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The "Red Hill" Soils of Western Oregon and Their Utilization

Agricultural Experiment Station
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SUMMARY

1. The "red hill" soils occupy the major area in Western Oregon. The portion under cultivation forms an important group agriculturally.

2. General farm crops, prunes, nuts, and small fruits do well on these soils.

3. The physical soil characteristics correlate with the type of weathering they have undergone during their development. They are rather heavy textured, yet friable, usually well drained, can be worked early, and in general do not erode seriously.

4. Chemically, these soils are characterized by their distinct acid reaction, low content of available phosphorus and calcium, and limited total supply of sulfur. The nitrogen and organic-matter supply is moderate.

5. The use of basic lime is fundamental to the successful growing of soil-building legumes.

6. The building up and maintenance of an adequate supply of organic matter of a high nitrogen content is necessary, owing to the type and distribution of rainfall.

7. Crop rotation requires little cash outlay and is essential for continued high yields with a decrease in the unit cost of production.

8. Field crops on these soils give definite and usually profitable increases in yield from the use of soluble phosphate fertilizers.

9. Previous treatment with lime and manure increases the efficiency of soluble phosphate applications.

10. The use of land-plaster or calcium sulfate for legumes is an established practice and supplies both sulfate and calcium. It is regarded a safer practice than the use of elemental sulfur on these acid soils.

11. The uncleared logged-off areas can be improved with but little cost for grazing. The rougher steeper areas should be used for reforestation.

12. Greenhouse and laboratory results correlate with field trials.

The foregoing program with lime, phosphated manure, and rotation with legumes to which calcium sulfate has been applied, will go far toward providing a permanent system of soil fertility and management for these "red hill" soils.

The "Red Hill" Soils of Western Oregon

By

C. V. Ruzek and W. L. Powers

THE hill soils of Western Oregon are known locally as the "red hill" soils and occupy extensive areas of the Cascade and the Coast ranges. They are residual soils developed on consolidated rock material and may be classified broadly into two groups, those derived from basic igneous rocks consisting of basalt and diabase, and those derived from sedimentary rocks consisting of sandstone and shale. The weathering and development of the soil horizons are less pronounced than of the soils of the old valley-filling materials. They do show, however, the translocation to some extent of clay from the surface to the lower soil layers. Over much of the area it is difficult to identify from the characteristics of the soils the rock formation from which they are derived. Hence, in classifying these soils, correlations were in part with characteristics of the soil profile, degree of weathering, and color. Soils of the igneous group include the Olympic, Aiken, Cascade, Polk and Viola soil series. The sedimentary group includes the Melbourne, Carlton, and Sites soil series.

The range in topography is from very smooth rolling to hilly and mountainous areas with steep slopes. The native vegetation is chiefly fir with a scattering of oak, cedar, and spruce. Over much of the cleared and burned-over areas there is a vigorous growth of fern. Both surface and internal drainage are good except in some of the heavier types of the Carlton and the Viola series. Erosion is slight even on the steeper areas. This is undoubtedly because the soils are permeable and a vast area is still in timber or rapid natural reforestation. The area of these hill lands in cultivation is quite extensive, yet is but a small percentage of the total. This

TABLE I. RESIDUAL SOILS OF THE WILLAMETTE VALLEY

Soils—Group and series	Description	Area
I. Soils derived from Igneous Rock		*Acres*
a—Olympic Soil Series	Brown soil on brown subsoil over basalt	698,304
b—Aiken Soil Series	Red on red subsoil over basalt	283,264
c—Cascade Soil Series	Brown on yellow subsoil over basalt	85,760
d—Polk Soil Series	Brown on red subsoil over basalt	30,912
e—Viola Soil Series	Gray-brown on drab subsoil mixed material	26,432
II. Soils derived from Sedimentary Rock		
a—Melbourne Soil Series	Brown on yellow on shale or sandstone	377,856
b—Carlton Soil Series	Gray-brown on gray mottled subsoil on shale	76,608
c—Sites Soil Series	Red on red subsoil on shale	39,680
III. Miscellaneous Residual Soils		
a—Rough Mountain Land		1,455,680
b—Rough Broken and Stony Land		140,032
c—Rough Stony Land		5,440

undoubedly is due to cost of clearing and the unfavorable topography over much of the area. The most extensive cleared areas are in the Willamette Valley and in many of these sections they have been farmed for long periods. In some cases, these soils have been farmed for approximately 75 to 90 years. When of good depth, they are naturally productive and under good systems of soil management excellent yields have been procured and maintained. The deeper soils are adapted to the growing of practically all the crops of the area. Tree fruits, small fruits, general farm crops, and grasses do well on these soils. Areas of different soils are shown in Table I.

PHYSICAL AND CHEMICAL COMPOSITION

Physical composition. Table II gives the results of mechanical analyses of samples of soil and subsoil. The soils have developed under the influence of a relatively high rainfall with chemical weathering predominating. This has resulted in fine-textured soil types with heavier-textured subsoils.

