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INVESTIGATION AND USES OF YELLOW PINE SOILS FOR HORTICULTURE AND AGRICULTURE.

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THESIS

S Y N O P S I S.

	Page.

INTRODUCTION.

The study of soils with a view to ascertaining their economic value has been, for years, the object of numerous interesting experiments.

The important results which have been obtained from such experimentation by others appeal with peculiar force to the ambitious student in seeking a subject for original investigation. This, especially is true when a comparatively new field for work is offered. Hence, the study of coniferous soils was the subject chosen for the investigation and experimentation which it is the design of this thesis to record.

The object of the experiments made, as described in detail in the following pages, therefore, was to discover in general the economic value of coniferous soils. In other words the experiments were carried on to determine whether coniferous soils could be used with profit, or with a promise of sufficient future advantage for horticultural or agricultural purposes. Furthermore, if the results of the experiments proved that coniferous soils were adapted to the growth of trees of different kinds, fruit trees in particular, and of garden vegetables, what are these values in a comparative way, or in respect to one or the other of these uses? Does investigation show that coniferous soils are best adapted to horticultural, or to agricultural uses?

And if for the one, or the other, for what kind of trees, or garden vegetables, forage plants or grains, can they be used with most assurance of satisfactory results?

The experiments here recorded, were carried on for a sufficiently long time to give such marked results as to warrant certain positive conclusions.

More extended investigations would, no doubt, show still more clearly whether these conclusions might be made broader in their scope, or whether they should be, in some respects, modified or changed.

Experiments covering more ground, or spreading over a wider range of horticultural and agricultural products, would, it need scarcely be said, better determine the fitness or the unfitness of evergreen coniferous soils for the cultivation of a certain, greater or less number of horticultural or agricultural crops.

Whatever may be done in this field by future investigators, it is hoped that the experiments herein recorded may be of some real and permanent value in a present as well as a future estimate of the adaptation of coniferous soils to the uses of horticulture and agriculture.

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THE ESSENTIAL ELEMENTS OF PLANT FOOD.

The influence of evergreen coniferous soils, or yellow Pine soils upon vegetation, and the uses of such soils for horticultural and agricultural purposes depend, necessarily, on the amount and ratio of the essential elements of plant food they possess.

What are the essential elements of plant food? It may not be amiss to answer this question first in the language of a recent writer, William Allen Hamor, who belongs to what is called the Liebig school, and who has formed his conclusions from its teachings. He says of the founder and his theories:

"It was in 1840, after exhaustive investigations on the weathering of rocks, on the formation of soils, and on the effects of rain and the gases which rain holds in solution, that Liebig published his classic work on the application of chemistry to agriculture and physiology. In this Liebig completely undermined the foundations of the humus theory and enunciated the following foundations of modern chemistry:

1. Inorganic substances for the nutritive material for all plants.
2. Plants live upon carbonic acid, ammonia (nitric acid) water, phosphoric acid, sulphuric acid, lime, magnesia, potash and iron; many need common salt.

3. Manure, the dung of animals, acts not through the organic elements directly upon plant life, but indirectly through the products of the decay and fermentative processes; thus carbon becomes carbonic acid, and nitrogen becomes ammonia or nitric acid. The organic manures, which consist of parts of the remains of plants and animals, can be substituted by the inorganic constituents into which they would be resolved in the soil.

Practical field trials, carried out by governments and large land owners, proved the correctness of Liebig's deductions from his laboratory experiments, and the many investigators in this line have come either directly or indirectly from Liebig's school".

The question may be answered in other language, and to some extent in a somewhat more explicit way: First, plants cannot exist without the two elements of which water is composed, that is hydrogen and oxygen. Second, plants need for their growth and development organic matter, which consists principally of carbon, hydrogen, oxygen, and nitrogen. Third, plants require certain inorganic matter in which is included potassium, phosphorus, sulphur, calcium, magnesium, iron.

Water, as a plant food, is by far the most important

factor in the growth of vegetation. Therefore, without a sufficient and continuous supply of this element, crops of no kind can be grown. This makes the preservation of water in the soil the leading problem of plant growth and cultivation. How can this problem best be solved? The solution, or a substitute for it, seems to rest in new methods of cultivation by irrigation and other means, the discussion of which is not within the province of this thesis.

The first three necessary elements of the second class of plant food, carbon, hydrogen, and oxygen, are easily supplied by the air and by water through the action of the sun's rays and atmospheric heat. The fourth element, nitrogen, which forms nearly eighty percent of the volume of our air is not so easily made available to plants in general. One notable exception, however, exists, the Leguminosae family. This family of plants has been found capable of obtaining nitrogen from the air through the nodules on the roots of all species belonging to its many genera.

Nitrogen is one of the most indispenable elements of plant food. When it is absent from any soil to an extended degree, the growth of all plants incapble of receiving it from the air will be greatly retarded; in many instances an attempted growth will be a complete failure.

The importance of nitrogen as an element of plant food is becoming more and more realized. A recent article in the "Review of Reviews" says, "That the earth may eventually cease to yield the requisite nourishment for the constantly increasing human race confronts us as a dire possibility. The prospect of a universal famine is not a mere figment of the imagination; and the efforts that are being made in our new country to enrich the soil by hitherto unknown means of supply will naturally arouse a widespread interest. Dr. Otto N. Witt, Professor in the great Technological Institute at Charlottenburg, gives an interesting account in the Berlin Woche of what is at present being accomplished in the way of producing nitrates, the life giving element of plants, and speaks of the possibility of their vastly increased production. The supply of nitrogen in the world is, in the fullest sense of word, inexhaustible, for it constitutes four-fifths of the atmospheric air which envelops the earth. Unfortunately, however, plants are for the most part incapable of absorbing and utilizing nitrogen in the molecular form in which it appears in the atmosphere. All higher plants demand the nitrogen requisite for their existence in combination with oxygen in the shape of nitrates. Certain bacteria, the nitrifying organisms found everywhere in the soil, can it is true, absorb nitrogen in combination with hydrogen as ammonia, they, on their part, converting it into nitrates. And putrefying matter, such as stable manure is valuable, since, again by the aid of bacteria, the nitrogen it contains is changed into ammonia which the nitrifying organisms of the soil convert into nitrates that serve to nourish the higher plants. Thus life is generated from death by a wonderful process, which we term, "the cycle of nitrogen".

Plants have no power to absorb nitrogen through their leaves, they must obtain the nitrogen they require, except in the family of Leguminosae, from the organic matter that is decaying in the soil; or, in semi-arid regions they may draw on a possible reserve supply, taken ages before from the air and stored up in the soil. The economy of Nature has caused this reserve supply to be fixed by the soil in these regions, but while it is slowly exhausted, and is still plentiful in many places, in some places it has been washed away, or has been used up by vegetation.

It may not be out of place here to refer to the fact that many plants of the Leguminosae family have been largely used as green manure, planted to enrich the soil. More than that in soils where the proper bacteria are not sufficiently abundant the leguminous plants used as manure are being inoculated with bacteria that their nitrogen supplying nodules may be increased in number. Professor Karl F. Kellerman, Plant Physiologist of the Department of Agriculture says, "The value of the legumes, plants belonging to the pea family, such as clovers, alfalfa, cow peas, soy beans, peanuts, field peas, vetch, etc., as green manures, or soil renovators is due to certain bacteria which develop nodules on the roots of these plants and which have the power of rendering the free nitrogen of the air available for plant growth. Without these bacteria, legumes, like other crops, exhaust the soil of its combined nitrogen. In many regions certain types of these important bacteria are abundant in the soil; in other localities they must be imported, or in other words, the leguminous crop to be grown there must be inoculated".

The inorganic elements of the soil, must easily exhausted, and therefore, most commonly lacking, are potash and phosphoric acid. To entirely use up these ingredients, however, a long time is required by most soils. Such a condition, moreover, can always be prevented by proper care of the soil and by due attention paid to rotation of crops.

The common sources of potash are wood and vegetable ashes, or potash can now be supplied from German potash mines. It may be mentioned that hope is now held out of finding a natural supply of potash in the United States. Geologists of the United States Survey declare "that the conditions in some portions of the arid West, regions just east of the Rocky Mountain wall and the Great Basin region, are not unfavorable to the discovery of large bodies of potash salts comparable to those of Germany.

The sources of phosphoric acid are the bones of animals, the tetra calcic phosphate of lime, a by-product of steel manufacture, and lime phosphate soluble in water.

R. W. Thatcher, in Bulletin No. 85, issued from the Department of Chemistry of the Agricultural Experiment Station, Pullman, Washington, says: "Experience has shown that it is possible to draw certain fairly definite conclusions as to the fertility or fertilizer needs of a soil from an analysis." In this connection Professor Hilgard, the celebrated authority on soils in this country says; 'As between soils of similar character and origin, the production and durability are sensibly proportioned to the plant food percentages when the latter fall below a certain limit.' With regard to the percentages of each of the critical elements of fertility, lime, potash, phosphoric acid and nitrogen, which are necessary for plant growth, the most complete standards which have been proposed are those of Professor Maerker, of the Halle Experiment Station in Germany. These are given in Professor Hilgard's new book on 'Soils', page 369, as follows:

Practical Ratings of Soils by Plant Food Percentages.

