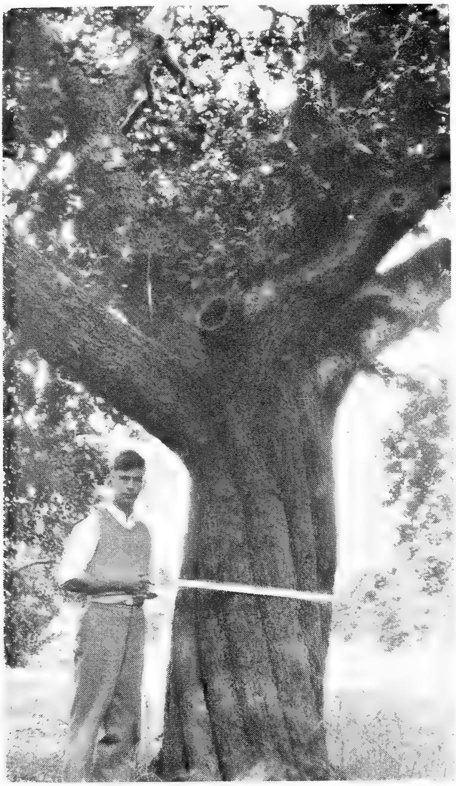

FIGURE 16.—Baldwin apple tree with a trunk 100 inches in circumference.

These graphs show that in the soils of group 3 roots extend sufficiently deep for good production, but that so many of the roots are dead or in bad condition that high production or long life of the tree cannot be expected.

In the soils of group 2, trees on the till ridges with compact till subsoil, and on the less well drained flatter areas of the lower gravelly slopes root to an average depth of about 3 feet. On the level imperfectly drained soils developed from water-laid material there is wide variation in depth and extent of rooting, the maximum penetration being about 6 feet, but in many places rooting is not abundant below 4 feet.

In soils of group 1, where deep penetration is not obstructed, roots extend to a depth ranging from 7 to 10 feet.

This agrees not only with production records but also with production stability, or uniformity of production. Trees which, by deep and extensive rooting, have the greatest soil and moisture resources give the largest and most consistent yields, and fruit of the best quality.

FIGURE 17.—The extent of roots in a strip 1 foot wide and 2 inches thick from surface to a depth of 9 feet.

CONCLUSIONS

In the principal commercial apple-growing district of western New York, extending for a distance of about 125 miles along the shore of Lake Ontario, a close relation is found between soil profile, depth of rooting, and apple production.

In extensive sections used for orchard planting the maximum depth of rooting is about 3 feet. In other sections of imperfectly drained soil it is about 6 feet, but in the deepest best-drained soils it is more than 9 feet.

Any orchardist of this district can, by careful observation and the use of pick and shovel, judge the value of his soil for orchard planting with a fair degree of accuracy. Dark-colored, poorly drained soils are to be avoided. Soil with imperfect underdrainage, indicated by strongly developed gray layers or by heavy mottling of light gray and rust brown, especially soils occupying flat topography and having impervious or shallow subsoils, are to be used with caution.

Soils and subsoils of nearly uniform color and with gradual gradations in texture are preferable to soils with sharp, abrupt changes in either color or texture.

The greatest aids to stabilization of production in this district, as in many others, are (1) the proper selection of soils for new plantings, (2) the cutting out of orchards where production is low and cannot be improved, (3) the elimination of marginal lands for orchard purposes, and (4) better control of moisture conditions, consisting in this district largely of providing better surface drainage.

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