Colloid or ultra-clay content. The chemical and physical properties of soils are to a large extent affected by the amount and condition of the colloidal fraction. Table III gives the colloid content and the chemical composition of the three horizons in typical hill soils as determined in the soils laboratories of the Oregon Agricultural Experiment Station.*

TABLE III. COLLOIDAL AND CHEMICAL COMPOSITION OF SOIL HORIZONS

Soil type and horizon	Colloid	Organic matter	SiO_2	Al_2O_3	Fe_2O_3	CaO
	%	%	%	%	%	%
Aiken clay loam						
I	39.5	3.07	47.15	22.80	16.74	0.66
II	42.5	1.78	47.28	21.83	17.52	0.39
III	51.8	1.03	55.99	24.14	18.44	0.48
Olympic clay						
I	50.8	3.50	46.54	18.77	18.32	4.23
II	55.9	1.70	49.97	19.09	17.79	3.44
III	58.0	1.18	46.91	12.47	22.28	3.20
Melbourne silty clay loam						
I	30.2	3.26	64.30	17.91	8.55	0.61
II	42.8	1.39	61.92	18.81	8.46	0.80

"Though the data presented here are far too meager for definite conclusions, the two hill soils, Aiken and Olympic, show only slight lateritic tendencies in their slightly lower SiO_2 content and higher Fe_2O_3 content. These soils are somewhat friable and inclined to good to excessive drainage."

Chemical analyses. Chemical analyses of soil samples taken in connection with the field operations of the soil survey work were made by the Department of Agricultural Chemistry. These data and analyses by the U. S. Bureau of Chemistry and Soils show relatively little differences

*R. E. Stephenson, *Colloidal Properties of Willamette Valley Soils.* Soil Science, Vol. 28, No. 3, Sept. 1929.

TABLE II. PHYSICAL COMPOSITION OF RED HILL SOIL TYPES

Soils—Series and type		County	Soil depth	Fine gravel 2-1 mm.*	Coarse sand 1-.5 mm.	Medium sand .5-.25 mm.	Fine sand .25-.1 mm.	Very fine sand .1-.05 mm.	Silt .05-.005 mm.	Clay .005-0 mm.
I. Igneous				%	%	%	%	%	%	%
Olympic	Loam	Multnomah	Soil	1.7	2.9	2.2	11.4	34.5	37.7	10.2
	Loam	Multnomah	Subsoil	.5	2.9	2.2	8.6	28.8	46.4	10.4
	Silt Loam	Multnomah	Soil	.7	3.5	2.1	8.3	14.4	49.8	21.1
	Silt Loam	Multnomah	Subsoil	.4	1.4	1.0	3.1	14.4	48.9	30.6
	Clay Loam	Clackamas	0-10″	1.4	4.2	2.9	9.7	8.6	42.6	30.7
	Clay Loam	Clackamas	10-36″	.8	3.7	2.5	8.6	9.5	36.4	38.5
	Silty Clay Loam	Polk	0-12″	1.2	2.3	1.4	10.0	8.0	50.0	27.0
	Silty Clay Loam	Polk	12-36″	.7	2.1	1.4	9.0	11.6	51.3	23.9
	Clay	Yamhill	Soil	.9	2.1	1.3	7.2	10.9	36.8	40.7
	Clay	Yamhill	Subsoil	.7	1.3	1.0	5.7	12.0	32.8	46.5
Aiken	Clay Loam	Yamhill	Soil	1.2	3.5	2.4	7.6	8.8	44.5	32.2
	Clay Loam	Yamhill	Subsoil	.6	3.0	1.8	6.4	10.6	40.8	36.6
Viola	Clay Loam	Clackamas	0-12″	2.5	5.8	4.0	13.0	12.2	42.3	20.3
	Clay Loam	Clackamas	12-24″	.8	5.0	3.6	15.6	16.4	37.3	21.4
	Clay Loam	Clackamas	24-36″	2.2	5.6	4.6	12.2	13.8	34.1	27.5
Cascade	Silt Loam	Multnomah	Soil	.9	2.1	1.0	2.6	30.4	53.9	9.0
	Silt Loam	Multnomah	Subsoil	.0	1.4	1.0	6.2	36.0	45.1	10.2
	Silt Loam	Multnomah	Lower subsoil	.0	2.9	2.1	11.7	25.6	49.0	8.7
II. Sedimentary										
Melbourne	Loam	Washington	Soil	.4	.8	1.1	9.5	38.6	37.9	11.4
	Loam	Washington	Subsoil	.0	.3	.8	9.9	37.7	39.5	11.9
	Clay Loam	Polk	0-2½″	.7	.9	.8	11.4	22.8	42.6	20.9
	Clay Loam	Polk	2½-10″	.5	1.3	.8	10.5	17.8	46.5	22.7
	Clay Loam	Polk	10-28″	.0	.2	.3	11.6	19.0	39.3	29.6
	Clay	Yamhill	Soil	1.6	6.4	2.7	7.7	6.1	36.5	39.0
	Clay	Yamhill	Subsoil	1.0	4.4	2.7	9.0	8.2	35.1	40.0
Carlton	Silt Loam	Washington	Soil	.1	1.6	.8	1.8	16.3	62.9	16.4
	Silt Loam	Washington	Subsoil	.0	.2	.3	4.5	18.4	64.0	12.6
	Silty Clay Loam	Yamhill	Soil	.0	.3	.3	2.2	4.5	65.6	27.0
	Silty Clay Loam	Yamhill	Subsoil	.0	.1	.3	2.3	8.9	65.7	22.7
Sites	Clay	Benton	0-8″	2.5	3.4	1.7	6.7	5.5	38.2	41.9
	Clay	Benton	8-36″	1.0	2.8	1.8	6.6	6.0	32.6	49.2

*mm.=millimeters and refers to diameter of particles.

in composition between the soils classified as derived from basaltic rock and those from sedimentary rock. Table IV gives the results of the chemical analyses of soil and subsoil samples.