According to Professor Maerker, Halle Sta. Germany.

Grade of Soil.	Potash.	Phosphoric Acid.	Lime Clay Soil	Lime Sandy Soil	Total Nitrogen
Poor	Below .05	Below .05	Below .10	Below .05	Below .05
Medium	.05-.15	.05-.10	.10-.25	.05-.10	.05-.10
Normal	.15-.25	.10-.15	.25-.50	.10-.20	.10-.15
Good	.25-.40	.15-.25	.50-1.00	.20-.30	.15-.25
Rich	Above .40	Above .25	Above 1.00	Above .30	Above .25

These estimates are in very close agreement with nearly all of those which have been suggested by other soil chemists, in all parts of the world, although different methods of analysis are used by men in different countries."

The importance of these figures, as representing an authoritative standard, in any investigation of soils, can readily be seen. They afford a means of comparison and serve to confirm, or disprove, or modify conclusions from results obtained by original experiments.

THE PRESENCE OF AVAILABLE PLANT FOOD.

All life is subject to waste and decay. All life is, therefore, dependent upon the nourishment that makes possible its constant renewal. Foods are as great a necessity to plants as to animal life. The soil is one of the mediums through which foods are conveyed to plants. If the soils do not contain some of the essentials of these plant foods, or if the supply is not replenished by natural or artificial means, starvation must result for plants in such soils. To make the statement more concise, on the availability of plant foods rest the success or failure of a crop, or the growth of such plant life. This statement is made in the face of the fact, that carbon in the form of carbon dioxide as it is taken from the air by means of their leaves, is one of the principle plant foods. While plants are built up to a large extent of carbon, yet the other constituents, both organic and inorganic compounds in the soil that constitutes the smaller portion of the plant food, are as essential to the growth of the plants as the carbon.

The essential importance of soil to the greater percent of plant life is due to the provision of nature, which makes the roots and rootlets with the root hairs of plants their means of obtaining nourishment. As most of the plants take up from the soil by means of the little root hairs, or other organs attached to the roots some of this most essential plant food for their growth, it follows, therefore, that the first necessity of plant growth is the development of their roots. The roots must first be properly nourished, or they will not make the growth required for the support of healthy plants. The entire plant depends upon the proper growth and development of the root-system. That the root development comes first is seen in almost any seed at the time of its sprouting, for the radical, or little rootlet develops first and grows downward to meet the soil, or moisture and soil. If the roots are not in size, number and texture, what they should be, they will not be able to furnish sufficient sustenance to the upper portion of the plant to enable it to perform its proper functions, to bring the best results. It is clear then that in the study of soils in connection with plant life and fruit production, the roots and rootlets as well as the root hairs in their relation to the soil and the plant food found therein, are of the first importance and considerations.

The roots of plants with few exceptions live whole in the soil, and there it is that they must find as in a storehouse a sufficient amount of available plant food in the shape of nitrates and other compounds soluble in water ready to be taken up for growth. Besides the available plant foods in the soil there should be present in the soil organic and inorganic elements and compounds, which may in future time by disintegration become available as plant foods.

On the presence or absence of both the available and unavailable plant foods in any soil, depends the good or poor growth and development of plant life, in the soil.

THE POISONOUS MATTER IN THE SOIL.

Another matter of scarcely secondary importance, in connection with the amount of available plant food in soils, cannot be overlooked in this study. To be available for plant growth and plant life in general, the various elements of plant food must conform to certain restrictions, or conditions. There may be too much of one element, or too little of another. The food elements must be properly balanced for the special needs of the plant, to give it healthy growth. And as great danger, possibly a greater danger, lies in an overabundance of an element of plant food as in its lack. An overabundance of mineral salts in the soil, for example, may act as a poison upon the plant. That is the excess of mineral salts may prevent the roots from performing their functions. The overabundance of water (hydrogen and oxygen) may often prove disastrous; it acts in a way similar to the action of carbonic acid on animal life. Again, there may be an abundance of certain other necessary plant food in the soil which the plant is not able to use; that is, it is hindered, if not entirely kept from using this food because of an excess of other elements.

In the following record of experiments with evergreen coniferous forest soils, carried on with a view to determining their value for agricultural and horticultural purposes, the results shown were deduced from careful investigations based upon the foregoing requisites for plant growth, and judgments made accordingly.

INVESTIGATION AND USES OF YELLOW PINE SOILS FOR HORTICULTURE AND AGRICULTURE.

GENERAL CHARACTER OF THE EXPERIMENTS CARRIED ON.--The work of investigation to determine the uses and value of coniferous soils for horticultural and agricultural crops was carried on in a greenhouse where the plants experimented upon were brought under the same climatic conditions. An exact description of each of the four soils used is given in the following pages. The four soils were Palouse soil; Yellow Pine soil; New Sawdust soil; Old Sawdust soil. The special purpose of the Palouse soil was to act as a check upon the other three soils.

SOILS IN GENERAL.--Before entering upon the analysis of the soils used in the experiments herein described, it will be in place here to dwell for a little space upon the technical meaning of the term "Soils". "Soil" as some one has poetically said, "is the loose mantel of material covering the earth . It consists of disintegrated elements of the earth's crust, mixed with varying amounts of decayed vegetable matter. The earth's crust is composed of more than seventy elements, most of which are present in very small proportions". Eighteen of these elements alone are of importance in soil formation and plant growth, most of which have been referred to in the previous chapter concerning the Essential Elements of Plant Food.

SOIL FORMATION.--Professor R. W. Thatcher, Professor of Chemistry and Soil physicist at Washington State Agricultural College, and Director of the Department of Agriculture of that College, says, "All soils are produced by the disintegration or mechanical breaking down, and decomposition or chemical breaking down of rock. This breaking down, or weathering, as it is termed, is caused by the joint action of air, moisture and sudden changes of temperature, and of growing or decaying vegetation, on the rocks of which the earth's crust is composed. The action is generally slow, but is continuous and very powerful. When it has been going on long enough so that the rock is reduced to a fine powder, and this rock waste is mixed with a certain amount of decaying vegetable matter, soil is produced. It will be apparent that soil consists essentially of two major constituents, namely, mineral matter, or rock waste, and organic matter, or vegetable matter in various stages of decay.

The organic matter is very complex in its nature, and exists in every stage of decay from the woody fibre of growing plants to the gases which are the result of the complete decomposition of vegetable matter. In the analysis of soil a distinction is made between volatile and organic matter, which comprises all the material which may be driven off or burned off from a soil by high heat, and includes combined water and certain gases, as well as the purely vegetable matter of the soil, and humus, or that part of the organic matter which is in certain intermediate stages of decay and may be dissolved out of the soil by dilute solutions of ammonia or other alkaline liquids. Humus is that part of organic matter which is in the proper form to serve as a supply of plant food. It is of very great value because it not only supplies a very necessary element of plant food, nitrogen, but has also the power to attack some of the inert mineral matter of the soil, and change it into forms which are available for plant food purposes."

THE PALOUSE SOIL.--The Palouse soil, or as it is otherwise termed, the soil of the Inland Empire, has its origin, for the most part, in the disintegrated lava bed of Basalt. It is a fine dust-like soil, capable of holding moisture for a great length of time. While it is not one of the richest of soils in its total amount of plant food, it is very rich. Like many other soils of the semi-arid regions it has had its plant food stored up for ages. Professor Thatcher gives an analysis of this soil, or its equivalent, in Bulletin 85, "Washington Soils" previously referred to. It is an analysis of Whitman County, Washington soil, and was sent to him in response to his request by Mr. S. A. Small of Winona, Washington. Professor Thatcher says of this soil, "It shows the same general characteristics as the Palouse basaltic soil." The analysis is as follows:

WHITMAN COUNTY SOIL ANALYSIS.

Insoluble Silica		79.740%
Hydrated "		2.220%
Soluble "		0.495%
Potash (K_2O)		0.506%
Soda (Na_2O)		0.249%
Lime (CaO)		0.508%
Magnesia (MgO)		0.194%
Manganese Dioxide (MnO		
Iron Oxide (Fe_2O_3)		5.196%
Alumina ($Al\ O$)		4.735%
Phosphoric Pentoxide (P_2O_5)		0.187%
Sulphur Trioxide (SO_3)		0.34 %
Carbon Dioxide (CO_2)		
Volatile and organic matter		5.190%
	Total	99.254%

Humus	2.848
Total Nitrogen	0.138
Moisture in dry air soil	1.630

In the Palouse soil, as will be seen, the proportions of humus and nitrogen are very small. The nitrogen present, however, is wholly of the available kind, hence the soil is rich, though humus to a large degree is absent.

THE YELLOW PINE SOIL, same as found in Jack Pine and Red Pine regions of Michigan.--The coniferous soil used in the experiments was obtained from the mountains where granite rock exists. It is composed of the disintegrated rock in combination with the humus from evergreen conifers, Yellow Pine needle soil. It is generally believed that this soil is not very rich in plant foods.

We are indebted to the same authority, Professor R. W. Thatcher for an analysis of this soil also:

ANALYSIS OF EVERGREEN CONIFEROUS SOIL.

From the Foothills of Tatunah Mountain Range.

Near Moscow, Latah County, Idaho.

Gravel and Granite Sand	50%
Fine Earth	50%

Results of Partial Analysis.

Potash	0.277%
Lime	0.852%
Phosphoric Acid	0.210%
Nitrogen	0.294%
Humus (?)	
Alkali (?)	
Volatile and organic matter (?)	

This analysis shows a high percent of nitrogen in coniferous soil, but the nitrogen is not in an available form. A more complete analysis might have shown the total amount of plant food in this soil to be very large, especially in the element of humus. There is no method, however, whereby we can determine with certainty how much of the total plant food in the soil is available for the use of different crops, except that of experiment. It is, therefore, by experimenting alone, through the planting of certain crops that it is possible to ascertain whether there is a sufficient amount of available nitrogen and other plant food in the soil for the successful cultivation of these crops.

THE NEW SAWDUST SOIL.--This soil was made up of two-thirds Palouse soil and one-third fresh sawdust from a coniferous lumber cutting saw-mill. The purpose of this combination was to find out whether the addition of one-third of this kind of humus material to the Palouse soil would influence plant growth.

THE OLD DECAYED SAWDUST SOIL.--This soil was made up of one-third old Yellow Pine lumber sawdust, which had been decaying near a mill-site for ten years or more, and two-thirds Palouse soil. The object of this combination, like that of the fresh sawdust and Palouse soil, was also to discover what effect the decayed wood fibre in the form of humus would have on plant growth.

Into the four different soils which have just been described were planted, or sown, at the same time, under equal conditions and environments, the trees and vegetables, shrubs and cuttings named in the following list:

TREES (Seedlings).

American White Ash	Fraxinus americana.
Hard Maple	Acer saccharum
English Oak	Quercus
Plum	Prunus domestica
Locust	Robinia pseudacacia
Black Cherry	Prunus serotina
Bartlett Pear	Pyrus communis
Apple	Pyrus malus

SHRUBS (Plants)

Raspberry	Rubus strigosus
Loganberry	Rubus

Blackberry	Rubus villosus
Gooseberry	Ribes grossularia
Currant	Ribes
Grapes	Vitis

GRAINS AND VEGETABLES.

Field Peas	Pisum sativum
Bush Beans	Leguminosae
Beets	Beta vulgaris
Tomatoes	Lycopersicum esculentum
Radish	Raphanus sativus
Lettuce	Lactuca sativa
Carrots	Daucus domestica
Strawberries	Fragaria
Hairy Vetch	Vicia sativa
Wheat	Triticum vulgare
Oats	Avena Sativa
Barley	Hordeum
Corn	Zea mays
Alfalfa	Medicago sativa
White Clover	Trifolium repens
Field Vetch	Vivia sativa
Squash	Cucurbita
Geranium	Geraniaceae
Rose	Rosaceae
Cabbage	Brassica oleracea
Celery	Apium graveotens
Parsnip	Pastinaca sativa
Apple Seed	Pyrus malus

From the time in the Fall of the year when the seeds were sown and the shrubs and trees planted until the beginning of Summer following, daily watch was kept and the results of the experiments in each soil were carefully recorded. First, the time required for the germination of the seed and the leafing out of the shrubs and trees, in the different soils, was noted, then the subsequent progress of the plants from day to day was entered upon the record.

The degree of moisture and the climatic conditions to which the plants were subjected during their growth and development were kept as nearly uniform as was possible to obtain in a greenhouse.

The following records show in detail what was accomplished by the investigation of the suitability of the different soils, and their relative values, for the growth and productivity of the plants used in the experiments.

TREES (Seedlings).

THE AMERICAN WHITE ASH (Fraxinus Americana).--
Two trees of small size, not over two feet in height and one-half inch in diameter, each two years old and having about the same amount of root-system, were planted into twelve-inch pots, one in coniferous, the other in Palouse soil.

The tree planted in the coniferous soil began to show its leaves twelve days earlier than the tree planted in Palouse soil.

The tree planted in the coniferous soil grew more rapidly than the tree planted in the Palouse soil. The leaves of the former were of a much darker color than those of the latter. These relations continued unchanged throughout all subsequent growth of the two trees.

Root Systems.

The root system of the tree in the coniferous soil was much larger and coarser than that of the tree in the Palouse soil.

There was a most noticeable difference also in the color of the roots of the two trees; that of the roots of the tree in the Palouse soil was a yellowish gray; that of the roots of the tree planted in the coniferous soil was dark brown.

THE BLACK LOCUST(Robinia Nsendacacia).--The trees planted were one year old, not over two feet in height and a little more than one-fourth of an inch in diameter. Their root systems were about equal in amount.

The trees were planted in ten inch pots. The tree in the coniferous soil started to leaf out eight days earlier than the tree in the Palouse soil.

The subsequent growth of the two trees showed the same ratio of progress until the end of the experiment.

The foliage of the tree planted in the coniferous soil was darker in color, but neither larger nor smaller than that of the tree planted in the Palouse soil.

Root Systems.

The root system of the trees was about the same in both soils. The roots of the tree in the coniferous soil were, however, of a darker color than those of the tree in the Palouse soil. Another decided difference was also marked; more and larger nodules developed on the roots of the tree in the coniferous soil than on those of the tree in the Palouse soil. (See Plate No. 7, page 71).

THE PLUM(Prunus domestica).--The trees chosen for the experiment were one year old. They were about eighteen inches high and one-fourth of an inch in diameter. Their root systems were as near equal as could be obtained. Both trees were free from all defects. Ten inch pots were used.

The leaves appeared on the tree planted in the coniferous soil, nine days earlier than those on the tree planted in the Palouse soil. The growth was equal, however, in both soils from the time leaves first showed themselves on the trees until the end of the experiment. The size of the leaves, also was alike on both trees. The color of the leaves, however, was of a much darker color on the tree growing in the coniferous soil than those of the tree in the Palouse soil.

Root System.

The root system of the tree in the Palouse soil was small and consisted of small, fine roots. That of the tree in the coniferous soil was coarse and made up of a considerable number of large roots. The color of the roots of the tree in the Palouse soil was yellow, while that of the tree in the coniferous soil was dark brown.

THE HARD MAPLE(Acer saccharum).--Two trees of about equal size were planted into twelve inch pots. The trees were twenty inches high and five-tenths of an inch in diameter. They were about one year old and had approximately the same amount of root system. The trees were perfectly healthy in every way and without deformities or defects of any kind.

The opening of the buds on the tree planted in the coniferous soil was noticed a few days earlier than the same point reached by the tree planted in the Palouse soil. The leaves of the tree growing in the coniferous soil were no larger, but were of a darker color than the leaves on the tree in the Palouse soil. The tree in the coniferous soil, however, showed a more vigorous growth than was shown by the tree in the Palouse soil.

Root Systems.

The root system of the tree in the coniferous soil was very much more extensive than that of the tree in the Palouse soil. The roots of the former were, also much larger and coarser than those of the latter. The same contrast of color noticed in the roots of trees previously described was again shown in these Maple trees. That is, the roots of the tree in the coniferous soil were dark brown, while those of the tree in the Palouse soil were lighter in color, showing a yellowish tinge. (See Plate No. 1, page 62).

THE SCARLET OAK(Quercus coccinea).--The trees, each two years old, were planted in the different soils in twelve-inch pots. Each tree was twenty inches in height and fourteenth of an inch in diameter. The trees were both as nearly perfect as possible; or, in other words were healthy and free from defects and deformities. Leafage appeared on the tree in the coniferous soil about one week earlier than on the tree in the Palouse soil. The color of the leaves themselves were somewhat smaller in size than the leaves on the tree in the coniferous soil.

Root Systems.

The roots of the tree in the Palouse soil were very much smaller as well as fewer in number than the roots of the tree in the coniferous soil. In regard to the color of the roots the same difference heretofore mentioned in the description of other trees was seen; the tree in the coniferous soil had dark brown roots, while the roots of the tree in the Palouse soil were of a yellowish gray color.

THE CHERRY(Prunus serotina).--The cherry trees planted were seedlings measuring about twenty-four inches in height and five-tenths of an inch in diameter. They were vigorous trees showing no deformities, and had developed about the usual amount of root system. They were planted into twelve-inch pots. The tree in the coniferous soil showed its first leaves eight days earlier than the one in the Palouse soil. In neither soil was the growth satisfactory; in fact very poor in both soils. It was so poor indeed in the Palouse soil that the tree failed entirely before the experiment could be carried to a close. One difference was shown in the trees; the foliage of the tree in the coniferous soil was of a much darker color than that of the tree in the Palouse soil.

Root Systems.

The roots of the tree in the coniferous soil were very much larger and coarser than the roots of the tree in the Palouse soil, which were fine and small. The color of the roots of the tree in the Palouse soil was of a light grayish yellow, while that of the roots of the tree in the coniferous soil was dark brown.