TABLE IV. CHEMICAL COMPOSITION OF "RED HILL" SOILS
Analyses of Soil Survey Samples by Department of Agricultural Chemistry, Oregon Agricultural Experiment Station

Soils—Group, Series, and Type	Pounds an acre to plow depth of soil of 6⅔ inches or 2,000,000 pounds							
	County	Depth	Potassium	Calcium	Magnesium	Phosphorus	Sulfur	Nitrogen
I. SOILS DERIVED FROM IGNEOUS ROCKS		*In.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
A. Olympic soil series								
Loam	Marion	0-8	7,200	10,600	5,800	1,780	680	2,180
Loam	Marion	8-20	6,400	8,200	4,300	1,360	460	2,540
Loam	Marion	0-8	12,400	9,600	4,600	3,120	900	8,040
Loam	Marion	8-21	12,800	9,400	4,000	2,920	920	6,320
Loam	Clackamas	0-10	22,000	10,800	6,400	1,454	340	3,240
Silt Loam	Washington	0-15	34,200	28,000	10,800	4,400	460	2,480
Silt Loam	Washington	15-36	31,000	19,200	13,600	2,880	154	780
Silt Loam	Benton	0-10	18,200	25,000	10,600	6,200	920	5,160
Silt Loam	Linn	0-12	10,400	4,000	2,800	4,700	820	10,800
Clay Loam	Polk	0-10	17,800	7,200	2,200	2,130	172	3,220
Clay Loam	Polk	0-7	13,800	8,600	5,000	1,704	160	3,640
Clay Loam	Lane	0-10	20,860	17,400	5,720	2,840	240	4,220
Clay Loam	Lane	10-36	19,260	11,840	7,080	1,480	100	1,320
Silty Clay Loam	Marion	0-8	10,200	10,200	6,300	2,860	1,040	2,980
Silty Clay Loam	Marion	8-28	10,200	10,800	9,600	4,160	620	2,440
Silty Clay Loam	Benton	0-10	36,800	6,600	4,800	1,080	340	2,420
Silty Clay Loam	Lane	0-9	18,860	8,800	5,060	1,760	80	2,140
Silty Clay Loam	Lane	9-28	15,640	7,080	7,040	880	60	780
Clay	Yamhill	0-10	16,600	22,200	6,600	500	....	3,020
Clay	Yamhill	10-36	10,400	25,200	13,200	480	....	880
B. Aiken Soil Series								
Silt Loam	Yamhill	0-20	12,600	5,200	Trace	3,400	340	3,340
Silt Loam	Yamhill	20-36	5,000	5,200	1,000	2,800	....	1,260
Clay Loam	Clackamas	0-7	13,600	4,400	4,800	1,554	80	1,520
Silty Clay Loam	Yamhill	0-10	21,000	13,200	1,800	4,200	540	5,400
Silty Clay Loam	Polk	0-7	18,200	3,600	3,000	1,200	200	3,040
Silty Clay Loam	Marion	0-8	12,200	7,000	10,200	3,420	180	4,160
Silty Clay Loam	Linn	2-10	9,000	3,800	2,200	2,940	460	5,400
Silty Clay Loam	Lane	0-12	9,240	4,280	4,240	1,580	560	3,920
Silty Clay Loam	Lane	12-34	7,800	5,160	4,240	840	200	1,020
Clay	Washington	0-15	12,600	5,200	3,000	3,400	340	3,340
Clay	Washington	15-36	5,600	7,200	1,800	3,600	....	900
C. Viola Series								
Silt Loam	Clackamas	0-12	18,600	8,800	4,400	2,700	186	980
Clay Loam	Polk	0-7	26,200	4,800	2,400	1,154	194	2,080
Silty Clay Loam	Marion	0-16	23,600	11,800	5,000	1,420	420	2,980
Silty Clay Loam	Marion	16-32	15,000	20,400	7,800	460	60	540
Silty Clay Loam	Linn	0-12	27,400	10,000	5,600	380	360	2,400
D. Polk Series								
Clay Loam	Marion	0-8	11,200	13,000	9,200	3,160	840	6,380
Clay Loam	Marion	8-28	10,200	8,000	6,100	2,420	140	4,160
Silty Clay Loam	Lane	0-8	8,880	9,000	Trace	3,280	220	5,280
Silty Clay Loam	Lane	8-20	8,380	7,400	Trace	2,540	180	2,560
E. Cascade Series								
Loam	Multnomah	0-12	31,200	20,120	9,600	2,540	320	2,800
Silt Loam	Clackamas	0-12	23,000	7,200	2,900	850	300	3,120
Clay Loam	Benton	0-12	32,400	12,600	5,600	1,020	300	1,980
Silty Clay Loam	Linn	0-12	23,600	5,600	2,800	1,260	540	4,400
Clay	Linn	0-8	9,200	10,800	4,800	920	740	3,680

TABLE IV (Continued). CHEMICAL COMPOSITION OF "RED HILL" SOILS
Analyses of Soil Survey Samples by Department of Agricultural Chemistry,
Oregon Agricultural Experiment Station