THE PEAR(Pyrus communis).--Two one year old trees were chosen for the experiment. They were eighteen inches in height and fourteenth of an inch in diameter. They were healthy trees, without deformities, and with normal root systems about alike in both. Twelve inch pots were used. The tree in the coniferous soil leafed out five days earlier than the tree in the Palouse soil. Subsequent growth of the two trees showed about the same ratio of progress. The leaves were alike in size on the two trees, but the color of the foliage of the tree in the Palouse soil was lighter than that of the foliage of the tree in the coniferous soil.

Root Systems.

The tree in the Palouse soil developed a root system made up of roots of a fine and small type. In contrast, large, coarse roots formed the root system of the tree growing in the coniferous soil. The color of the roots, as was the case with other trees used in the investigation differed decidedly in the two soils; that of the roots of the tree in the coniferous soil being of a dark brown, while that of the roots of the tree in the Palouse soil was of a yellowish gray. (See Plate No. 11, page 76).

THE APPLE (Pyrus malus).--The trees experimented with were seedlings one year old. They were about thirty inches in height and five-tenths of an inch in diameter. Healthy trees, without blemishes, each having about the same amount of root system were selected. They were planted into twelve inch pots. The tree planted in the coniferous soil unfolded its first leaves one week earlier than the tree planted in the Palouse soil. A like progress in growth, or rather a like ratio of progress was maintained between the two trees throughout the experiment. The leaves on the tree in the coniferous soil did not differ in size from those on the tree in the Palouse soil, but were of a darker color.

Root Systems.

The roots of the tree in the coniferous soil were larger, coarser, and more in number than those of the tree planted in the Palouse soil. The color of the roots of the tree in the Palouse soil was yellowish, while that of the roots of the tree in the coniferous soil was dark brown. (See Plate No. 3, page 65).

THE RASPBERRY(Rubus strigosus), THE BLACKBERRY (Rubus villosus), THE LOGANBERRY(Rubus (?)).--These three plants were dug up with about the same amount of root system and with the same length of stem, the latter being in each plant about six inches long. The plants were replanted in the two soils, in ten-inch pots, December 11, 1909. The plants sprouted in each soil at about the same time, from February 10-12, 1910. There was very little difference in their growth in the different soils. In other words these berry plants grew about as well in the coniferous as in the Palouse soil. The leaves of the plants in the coniferous soil were of a darker green than those on the plants in the Palouse soil. The size of the leaves, however, was about the same on the plants in both soils.

Root Systems.

The roots of the plants in the Palouse soils were fine in texture, small, numerous and of a yellowish color, while those of the plants in the coniferous soil were large, coarse, and less numerous, and of a darker green color. (See Plates 40 and 41, pages 118 and 119).

THE GOOSEBERRY(Ribes grossularia), THE CURRANT (Ribes (?)), THE GRAPE(Vitis (?)).--For the experiments with these three plants, cuttings were used. These cuttings were five inches long and three-tenths of an inch in diameter. They were taken from well-grown, healthy stocks, and were planted into ten inch pots. Two buds on each plant were left above the soil for growth. The cuttings were planted December 11, 1909. The cuttings of all three plants in the coniferous soil started to leaf out February 2, 1910. Ten days longer were required to bring the plants in the Palouse soil to the point of leafage; their first leaves appeared February 12, 1910. Very little difference is noted in the subsequent growth of the plants in the two soils, except in the case of the grapes. The grape cutting made a better growth in the Palouse soil than its mate in the coniferous soil. The leaves of the three plants in the coniferous soil were darker in color than those of the plants in the Palouse soil.

Root Systems.

The roots of the plants in the Palouse soil were fine, small, and numerous, while those of the plants in the coniferous soil were large, coarse, and few in number. There was little difference in the color of the roots in the two soils.

GRAINS AND VEGETABLES.

THE FIELD PEA(Pisum sativum).--The four soils, Coniferous, Palouse, Old Sawdust, and New Sawdust were used in the experiment with the field pea. The soils were filled into six inch pots in which the seed was sown on December 11, 1909. Germination took place in all at about the same time, December 18, 1909. Three plants were left growing in each pot. These indicated from the start that there would be very little difference in their growth, in the different soils. A slight difference, however, was shown in later growth, the plant in the coniferous soil producing a healthier looking stalk and its color being of a darker green. The plants in the three other soils continued to be about equal in growth and general appearance.

Root Systems.

The roots of the plants in all of the four soils showed nitrogen nodules. The nodules were more numerous, however, on the roots in the coniferous soil than upon those developed in the other soils. In the Palouse soil and in the New Sawdust soil the roots were similar in fineness, size and number. In like manner, the roots in the coniferous and Old Sawdust soils corresponded in number, size and texture. In the two last mentioned fewer roots were developed and they were larger and coarser than the roots in the other two soils. The color of the roots was about the same in all of the four soils.

THE GARDEN BEET(Beta vulgaris).--Seeds of the garden beet were sown into each of the four soils, in six inch pots on December 14, 1909. About January 2, 1910, the plants began to spring up. The seeds sown in the Palouse soil germinated slightly in advance of those in the other soils. Later developments proved that the Palouse soil was germinated slightly in advance of those in the other soils. Later developments proved that the Palouse soil was the best of the four soils not only for the germination of the seed, but for the growth of the plant. The coniferous soil ranked second in value, old sawdust third, and new sawdust fourth, for adaptability to the culture of the garden beet. The description of the root system is given in the description of the Plates Nos. XXXVIII and XXXIX, pages 115 and 116).

THE POTATO(Solanum tuberosum).--The same variety of the potato was used, for the experimant, in all of the four soils. The portions of the tubers planted, were as nearly as possible of a like size pieces from one-half to three-fourths of an inch in thickness including two eyes. They were planted in the different soils into six inch pots, December 14, 1909. The plants came up in each soil, at about the same time, April 1, 1910. Their growth was very nearly alike in all of the four soils. Towards the end, however, the plant in the Palouse soil grew a little higher than the plants growing in the other soils. The stalks produced by the coniferous and old sawdust soils were thicker and more vigorous than those nourished by the Palouse soil and the new sawdust soil. The color of the stalks and leaves of the plants in the old sawdust soil and in the coniferous soil was of a much darker green than of those in the other two soils. For root system and tubers formed see description of Plate No. XLIII, page 122.

TOMATO SEED AND TOMATO PLANT(Lycopersicum esculentum).--The four soils, in six inch pots,as usual, received the tomato seed sown December 11, 1909. The seeds germinated and showed their first leaves above the soil January 10, 1910. There was no difference in point of time of germination of the seeds in the different soils. After germination, however, the plants in the Palouse soil took the lead in growth and ketp it until the end of the experiment. Five plants were left for growth in each pot. The plants in the coniferous and old sawdust soils were darker green in color than the plants in the new sawdust and Palouse soils.

Root Systems.

The roots of the plants in the Palouse soil were small, numerous, and of a fine texture, while those of the plants in the other three soils were coarse, few and large. No difference appeared in the color of the roots of the plants in the different soils.

The tomato plants illustrated were plants that had been grown in three inch pots. They were of about the same size and quality. These plants were transplanted into six inch pots in the four different soils. Their subsequent behavior was similar to that of the plants raised from seed as described. For further explanation see Plate No. VI, page 70, and Plate No. XI, page 76.

THE BEANS(Leguminosae).--Four six inch pots each filled with a different one of the four soils were used for the sowing of the bean seed, December 11, 1909. This seed failed to come up in any of the soils. Another sowing was made on January 24, 1910. This last seed germinated and the plants appeared in all of the four soils at about the same time. Two plants were left in each pot. The growth differed little, if at all in the soils, throughout the experiment.

Root Systems.

The root system of the plants in the coniferous soil was larger than that of the plants in the other soils. The roots developed in the coniferous soil showed more and larger nitrogen fixing nodules.

The plants illustrated show a difference in respect to one soil, the new sawdust soil, in which the growth is less vigorous. See description of Plate XXIII, page 92.

THE RADISH(Raphanus sativus).--The radish seed was sown in the four different soils, each soil in the usual six inch pot, December 11, 1909. The seed in the Palouse soil germinated on the sixteenth of December and that planted in the other soils about two days later. The plants were thinned out, three only being left to grow in each pot. The growth in respect to the top part of the plants varied somewhat in the different soils; the plants in the Palouse soil took the lead, the others ranking as follows: those in the old sawdust soil second, in the new sawdust third, and in the coniferous fourth.

For description of the root systems of the radish in the different soils see description of Plates Nos. XXX and XXXI, pages 103 and 104.

LETTUCE (Lactuca Sativa).--Lettuce seed of the same variety was made use of in the experiment. It was sown in the four soils contained in the same sized pots, six inch found best adapted to most of the other seeds planted. The date of the sowing of the lettuce seed was December 12, 1909. On December 18, the new born plants pushed their way to the surface through all the four soils alike. Later their progress, in the different soils, became very different. In the coniferous and new sawdust soils the plants made very little growth. In the Palouse soil, on the other hand, the plants flourished and made a strong and vigorous growth. The plants in the old sawdust soil were second in ratio of development.

The description of the root systems is given in the description of the Plates XXVIII, and XXIX, pages 100 and 101

THE CARROT(Daucus carrota).--The carrot seed was planted at the same time and subjected to treatment similar to that given to the lettuce seed. The germination of the seed, and the subsequent development of the plants in the four different soils in likenesses and differences so nearly resembled like processes in the lettuce that a detailed account of the growth of the carrot above ground need not be given here.

The root systems of the carrot in the four soils are included in the description of the Plates Nos. XXXVI and XXXVII, pages 97 and 98.

THE HAIRY VETCH(Vicia villesa).--Again, as with the other vegetable seed with which experiments were made, the seed of the hairy vetch was sown into the four soils filled into six inch pots. This seed was sown December 14, 1909. Three weeks were required for its germination which took place January 6, 1910. The plants came up in all of the soils, with no apparent differences, and at the same time. They made, at first very slow growth. When the plants were thinned three were left to each soil. After a month or more all of the plants made a noticeably quicker growth. This growth was about equal in amount in all of the four soils, with possibly a trifling difference in favor of the coniferous soil.

Root Systems.

The roots of the vetch plants in the coniferous soil produced larger and more numerous nitrogen fixing nodules than the roots in the other soils. For more complete description see Plate No. XVIII, page 86.

THE WHEAT, OATS AND BARLEY(Triticum vulgare, Avena sativa, and hordeum)--These three grains were sown into the four different soils on December 11, 1909. For the use of the experiment with each kind of these small grains, as with the vegetable seeds, six inch pots seemed most suitable. The grains of all three kinds, sprouted and found their way through all of the four soils respectively, at about the same date, December 18, 1909. In their first growth the three kinds of plants displayed little difference in any of the soils, or in all of the soils. After this the plants were thinned out five only being left to each pot. In subsequent growth a change in their relative progress was manifested. The barley now took the lead, the oats followed second in order, and the wheat ranked third. With all of them the Palouse soil proved most favorable to their growth, the old sawdust ranking second, the new sawdust third, and the coniferous soil fourth. Of the three grains the barley matured first. And in correspondence with its growth in the different soils, the barley matured first in the Palouse soil, second in the old sawdust soil, third in the new sawdust soil, and last of all in the coniferous soil. The oats followed the barley in point of time of maturity, and in the same rotation as to the soils. The wheat was a little longer than either of the other grains in maturing, but followed the same rotation in time in the different soils.

Root Systems.

The roots of these three grain plants in the coniferous soil were alike coarse, large and few in number. In the Palouse soil the roots of all were fine, small and numerous. The color of the roots was the same in all of the four soils. For further account of the barley plants see description of Plates Nos. XXIV and XXV, pages 94 and 95. For oats and wheat plants see description of Plates Nos. XXVI and XXVII, pages 97 and 98.

THE CORN(Zea mays).--The corn was planted also on December 11, 1909. Six inch pots filled with the four soils were used. The seed germinated and the plants showed themselves January 2, 1910. The seed would have germinated, probably, somewhat earlier had it been subjected to greater heat. No difference was shown in this first process in the different soils. The seed not only came up in all the soils at the same time, but the first growth of the plants differed little. The plants were thinned out to three stocks to each pot. For some time afterward the growth in the different soils continued the same. When three weeks had passed, however, a marked difference mainfested itself between the plants in the Palouse soil and those in the other three soils. The ratio of growth in these three remaining soils differed also. The plants in the old sawdust soil making the next best progress to those in the Palouse soil, those in the coniferous soil coming third in order of growth and in the new sawdust soil fourth.

Root Systems.

The roots of the plants in the Palouse soil were much finer, smaller and more numerous than the roots in the old sawdust or coniferous soils. In the old sawdust, coniferous, and new sawdust soils, the roots were very much alike. For more detailed description of the corn plant growth and the effect of the differant soils see Plate No. XVII, page 85.

THE ALFALFA AND WHITE CLOVER(Madicago sativa, Trifolium repens).--For the experiments with these two leguminous plants six inch pots were again used. The seeds were sown into the four soils December 11, 1909. Both kinds of seed germinated seven days after they were sown, the plants appearing above ground in all soils alike, December 18, 1909. With one exception the plants showed little or no difference in point of growth in any of the four soils. The alfalfa plants were a little less vigorous in the coniferous soil than in the other three soils.

Root Systems.

The root systems of both the alfalfa and the white clover showed that in all of the four soils that nitrogen is fixed from the air by the nitrogen fixing nodules. In both kinds of plants the nodules were more numerous and larger on the roots in the coniferous soil than on those growing in the other three soils. The roots of the plants in the coniferous and old sawdust soil were larger and coarser than those of the plants in the other two soils. For further details see descriptions of Plates Nos. XV and XVI, pages 82 and 83.

THE FIELD VETCH(Vivia sativa).--In the experiment with the field vetch the same procedure was followed as that used in planting the field pea and the hairy vetch. The same time for germination was required for the seed of the field vetch as was noted in the field pea about seven days. The subsequent growth like that of the field pea did not vary greatly in the different soils, though it seemed to be slightly better in the coniferous soil. The root systems were the same as those observed in the field pea. See Plate No. XIII, page 79 and description.

THE CABBAGE AND PARSNIP(Brassica oleracea and Pastinaca sativa).--The seeds of the Cabbage and parsnip were sown into the four soils, December 11, 1909. Six inch pots as usual, received the seed, in the different soils with which they were filled. In each pot the seeds germinated in nine days. Many plants appeared, but they were thinned to five in each soil. These continued to grow with more or less vigor in all of the soils. The relative progress was about the same in both vegetables. Both made the best growth in the Palouse soil. The old sawdust soil proved to be second in its adaptability to the development of these plants, the new sawdust third, and the coniferous fourth. This ratio continued throughout the growth of the plants until the end of the experiment. The root systems of the cabbage and parsnip as produced in the experiments are given in the descriptions of Plates Nos. XXXII and XXXIII, pages 106-1(and Plates Nos. XXXIV and XXXV, pages 109 and 110.

CELERY(Apium graveolens).--The seeds of the celery were sown under conditions like those to which the seeds of the Alfalfa were subjected, and the sowing was similar in manner to that of the latter. The date of the sowing was December 11, 1909. The process of germination was very slow. More than a month passed before any of the celery plants appeared. The germination of the seeds, however, took place at about the same time in all of the four soils, January 14, 1910.

The plants were not thinned out. Their after growth showed some variation in the different soils. Again, the Palouse soil produced the most vigorous plants, while the old sawdust soil again ranked second in respect to the growth of the plants. The third best plants were developed in the coniferous soil. The new sawdust soil grew the poorest of the celery plants. In the old sawdust and coniferous soils the color of the plants was of a darker green than that of the plants in the Palouse and new sawdust soils.

Root Systems.

The roots of the plants in the Palouse soil were short, fine, and slender, but numerous. The plants in the coniferous and old sawdust soils had few roots and these were long and coarse or large. The roots of the plants in the new sawdust soil were of medium size, yet rather large than small, but were few in number. The color of the roots was alike in all, without regard to the character of the soil. See Plate No. XIX, page 88.

THE SQUASH(cucurbita).--The squash seed was planted in the four soils, in six inch pots, December 11, 1909. A month passed and no plants appeared. As the first seeds failed to germinate a second trial was made January 10, 1910. The seeds then planted came up on February 8, 1910. The time required for germination was the same in all the four soils. Two plants were left in each pot. A considerable variation was shown in the subsequent growth of the plants in the different soils. The Palouse soil as usual, took the lead, producing much more vigorous plants than these produced by the other soils. Next to the Palouse soil for the best growth of the squash came the new sawdust soil, the old sawdust and coniferous soils ranking third and fourth respectively.

Root Systems.

The roots of the plants in the Palouse soil were small, fine and numerous. In the coniferous soil the roots of the plants were coarse, large, and few. In color no difference was shown in the roots of the plants in the different soils. See Plate No. VIII, page 73.

THE APPLE SEED(Pyrus malus).--The seeds used for the experiment were taken, in the Fall of the year, from apples raised in the Washington State College. They were planted in the four different soils, each soil in its own six inch pot, December 11, 1909. The seeds germinated and the first seedlings came up through the soil February 3, 1910. The seeds in the coniferous soil made slightly better time in germination than was made by the seeds in the other soils, and in that soil the first seedlings appeared. In each pot, after the necessary thinning-out process, four plants were left for growth. The subsequent growth of the little trees was about the same in all of the four soils.

Root Systems.

The roots of the apple seedlings in the Palouse soil were small, fine and numerous; in the other three soils they were fewer in number, coarse in texture and much larger in size. A slight difference in color was shown in the different soils; the roots in the Palouse soil were yellowish in color; the roots in the coniferous soil were dark gray. See Plate No. XIX, page 88.

THE STRAWBERRY PLANT(fragaria).--The strawberry plants were taken from the Washington State College orchard on December 16, 1909, and planted into the four soils in six inch pots. The root systems of the four plants were about the same. The plant in the coniferous soil began to grow, putting forth new leaves, February 2, 1910. The plants in the other soils lagged behind ten days longer. When they began to grow, however, they kept up with the plant in the coniferous soil in all subsequent growth, which was nearly alike in all of the soils. The first runner, however, was put forth by the plant in the Palouse soil. The only other variation in the plants, above ground, was in the color of the leaves which were darker on the plants growing in the coniferous and old sawdust soils.