Soils—Group, Series, and Type	County	Depth	Potassium	Calcium	Magnesium	Phosphorus	Sulfur	Nitrogen
	Pounds an acre to plow depth of soil of 6⅔ inches or 2,000,000 pounds							
II. SOILS DERIVED FROM SEDIMENTARY ROCKS		*In.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
A. Melbourne series								
Loam	Multnomah	0-12	31,600	34,000	9,800	3,060	....	4,800
Loam	Benton	0-14	22,000	7,200	4,400	1,220	440	3,100
Loam	Lane	0-14	16,740	5,160	3,160	1,740	380	3,700
Silt Loam	Washington	0-15	35,800	25,800	10,600	1,060	....	1,380
Silt Loam	Washington	15-36	32,600	17,200	13,400	720	....	460
Silt Loam	Benton	0-8	38,000	12,400	8,400	1,360	480	3,600
Clay Loam	Washington	0-18	34,600	11,400	10,800	1,400	162	1,020
Clay Loam	Washington	18-36	38,600	9,800	9,800	600	....	1,840
Clay Loam	Polk	0-7	29,800	4,000	2,800	1,852	328	2,340
Clay Loam	Benton	0-10	28,000	6,200	14,400	1,280	480	3,200
Clay Loam	Linn	0-10	24,000	5,600	1,800	560	148	960
Clay Loam	Lane	0-9	48,820	7,040	6,500	1,660	220	1,700
Silty Clay Loam	Polk	0-7	15,400	7,800	9,800	1,960	194	4,960
B. Sites Series								
Silt Loam	Yamhill	0-12	15,800	6,200	600	140	....	4,800
Clay Loam	Benton	0-8	17,400	6,800	5,400	1,920	600	4,780
Clay Loam	Lane	0-9	10,560	4,960	3,720	1,980	580	2,140
Clay Loam	Lane	9-21	11,780	3,800	Trace	2,160	100	2,240
Silty Clay Loam	Yamhill	0-20	12,000	6,000	7,200	1,420	....	1,800
Silty Clay Loam	Yamhill	20-36	18,000	5,200	6,600	1,340	....	1,440
Silty Clay Loam	Polk	0-7	15,200	3,200	5,200	1,538	52	3,300
Silty Clay Loam	Benton	0-8	8,400	8,800	2,200	2,120	580	4,540
C. Carlton Series								
Silt Loam	Washington	0-16	39,400	23,600	13,400	1,260	124	1,180
Silt Loam	Washington	16-36	34,800	18,200	13,400	1,000	....	560
Silt Loam	Polk	0-7	40,800	8,800	8,400	1,668	354	3,420
Silt Loam	Benton	0-13	40,600	12,400	10,400	2,080	400	2,520
Clay Loam	Benton	0-20	39,800	19,000	10,400	1,660	....	3,000
Clay Loam	Benton	20-36	39,000	17,600	10,400	520	....	1,260
Clay Loam	Yamhill	0-10	20,800	18,800	38,000	1,940	....	5,000
Clay Loam	Yamhill	10-36	18,400	18,200	8,400	1,560	....	2,840
Clay Loam	Benton	0-10	45,600	10,800	10,000	2,760	280	2,400
Clay Loam	Polk	0-7	34,800	7,800	7,000	1,410	282	3,960
Clay Loam	Marion	0-8	39,600	18,400	11,500	1,780	260	2,740
Silty Clay Loam	Polk	0-7	41,400	6,800	13,000	1,548	246	3,440
Silty Clay Loam	Benton	0-8	32,400	6,400	4,000	1,300	320	1,740
Silty Clay Loam	Lane	0-10	46,500	7,040	8,300	1,280	600	2,620
Silty Clay Loam	Lane	10-22	41,340	7,280	8,300	1,360	320	1,240

These chemical analyses give the total content of the several limiting plant nutrients. They cannot be used in determining immediate productive capacity but can be used in cases where the plant nutrient is extremely low as compared with that of the average soil. The data are of very definite value as aids in determining practices to be used in improving the crop-producing capacity of the soil. The total potassium content of these soils is from medium to low compared to that of an average soil. Yet field trials with potassium fertilizers give no apparent increase in yields. The soils derived from sedimentary material run higher in potassium and lower in phosphorus than those derived from basaltic materials. The total phosphorus content is higher than that of the average soil, but the availability or rate of availability is low. Field trials with soluble phosphate fertilizer bear this out with rather marked increases in yield. With comparatively few exceptions the nitrogen content is not above average. The type and distribution of rainfall of the area tends to slow up biological soil processes that convert the unavailable organic nitrogen to usable nitrates. This fact, together with leaching during the early part of the season when crops need this element most, increases the need for relatively available nitrogen carriers.

The extremely small amounts of sulfur indicate a need for this element especially on legume crops. Where barnyard manure is not used, or commercial fertilizers containing sulfur, the deficiency should be amended by the use of sulfur-containing fertilizer materials.

The two elements calcium and magnesium function much the same in soils, and frequently compounds of these two elements are referred to as lime. Since soil acidity may be corrected by the use of lime and the loss of lime compounds from soils results in soil acidity, it is usually assumed that an acid soil is deficient in the elements calcium and magnesium. This is not always the case. An acid reaction simply means that these elements are not present in the carbonate form. The soils of the Aiken and of the Sites series are low in both total calcium and magnesium, while those of the other soil series range from medium to low. Without exception, the soils are acid. The lime requirement usually runs from one to two or more tons of ground limestone per acre. Over much of the cropped area the use of basic lime is now necessary for the successful growing of legumes.

TABLE V. TOTAL AND (EXCHANGEABLE) NEARLY AVAILABLE CALCIUM IN SOME RED HILL SOILS*

Soil type and horizon	Reaction value	Colloid	Organic matter	Total calcium (CaO)	Exchangeable calcium	Proportion of total calcium exchangeable
Aiken Clay Loam	pH	%	%	%	%	%
I	5.11	39.5	3.07	0.66	0.16	34.0
II	5.09	42.5	1.78	0.39	0.14	50.0
III	5.02	51.8	1.03	0.48	0.15	42.9
Olympic Clay						
I	5.26	50.8	3.50	4.23	0.55	18.2
II	5.55	55.9	1.70	3.44	0.71	28.9
III	5.78	58.0	1.18	3.20	0.67	29.4
Melbourne Silty Clay Loam						
I	6.14	30.2	3.26	0.61	0.25	56.8
II	5.73	42.8	1.39	0.80	0.24	42.1

*Reported by R. E. Stephenson, Soil Science 28:235.