Root Systems.

While the strawberry plants appeared to be so nearly alike, there was a marked difference in the root system of the plant in the Palouse soil and that of the plant in the coniferous soil. The roots of the plant in the coniferous soil, and also those of the plant in the old sawdust soil, were few, large, and very coarse in texture. The roots of the plant in the Palouse soil were numerous, small, and fine in texture. The roots of the plant in the new sawdust soil resembled those of the plants in the Palouse soil. In the coniferous and old sawdust soils the color of the roots were alike, a dark brown. The roots of the plants in both the Palouse and the new sawdust soils were of a yellowish color. See Plate, XX, page 89.

THE GERANIUM PLANT(Geraniaceae).--For the experiment with the geranium, plants were taken from three inch pots in which they had been growing and transplanted into six inch pots into which the different soils, as usual, had been filled. The transplanting was done December 13, 1909. Plants had been selected of as nearly as possible the same size, and of a like vigor of growth, and of the same variety, for planting in each soil.

From the beginning to the end of the experiment the plant in the Palouse soil made a much more vigorous growth than was at any time reached by the plants in the other three soils. In this point of growth the plant in the old sawdust soil was second best, while the plant in the coniferous soil ranked third, and that in the new sawdust soil was last in order of excellence. The foliage of the plants in the Palouse and new sawdust soils contrasted very strongly with the foliage of the plants in the coniferous and old sawdust soils. In the first two the leaves and stems were very light in color; in the last two the foliage was of a darker green. The plants in the Palouse and coniferous soils produced flowers that were in all respects perfect. The flowers on the plants in the old sawdust and new sawdust soils were, on the other hand, incompletely developed and imperfect.

Root Systems.

The same differences in the root systems in different soils noticed in many of the plants which have been described, were seen in the root systems of the geranium plants. The roots of the plant in the Palouse soil were fine in texture, small in size, and many in number; those of the plants in the coniferous, old sawdust and new sawdust soils were coarse in texture, large in size and few in number. The color of the roots as developed in the four soils was in all very nearly alike. See Plate No. V, page 68.

THE ROSE PLANT(Rosacae).---The rose plants used in the experiment were taken from two inch pots in which they had been planted as cuttings. They were healthy plants of about equal size and alike in development or growth. They were planted into the four soils, contained the same sized pots most commonly used in the investigation, six inch, December 13, 1909. None of the plants made a very strong growth during the winter. There was some difference, however, in the progress they made in the different soils; it was observed that the plant in the coniferous soil grew more vigorously than the plants in the other soils. The leaves of the plant in the coniferous soil, moreover, looked healthier and were of a darker green color than the leaves of the plants in the Palouse soil, the old sawdust soil, or the new sawdust soil.

Root Systems.

The root system of the rose plant in the coniferous soil was very well developed, but the roots were few in number and these large in size and coarse in texture. The root systems of the plants in the other soils consisted of small roots, also few in number, but of a finer type than these developed in the coniferous soil. See Plate No. XXI, page 91.

CONCLUSIONS REACHED AND RESULTS OBTAINED.

In summing up the results of the experiments to determine the value of Yellow Pine or Jack Pine soil for plant growth a few prominent facts become manifest, and it seems most obvious that upon these facts it is proper to base all conclusions.

First, the experiments show that plants of the leguminousae family do well in the coniferous evergreen soil. The same plants make good growth also in the old decayed sawdust soil and in the new sawdust soil. In this connection the peculiar feature of the leguminosae family is brought to the front; plants of this family alone are capable of supplying their own nitrogen.

Second, plants which are not capable of supplying their own nitrogen, and which find it necessary to absorb a great deal of nitrogen in satisfactory growth, do not do well in the coniferous soils. These same plants, under the same conditions, thrive in Palouse soil, which soil is specially well-known for its fertility, the possession of a large amount of available plant food. This difference of growth in the two kinds of soil seems to prove conclusively that coniferous soils are to a large extent devoid of available nitrogen as a plant food.

Third, the experiments showed that the leguminous plants such as the clovers, locust, peas, vetches and beans, made as good a growth in the coniferous soil as in the Palouse soil. In some instances the growth of the plants of this family was better in the Yellow pine or coniferous soils than in the Palouse soil. This fact proves that, nitrogen excepted, all other plant foods are present in sufficiently available quantities in the evergreen coniferous soil. For illustration of this conclusion see Plate No. XXIII, page 92.

Again these facts find the same strong proof in the results of the study of the root systems of the different plants. Very slight difference is shown between certain vegetation that builds up its substance in the root, as in the radish, parsnip, carrot, beet and other like root developing plants, and certain other vegetation that makes its greatest and most important growth above ground, as in such vegetables as the cabbage, tomatoes, lettuce and the grains--all great consumers of nitrogen. In these two kinds of vegetation, so notably unlike in the manner of their growth, where the root system is concerned, the results of the experiments prove that nitrogen is lacking in the coniferous soils, while an abundance of plant food is present in the Palouse soil.

The experiments show that the vegetation grown in the old decayed sawdust soil and also that in the coniferous soil was of a darker green color than the vegetation grown in the other soils. This difference was due, no doubt, to the humus and the available amount of potash present in the coniferous and old sawdust soils. The specially vigorous growth of the trees and the potatoes, as well as the fine growth of the leguminous plants in these soils may be attributed to the comparatively larger quantities of potash and to the phosphoric acid present in them.

The horticultural trees made as good, if not better growth in the humus soil of the needle leaf or old sawdust, as in the Palouse soil. This fact proves that there is a sufficient amount of plant food in this humus soil for the sustenance and growth of these trees. It proves, moreover, that the lack of nitrogen is of less importance in the growth of fruit trees than the lack of potash and phosphoric acid, two food elements which are abundant and available in the coniferous soils. These conditions observed in the experiments with the horticultural fruit trees, obtained also in the growth of forest or landscape gardening trees, maples, oaks, locusts, ashes and others, and the same conclusions are warranted; that in their cultivation of growth; the absence of potash and phosphorus in the soil counts for much more than the absence of nitrogen; and, therefore, that the coniferous soils in which these elements are plentiful, though nitrogen is wanting, are adapted to the growth of forest as well as fruit trees.

For a long time it has been supposed that coniferous soils had in them some poisonous substances in the form of acids, resin and oils. That idea had not held good in the experiments followed in this investigation. It has been demonstrated that not only do trees and other plants which require little or no nitrogen, but plenty of potash and phosphoric acid grow vigorously in the coniferous evergreen soils, but that trees and plants which supply their own nitrogen flourish in these soils. More than that, these same trees and plants able to supply their own nitrogen do as well in the coniferous soil as they do in a soil like the Palouse-rich in food elements, containing no poisons, and devoid of humus. In some cases such trees and plants have done better in the coniferous than in the Palouse soil.

There can be no doubt that the old saying "Fertility is more than soil" has been abundantly evidenced and has gained some strength in these experiments. It must be borne in mind, the fact cannot be expressed too often or too emphatically, that fertility is more than mere abundance of plant food. Fertility takes into consideration humus, climate, water and tillage.

PRACTICAL IMPORTANCE OF THE
EXPERIMENTS.

If the conclusions reached through the results of these experiments are correct, they cannot fail to be of vast importance in practical application in the great North-west, the Michigan pineriet and in many sections of the North-east, where the forests are composed chiefly of evergreen trees. The investigation into the uses of coniferous evergreen soil seems to have proved beyond peradventure its great latent possibilities for certain horticultural and agricultural purposes. The results of the experiments offer a solution of the great, much discussed question, "What profitable use can be made of the logged off lands and the cut over lands while the stumps are decaying?"

Other careful students have come to similar conclusions, as to the use of these lands, but from a different standpoint. They have realized that the stumps cannot be removed in any practicable way and suggest that these lands be made of present use for dairying and fruit-raising purposes.

In these experiments the soil has been analysed in a chemical way and it has been found that grasses and trees can find abundant nourishment in most of these coniferous soils. By the actual growth of all manner of vegetables in those soils under like conditions it has been conclusively proved that grasses, aside from grains and cereals, and fruit trees are, of all vegetation, the best adapted for culture in coniferous evergreen soils.

The chemical analysis of evergreen coniferous soil from many parts of the North-western country and the Eastern and Southern pineriet shows that the amount of nitrogen available is very small in all cases, while the total amount present may still be large enough for crop growth.

A general theory, which has been held for a long time and is still believed, is that trees enrich the soil through the falling of their leaves; that these fallen leaves producing humus, supply nitrogen. This theory is contradicted, however, in its application to the coniferous species of trees. Investigation discloses the fact that coniferous trees use up the nitrogen as fast as it is produced. Nothing, therefore, can be added by these trees to the soil except what may be given by old or decayed wood after the land has been logged off. If refuse were allowed to decay slowly on the logged off land, and if there should be no more forest growth or growth of any kind, the land would become rich in nitrogen for future plant growth. In most cases this fortunate condition is not permitted. In many places fire sweeps over the land again and again, burning up or destroying the nitrogen. Often water washes the nitrogen to the seas. Not infrequently, a second growth springs up which finds nourishment in the decayed or decaying material, and absorbs the nitrogen as fast as it is produced and made available.

It would seem to be the part of wisdom, therefore to plant these logged-off and cut-over areas in trees which do not require for their growth a large amount of available nitrogen, and in such grasses and forage plants as are able to do without much or any nitrogen that must come from the soil.

It has been proved that all plants of the Leguminosae family will do well on all such land if moisture is present in sufficient quantity.

The leguminous plants, moreover, will enrich the soil, and never deplete it, and if in later years other crops should be planted there, there would be an assurance of an abundant harvest.

In the course of years the old stumps will disappear and in their place the logged-off land, properly used, will be covered with fine fruit trees or meadows of great fertility.

It may again be repeated that the common belief that coniferous soil has been made poisonous through the presence of turpentine, pitch, rosin, and similar substances, has long been exploded. The experiments connected with this investigation, as has already been said, prove indisputably that leguminous plants grow not only as well, but even better in coniferous soil as in any other under like climatic conditions.

It is safe to predict a great future for these lands and great financial success for men who use them for fruit raising or turn them into dairies large or small.

As a rule these coniferous soils are porous enough, and the land they compose is sufficiently well drained to make good fruit farms under favorable climatic conditions.

It is true, failures have been reported in respect to the growth of legumes on coniferous soils. These failures have been for the most part a question of moisture. In some cases the moisture from above has not been sufficient; in others the ground has been left so loose that there could be no capillarity from below. Newly cleared land containing a large amount of undecayed humus must be packed solid, or plowed deeply that enough sub-soil may be brought up to mix with the top soil and thereby insure capillarity.

The chemical analysis of the evergreen coniferous soils showed that they include in their composition a sufficient amount of all kinds of plant food. What per cent of these food elements was available for plant food could only be ascertained by actual experiment with a variety of vegetation planted into these soils under like climatic conditions. This experiment has been made, as detailed in this thesis, and the fact that only a small per cent of plant food in the coniferous soils is available, has been determined. In short it has been proved, that, with the exception of certain grasses, leguminous plants and fruit trees, coniferous soils do not furnish enough available plant food for plant growth, or for the cultivation of crops in general. The exceptions, however, are sufficient to show the great possible value of coniferous soils for agricultural and horticultural purposes.

The importance of the experiments as shown in the conclusions reached in reference to fruit culture in coniferous soils finds confirmation in the following testimony of Professor L. F. Henderson:--

"There is no doubt that an admixture of pine needles improves the soil for tree growth. I have seen that on my ranch near Moscow, and again on my ranch at Hood River. Most persons have a theory that raw land into which quantities of needles have been plowed is bad for fruit trees, shows 'too much resin', 'too drying,' etc., but it is all bosh. Newly cleared land at Hood River last year grew the finest young trees any one had seen, and on my place was no irrigation. It is the same thing on my Moscow ranch. It seems that the consequent addition of humus is just what the young trees want. I have heard of people living in the peach belt of New Jersey going miles to get pine needles with which to enrich their peach orchards."

THE HORTICULTURAL AND AGRICULTURAL USE OF YELLOW PINE CONIFEROUS SOILS.

The results of the experiments to ascertain the use, if any, of the evergreen yellow pine coniferous soils for horticultural and agricultural purposes may be summed up as follows:

First, In all cases where the climate and moisture conditions are suitable, trees and plants which require very little immediately available nitrogen may be planted and raised successfully in the evergreen coniferous yellow pine, Jack and red pine soils.

This promise having been positively established, the following recommendations may be confidently accepted and put into practice:

(A)--That fruit trees of all kinds, such as apple, peach, pear, plum, cherry, quince, and nut trees of various kinds be planted in evergreen coniferous Yellow Pine soils. They may be expected to do well if as has been said, climate and moisture conditions are favorable and a small amount of fertilizer is used.

(B)--That evergreen coniferous soils be made use of for the culture of all kinds of berry crops, strawberries, loganberries, raspberries, blackberries, currants and others. These may be grown successfully in evergreen coniferous soils under the favorable conditions referred to in connection with the raising of fruit trees in these soils.

(C)--That if the locality and situation provide the proper climatic conditions and the necessary moisture, trees of the leguminosae family and any others so constituted as to be able to supply their own nitrogen, be planted in coniferous yellow pine soils. A specially insistent recommendation may be given for the use of these soils for those trees which are able to supply their own nitrogen as they will not only be highly adaptable for cultivation, but will add greatly to the value of the land. That is, they will give back to the soil ingredients for its enrichment, and make it ready for future crops that demand ready or available nitrogen for successful cultivation.

Second,

(A)--If climatic and moisture conditions are suitable there is no reason why such plants as the beans, vetches, clovers, peas and all other forage plants or garden vegetables, belonging to the leguminosae family, should not grow well in coniferous evergreen soil. The experiments have demonstrated the fact that these classes of plants are as well adapted to growth in the coniferous as in the Palouse soil. Indeed the burden of proof seems to be that they are better adapted for growth in the Yellow pine soils than in the Palouse or any other soil. It would be the province of these leguminous vegetables also, in that they have the faculty of absorbing their own nitrogen, to enrich the soil for other future crops of a different nature.

(B)--The plants which have little need of available nitrogen, but which cannot flourish without potash and humus, such as potatoes, strawberries, and other berry plants, can be recommended for culture in evergreen coniferous yellow pine soils, provided, as in the case of fruit trees, of berries, and of leguminous trees and plants, climatic conditions are favorable.

Third, on the other hand, plants which require a large amount of ready available nitrogen, or plant food, cannot be recommended for cultivation in coniferous evergreen soils. These plants include the corn, the grains, such as oats, barley and wheat, and nearly all nonleguminous vegetables, or garden plants, such as the tomato, radish, celery, cabbage, lettuce, parsnips, carrots, squash, and others. These cannot be expected to do well in the coniferous yellow pine soils which the experiments show do not furnish them the amount and kind of plant food they need for successful growth.

In conclusion, it may be said, that while the investigation has been thorough, and as far as possible exhaustive, it would be presumption to claim from it a complete solution of the question of the practical use of coniferous evergreen soils. Many facts in regard to the behavior of a comparatively wide range of plants in these soils have been made clearer, but the question of soil fertility, whether of coniferous yellow pine or other soils, is too great to be solved by one series of experiments covering but one year, or perhaps even by repeated experiments involving the labor of many years. The absolute value of these soils for fruit production alone demands an investigation directed specifically to that branch of the subject, and if undertaken, will require the study, observation and experience of years for the full and satisfactory solution of the question of the horticultural use of coniferous evergreen pine soils.

It is hoped that at some future time this thesis, which has dealt with the subject in a somewhat general way may be followed by another, covering the results of an investigation of the value of coniferous evergreen soils for the specific purpose of fruit production.

C. A. [illegible]

GENERAL DESCRIPTION OF THE PLATES.

In the descriptions of the growth of the trees, it is granted that the first growth of the leaves and part of the stems may have come from the stored up food, yet later growth shows the influence of the different soils.

DESCRIPTION OF PLATE NO. 1.

Hard Maple (Acer saccharum).

The illustration clearly shows that the tree in pot No. 2 is the most vigorous. The leafage on it is heavy, while on the contrary, the tree in pot No. 1 in the Palouse soil, has developed very few leaves. The tree in pot No. 2, in the coniferous soil, has also produced a number of young shoots. The tree in the Palouse soil has developed but one shoot. The leaves of the tree in the Palouse soil, it will be seen, are larger than the leaves on the tree in the coniferous soil. The reason for this difference in the size of the leaves may no doubt be sufficiently accounted for by the fact that the growth in the one tree is confined to one shoot, while in the other it is distributed among many shoots.

PLATE NO. 1---MAPLE.

Palouse Soil No. 1.
Coniferous Soil No. 2.

DESCRIPTION OF PLATES NOS. 2 and 3.

The Pear (Pyrus communis).
The Apple (Pyrus malus).

The pear tree in the coniferous soil, pot No. 2, shows a slight tendency toward the development of larger number of leaves, otherwise the two trees have made an equal growth in their different soils.

The apple tree, as illustrated in Plate No. 3, reached a greater height in the coniferous soil, pot No. 2, but its companion in the Palouse soil attained a greater amount of leaf surface. Otherwise, the two trees display little difference in development in the two soils.

PLATE NO. 2---PEAR.

Palouse Soil No. 1.
Coniferous Soil No. 2

PLATE NO. 3---APPLE.

Palouse Soil No. 1.
Coniferous Soil No. 2.

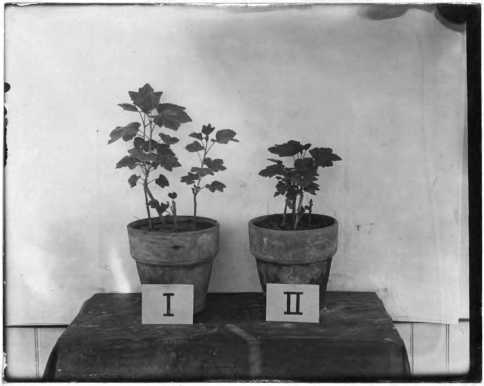
DESCRIPTION OF PLATES NOS. 4 and 5.