In a study† of the colloidal properties of these soils, the nearly available or exchange calcium determinations were made on the colloidal material from the different soil horizons. These data (Table V) show that, compared with other Willamette Valley soils, those of the Aiken and of the Melbourne soil series have the lowest amount of exchange calcium.

†R. E. Stephenson, Soil Science, Vol. 28, No. 3, Sept., 1929.

RESULTS OF FIELD EXPERIMENTS

Fairly complete and permanent fertilizer trials in cooperation with growers and county agricultural agents have been carried on for a number of years. The results of these tests show rather definitely that there are a number of soil and fertilizer practices that can be used profitably with the group of hill soils as a whole. The increases are most marked on the soil areas that have been cropped for an extended period of time.

Use of lime. Liming to make possible the successful growing of clovers and other legume crops is the first step in building up much of

Figures 1 and 2. Effect of lime on vetch and oats, Lincoln county. *Above:* Unlimed plot where vetch failed. *Below:* Increased hay yield of one ton per acre on limed plot. On this land lime is essential to legumes and maintenance of soil nitrogen and humus.

the hill soil. The need for and the response to basic lime as shown by laboratory tests and field trials is quite marked. Experience has shown that the increases in yields from liming are determined not only by the degree of acidity but also by the system of farming followed on these soils. Where livestock has been kept, to which most of the crops grown are fed, the need for liming and the response from its application on legumes is less than in systems where the crops are marketed directly. Over much of the area continuous grain farming has resulted in depleting the fertility and developing a degree of acidity that now makes liming necessary for the growing of clover. Under these conditions, liming leads also to larger yields of practically all the common field crops. There are also indirect benefits from liming. The deep-rooted legumes leave, in the soil, roots and stubble that decay rapidly, thus liberating plant nutrients contained in them and reacting with insoluble plant nutrients to make them more available. The increase in crop growth following legumes is quite marked although the full results become noticeable gradually as the benefits accumulate. It is not usually economical and frequently not necessary to supply an initial application large enough to neutralize an acid soil completely. The tendency is toward lighter and more frequent applications.

Use of sulfur. Sulfur is an essential plant nutrient and is removed from the soil by certain crops in amounts equal to and in some cases larger than phosphorus. The supply of sulfur in these hill soils is exceptionally low. The system of farming followed over much of the area has resulted in little or no addition of sulfur to the soil. Field trials in which sulfur has been used have given increases in yield, especially when applied to the legume crop. Tables VI and VII give the results of field trials with sulfur fertilizers.

TABLE VI. COOPERATIVE FERTILIZER TRIAL ON OLYMPIC CLAY LOAM
C. T. Gilbert Farm, Shaw, Oregon

Treatment and rate per acre	Yields per acre			
	Corn ensilage	Wheat and straw	Corn ensilage	Alfalfa
	Tons	*Tons*	*Tons*	*Tons*
Check	6.88	2.05	....	2.56
Rock phosphate, 500 pounds	6.28	2.03	....	3.22
Treblephosphate, 100 pounds	8.00	1.84	....	3.06
Superphosphate, 250 pounds	8.86	1.73	....	2.82
Check	7.52	1.80	....	2.50
Land-plaster 200 pounds	9.40	1.80	5.47	2.74
Sulfur, 100 pounds	9.40	1.68	5.58	3.30
Sulfur, 100 pounds, and rock phosphate, 500 pounds	11.00	2.30	5.40	2.74
Check	8.28	2.35	5.00	2.50
Average of Checks	7.49	2.07	5.00	2.52

Experience has proved that the use of calcium sulfate (land-plaster) as a top dressing on a legume crop in the early spring results in profitable increases in yields. The usual rate of application is from 50 to 80 pounds per acre. Since these soils are low in replaceable calcium, the land-plaster is preferable to elemental sulfur because of its calcium content. Calcium

TABLE VII. COOPERATIVE FERTILIZER TRIAL ON CARLTON SILTY CLAY LOAM

Alfred Abraham Farm, North Albany

Grain 50 years; winter wheat, clover, spring grain since 1903. Sheep pastured.

Treatment and rate per acre	Clover seed	Yields per acre: Spring wheat, Lime	Spring wheat, No lime	Winter wheat, Lime	Winter wheat, No lime
	Lbs.	*Bu.*	*Bu.*	*Bu.*	*Bu.*
Check	175	......	11.0	19.5	28.0
Sodium nitrate, 150 pounds	235	......	21.3	29.1	29.3
Rock phosphate, 1,000 pounds	290	16.1	19.7	21.3	30.0
Treblephosphate, 150 pounds	260	16.1	23.7	31.3	32.1
Check	215	14.0	19.0	44.3	35.8
Sulfur, 150 pounds	280	20.5	31.7	34.3	35.8
Nitrate of soda, 105 pounds; Treblephosphate, 110 pounds	285	16.8	12.0	37.3	40.6
Nitrate of soda, 105 pounds; Treblephosphate, 110 pounds; Muriate of potash, 110 pounds	275	15.1	10.3	38.0	34.1
Check	200	14.5	10.0	38.5	37.5
Manure, 20 tons	......	18.5	9.8	35.6	44.0
Manure, 20 tons; Rock phosphate, 1,000 pounds; Sulfur, 150 pounds	......	19.5	15.0	39.1	42.3
Manure, 20 tons; Treblephosphate, 110 pounds	......	14.5	12.7	37.6	45.0
Check	......	8.5	9.2	37.8	39.1
Average of Checks	197	12.3	12.3	35.0	35.1

sulfate is also preferable because sulfur may increase acidity in these humid soils.

Use of phosphates. Phosphorus is an essential nutrient that appears to encourage fruiting or seed formation, promote root development and favor hardiness.

The phosphorus supply of the hill soils is slowly available to crops. Laboratory tests and field trials often show a deficiency in available phosphate. This deficiency is very striking where grain farming has carried phosphorus from the farms. Although the loss of phosphorus is not as great with livestock farming, there is nevertheless a loss from the soil that can only be replaced by phosphate fertilizers or in manure produced from feed purchased from outside sources.

Field trials carried on for a number of years with phosphate carriers have given consistent increases in yields. The largest and most economical returns have been obtained with the soluble superphosphates. These phosphates in combination with barnyard manure have produced especially large increases. Table VIII gives the results of field trials on the hill phase of the Powell silt loam soil type. Similar results have been obtained in cooperative trials by county agricultural agents on the Olympic and the Aiken soil series.

The common phosphorus fertilizers are:

(1) Ordinary superphosphate (16% P_2O_5)
(2) Treblephosphate (45% P_2O_5)
(3) Basic slag (17% P_2O_5)
(4) Bonemeal (23% P_2O_5)
(5) Ground rock phosphate (25-30% P_2O_5)

TABLE VIII. COOPERATIVE FERTILIZER TRIAL ON POWELL SILT LOAM (HILL PHASE)
The Salzman Farm, Corbett, Oregon

Treatment and rate per acre*	Yields per acre					
	Corn ensilage	Potatoes	Oat hay		Clover hay	
			No lime	Limed	No lime	Limed
	Tons	*Bu.*	*Tons*	*Tons*	*Tons*	*Tons*
Sulfur, 100 pounds	11.98	235.8	0.96	0.89	2.94	2.40
Sulfur, 100 pounds; Manure, 10 tons	12.95	297.0	1.57	1.58	2.78	3.05
Rock phosphate, 500 pounds	11.61	189.0	0.96	1.16	2.50	2.94
Superphosphate, 250 pounds	12.59	217.5	1.09	1.20	2.78	3.27
Check	10.86	198.0	1.05	1.26	3.27	2.78
Rock phosphate, 500 pounds, Manure 10 tons	11.79	200.1	1.10	1.53	3.27	2.40
Superphosphate, 250 pounds; Manure, 10 tons	13.08	234.0	1.60	1.46	4.68	3.70
Check	11.23	174.0	0.94	1.26	3.18	2.78
Manure, 10 tons	11.92	197.0	1.34	1.44	3.49	3.05
Complete Fertilizer, 400 pounds (3-11-3)	13.34	172.5	1.22	1.12	3.18	2.94
Rock phosphate, 500 pounds; Sulfur, 100 pounds	....	....	0.94	1.28	2.18	3.05
Rock phosphate, 500 pounds; Sulfur, 100 pounds; Manure, 10 tons	....	....	1.20	1.57	3.70	3.49

*Fertilizer applied to the corn crop.

The superphosphates contain their phosphorus in a water-soluble form and in field trials have produced the most profitable returns. Basic slag, in addition to supplying phosphates, has a neutralizing value due to its lime content. For this reason, it has proved effective on highly acid soils, especially on legumes and other lime-requiring crops. Similarly, phosphate rock and bonemeal are relatively more useful on lime-deficient soils. On the other hand, the superphosphate produced marked increases on these highly acid soils. This undoubtedly is due to the readily available phosphorus and in addition, the precipitation of part of the soluble toxic aluminum in distinctly acid soils.

Nitrogen and organic matter. The building up and maintenance of a proper supply of organic matter in these soils is especially necessary, owing to the type and distribution of rainfall over the area. With very little rainfall during the summer, the need for a soil of high water-holding capacity is essential to meet water requirements of the growing crop, and at the same time function in regulating the supply of available nitrogen. The soil nitrogen is carried almost wholly by the organic matter. The value of organic matter is somewhat related to the rate of its decomposition and this in turn to its nitrogen content. Hence, after bringing up the supply of soil organic matter to a definite level, what is most desired is to keep it active and decomposing. Basic nitrogen carriers such as calcium nitrate, calcium cyanamid, or sodium nitrate are preferable to those such as ammonium sulfate which increase acidity with continued use in humid regions.

Phosphated barnyard manure. Barnyard manure is probably the most valuable source of organic matter that can be added to soil. Well-rotted manure is fairly concentrated in nitrogen content, and is a complete fertilizer. It is abundantly supplied with desirable bacterial flora that function in making plant nutrients available for crop use. In the types of farming usually followed on these hill soils, the supply of manure is too limited to meet the organic-matter requirements. Where barnyard manure is used, it has produced marked increases in yields. Further increases are secured when applications of soluble phosphate are used to supplement the manure at the rate of about 40 pounds of superphosphate per ton of manure. See Table VIII.

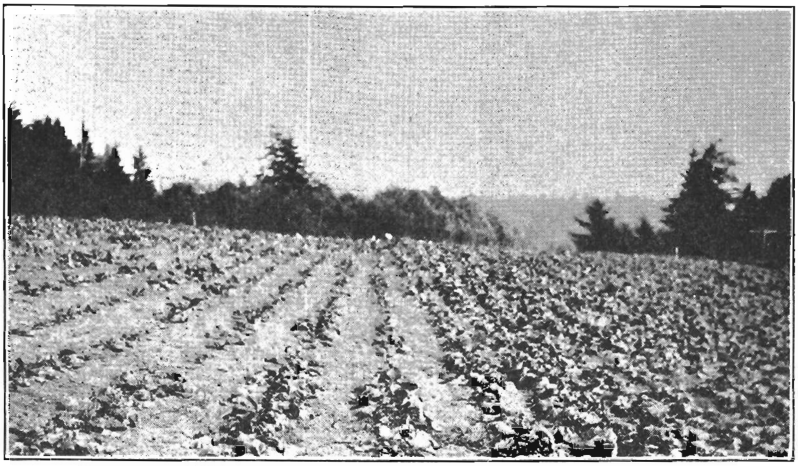

Figure 3. Effect of manure on rutabagas. Treated ground at right. Astoria Branch Experiment Station, 1929.

Crop residues and green manure crops. Crop residues and roots constitute a large portion of the organic matter that may be added to soils each year. Owing to distribution throughout the soil, they are especially effective. In order to make best use of this important source and realize the maximum benefits, systematic crop rotations should be followed. These will permit the more extensive use of legumes and of green-manure crops. Legumes will also increase the nitrogen content. To be most effective green manure crops should be hardy, rapid in growth, and produce an abundant succulent green growth. A crop of high nitrogen content is desirable and is an important factor in the rate of decay after turning under. Where bulky material such as grain straw is turned under, it should be supplemented with one of the readily available nitrogen fertilizers at the rate of 100 to 200 pounds per acre. Otherwise, the soil nitrogen may be used or tied up by the organisms that break down the bulky strawy material. The growing crop will in turn suffer, owing to a lack of available nitrogen.

Cover crops in orchards. In certain sections, orchards have been set out on lands that were prevoiusly cropped extensively. Building up the organic-matter supply is the major problem in handling these soils. Cover cropping meets this need best. Care must be exercised in getting the crop turned under to get the maximum growth and yet turned under early enough so that it will not compete with the growing tree for moisture in these droughty soils. The use of a quickly available nitrogen fertilizer applied as a top dressing in the early spring has given marked increases in yield on cover crops. It also makes for a more rapid succulent growth that can be turned under earlier. The rate of application is from 100 to 200 pounds per acre. Over much of the area, soluble phosphate fertilizers in combination with nitrogen carriers have increased the growth of the cover crop and improved the stand of vetch when used in combination with grain.

Figure 4. Results of cooperative fertilizer trial on cover crops. Nutcroft orchard, Washington county.

Crop rotation. Crop rotation is not only profitable but necessary in the successful handling of these soils. Experience has shown that with crop rotation, there are farms on these soils that are producing high yields after fifty years of cropping. Few growers appreciate the benefits that are derived from systematic rotation of crops. This is perhaps due to the fact that the benefits are accumulative over a long period of time and the means of comparing are not marked as in the case of applications of manure and other fertilizers. Crop rotation trials in this state and long-continued experiments in other states demonstrate clearly the following facts:

1. "In general, crop rotations have been 90 per cent as effective as farm manure and complete fertilizer in increasing yields of corn, oats and wheat, and 95 per cent as effective in maintaining yields."

2. "Benefits of crop rotation do not impair those received from manure and commercial fertilizers."

3. "The influence of crop rotation is higher on soils containing plenty of lime."

4. "Soils under long cultivation give best results when crop rotation, farm manure and commercial fertilizers are used together."*

Crop rotation is an economic treatment that should increase yields and decrease the unit cost of produce.

A rotation should contain:

(1) a cash crop
(2) a legume crop
(3) a cultivated crop
(4) a feed crop for livestock.

The benefits of such a rotation lie largely in the economical use of the soil's resources and in the control of diseases, insect pests, and weeds affecting the crops grown. Economic factors must be taken into consideration and the crops grown should fit the type of farming the grower prefers. For livestock or general farming, a rotation of grain, clover, and corn or other row crops can be used to advantage. Such a rotation is quite flexible. Other legumes may be substituted for clover, and the duration of this type of crop regulated. Where sheep constitute the bulk of the livestock, a rotation of fall-sown grain, clover, and spring grain is used to some extent. The elimination of the cultivated crop, though, increases the difficulty in controlling weeds.

Improving of land for grazing. There are large areas of logged-off stump lands of these hill soils that can be improved for grazing with but little outlay. Logging operations leave behind a large amount of debris. In order to get rid of the debris and lessen the fire hazard, it is customary to burn over the logged-off land as soon as convenient. A good burn will ordinarily clear the land so that cattle or sheep can find their way through without difficulty. The burn leaves behind a layer of ashes that affords an excellent seed-bed on which grass can be seeded for permanent pasture. Native vegetation also springs up with vigor. Fire-weed and other annuals and types of shrubs gradually appear. Along with the deciduous shrubbery will come a vigorous growth of fir seedlings. With the seeding of grass and grazing, the inroads of brush and tree growth are retarded and can be controlled with less effort. On the shallow and steep areas it is perhaps preferable to allow the native vegetation to grow and reforestation to take place. Repeated burning is harmful and successive growths after each burn are less vigorous. Fern is usually found over most of the

*Weir, W. W., U. S. Department of Agriculture Bulletin 1377.

areas, but does not develop into a problem until the land has been burned over a number of times.

GREENHOUSE AND LABORATORY TESTS

In tests carried on in the greenhouse, soils that respond to field applications of soluble phosphate fertilizers were used. Two-gallon containers with nine pounds of soil were brought to optimum moisture content. The treatments were planned to determine, first, whether or not the soil supply of phosphorus could be made more readily available, and second, what phosphate carriers can be used to advantage. The data obtained are in agreement with those of the field trials in showing up the marked deficiencies of these soils. All phosphate carriers produced increases in yield. The use of lime is beneficial for legumes, but undoubtedly decreased the availability of some of the less soluble phosphate carriers, as shown by crop response. Laboratory tests with both weak and strong solvents have failed to show these differences.

Laboratory tests to determine the effect of soil reaction on the availability of the soil phosphate supply of the Aiken clay loam showed little correlation. This would tend to prove that the benefits derived from liming this soil are mainly due to correcting acidity and that the sulfur benefits are due to serving as a plant nutrient rather than affecting the availability of the phosphorus. Field and greenhouse tests with basic lime and with sulfur on this soil gave marked increases in crop yields. The soil was placed in jars and treated with varying amounts of elemental sulfur and precipitated calcium carbonate. An optimum moisture content was maintained. At the end of nine months, determinations were made. The results are given in Table IX.

Figure 5. Effect of soluble phosphates on Aiken Clay Loam. 2: Ordinary superphosphate. 3, 4, 5: Ammoniated phosphates. 22: No phosphates. Nitrogen was supplied to each in equal amounts.

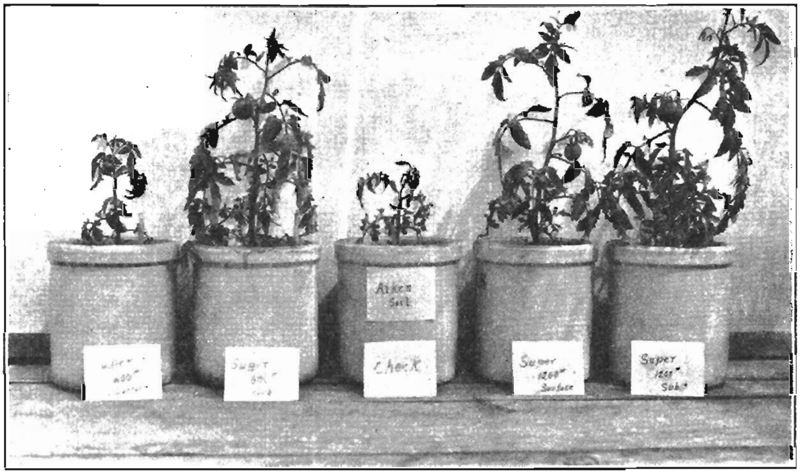

Figure 6. Effect of phosphate treatments and placements on Aiken Clay Loam.

TABLE IX. EFFECT OF REACTION ON SOIL PHOSPHATE AVAILABILITY

Treatment rates per acre	Reaction		Phosphate
	Soil	Soil extract	
	*pH**	*pH*	*p.p.m.*†
Check	5.9	5.9	.019
Calcium carbonate, 500 pounds	6.0	6.5	.008
Calcium carbonate, 1,000 pounds	6.1	6.4	Trace
Calcium carbonate, 2,000 pounds	6.5	7.5	Trace
Calcium carbonate, 4,000 pounds	6.6	7.0	Trace
Calcium carbonate, 8,000 pounds	7.2	7.5	.018
Sulfur, 200 pounds	5.6	6.5	Trace
Sulfur, 400 pounds	5.4	6.0	Trace
Sulfur, 800 pounds	5.3	6.2	Trace
Sulfur, 1,200 pounds	5.2	6.2	Trace
Sulfur, 2,000 pounds	5.1	6.0	.017

*pH=intensity of acidity. Pure water of neutral reaction has a reaction value or pH of 7.0.

†p.p.m.=parts per million.

A second and third series of the same soil were used to determine the absorbing capacity for phosphate. The amount taken up by the soil is given in Table X.

The data show that in the range of reaction (pH 5.2 to 7.2) at which most of our crops are grown, this soil has an exceptionally high capacity for phosphates. When soluble phosphates are added, the reaction undoubtedly takes place very quickly, but this freshly precipitated material on account of its fine state of division is available for crop use for some time. This assumption is borne out by field and greenhouse tests. It emphasizes the need of applying phosphate fertilizers at the time of seeding close to the seed or young plant. Figure 6 shows the marked effect of phosphate placement.

TABLE X. ABSORPTION OF SOLUBLE PHOSPHATES BY AIKEN CLAY LOAM

Soil reaction or pH	Phosphates absorbed from additions of PO_4	
	2 p.p.m. PO_4	20 p.p.m. PO_4
5.9	1.82	19.86
6.0	1.80	19.83
6.1	1.80	19.89
6.5	1.77	19.88
6.6	1.87	19.87
7.2	1.87	19.87
5.6	1.83	19.72
5.4	1.87	19.85
5.3	1.94	19.88
5.2	1.87	19.55
5.1	1.86	19.83

A SIMPLE SOIL MANAGEMENT SYSTEM

The management or system of handling these "red hill" soils is similar to that usually practiced in maintaining the fertility of mineral soils. It is simple and so flexible that it can be adapted to a wide range of crops or types of farming. The soils are quite generally acid in reaction and hence basic lime is necessary for the successful growing of legumes. The latter is of especial importance with the utilization of crop residues and farm manure in the nitrogen economy of these soils. Both phosphorus and sulfur usually need attention and must be added in the form of some commercial fertilizer material, the former to field crops and the latter in the form of land-plaster to legumes. These practices are most effective when carried on with a suitable crop rotation.

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