The Currants (Ribes).
The Geraniums (Geraniaceae).

Plate No. 4 illustrates the growth made by the currant plants in the two soils. The plant in the Palouse soil, pot No. 1, made a somewhat better growth in height than was made by the plant in the coniferous soil. The plant in the latter soil, however, as may be noted in the illustration, is more bushy. These differences which about equalize each other, may be said to indicate an equality of growth in the two soils.

Plate No. 5 shows the geranium as grown in the four soils. A glance at the illustration is sufficient to show the great superiority of the growth made by the plant in the Palouse soil, pot No. 1. This will be made more emphatic when it is remembered that the four plants were of the same height and variety when planted, on the same date, and that they were developed under like moisture and climatic conditions.

PLATE NO. 4---CURRANTS.



Palouse Soil No. 1.
Coniferous Soil No. 2.

PLATE NO. 5---GERANIUMS.

Palouse Soil No. 1.
Coniferous Soil No. 2.
Old Sawdust Soil No.3.
New Sawdust Soil No.4.

DESCRIPTION OF PLATES Nos. 6 and 7.

Tomato from seed (Sycopersicum esculentum).
Locust seedlings (Robinia pseudacacia).

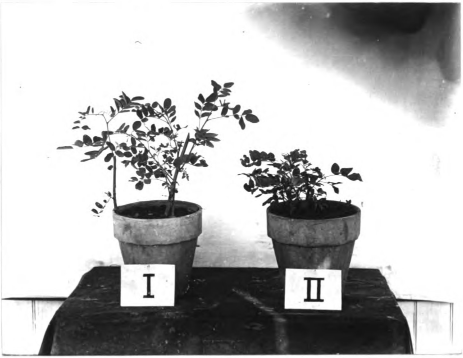
The illustration and comparison of the plants pictured show plainly that the Palouse soil is well adapted to the growth of the tomato. The plant in pot No. 1, in the Palouse soil, has reached nearly twice the height of the plant in pot No. 2, in the old sawdust soil. The plant in the old sawdust soil, however, has made a fair growth, but the plants in the coniferous and new sawdust soils, pots Nos. 3 and 4 seem to show conclusively that these soils are not suited to tomato culture.

The locust in the Palouse soil, as shown in pot No. 1, grew taller than its mate planted in the coniferous soil, pot No. 2. The latter plant produced more branches and was bushier, than the plant in the Palouse soil. Otherwise the growth of the two trees, as can be seen in Plate 7 was much the same.

PLATE NO. 6---TOMATO---FROM SEED.

Palouse	Soil No. 1.
Old Sawdust	Soil No. 2.
Coniferous	Soil No. 3.
New Sawdust	Soil No. 4.

PLATE NO. 7---LOCUST SEEDLINGS.



Palouse Soil No. 1.
Coniferous Soil No. 2.

DESCRIPTION OF PLATES NOS. 8 and 9.

The Squash (Cucurbita)
The Apple Seedlings (Pyrus malus)

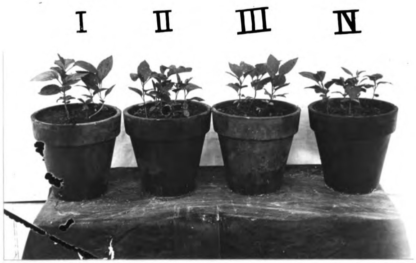
The growth of the squash in the Palouse and old sawdust soils, pots No. 1 and No. 2, is seen to be about the same. The plants in the new sawdust soil and in the coniferous soil, pots Nos. 3 and 4, are paired in like manner or show about equal growth. The leaves are alike with the exception of those on the plant in the old sawdust soil, pot No. 2, which are shown to be a little larger than those on the plants in pots Nos. 1, 3 and 4.

The growth of the apple seedlings, as pictured in Plate 9, has very little variation in the four soils. Pot No. 1, shows that the plant in the Palouse soil reached a slightly better growth in height.

PLATE NO. 8---SQUASH.

Palouse	Soil No. 1.
Old Sawdust	Soil No. 2.
New Sawdust	Soil No. 3.
Coniferous	Soil No. 4.

PLATE NO. 9---APPLE SEEDLINGS.



Palouse	Soil No. 1.
Old Sawdust	Soil No. 2.
New Sawdust	Soil No. 3.
Coniferous	Soil No. 4.

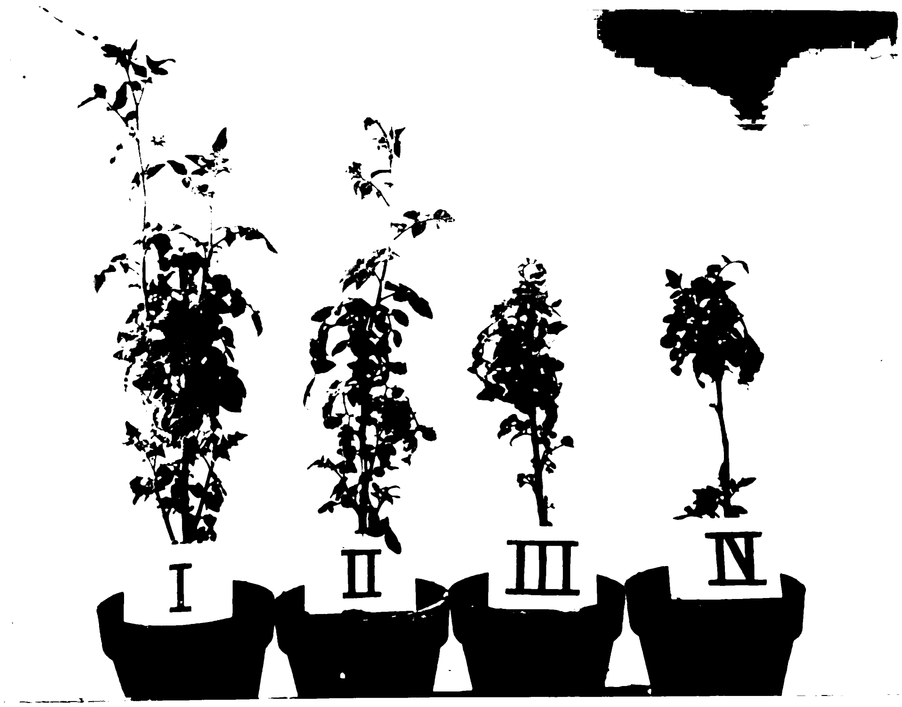
DESCRIPTION OF PLATES NOS. 11 and 12.

Tomato Plants (Lycopersicum esculentum)
Potato Seed (Solanum tuberosum)

The tomato plant in pot No. 1, Palouse soil, shows the best growth. Not far behind it in growth, as illustrate is the plant in pot No. 2, produced in the old sawdust soil. The other two plants, in pots 3 and 4, give evidence of small growth, by comparison, since all were of equal height when they were planted.

The potato plant in pot No. 1 is the highest of the four plants, yet not much higher than the plant in pot No. 2. The plants in pots No. 3 and 4 show thicker stalks than those in pots No. 1 and No. 2. The differences seem, however, to balance each other, and the plants, as can be clearly seen in the illustration, are in a thrifty growing condition.

PLATE NO. 11---TOMATO PLANTS.



Palouse	Soil No. 1.
Old Sawdust	Soil No. 2.
New Sawdust	Soil No. 3.
Coniferous	Soil No. 4.

PLATE NO. 12---POTATO.

Palouse Soil No. 1.
Old Sawdust Soil No. 2.
New Sawdust Soil No. 3.
Coniferous Soil No. 4.

DESCRIPTION OF PLATES NOS. 13 and 14.

The Field Vetch (*Vicia sativa*)
The Field Pea (*Pisum sativum*)

The vetch in pot No. 1, which was grown in conifero soil, displays a fine growth including the development of a large number of pods. The plants in pots No. 3 and No. 4, grown in Palouse and new sawdust soil, are about equal in size. The plant in pot No. 2, grown in old sawdust soil, is the smallest of the four plants, and shows very few pods.

The field vetch in the coniferous soil, in pot No. 4, represents the most vigorous growth made by the four plants in the different soils. The illustration, however, shows but little variation in growth in the different soils.

PLATE NO. 13---FIELD VETCH.

Coniferous Soil No. 1.
Old Sawdust Soil No. 2.
Palouse Soil No. 3.
New Sawdust Soil No. 4.

PLATE NO. 14---FIELD PEA.

Palouse	Soil No. 1.
Old Sawdust	Soil No. 2.
New Sawdust	Soil No. 3.
Coniferous	Soil No. 4.

DESCRIPTION OF PLATES NOS. 15 and 16.

Alfalfa (Medicage sativa)
White Clover (Trifolium repens)

The alfalfa in the coniferous soil did not do as well as was expected of a leguminous plant which gathers its own nitrogen. The reason for its failure to make as good a growth in that soil as in the other three soils is difficult to explain. The plants in the Palouse, old sawdust, and new sawdust soils, shown in pots Nos. 1, 2 and 3, by their apparently equal growth demonstrate a like suitability of these soils for alfalfa culture.

The white clover, as Plate 16 shows, did equally well in all of the four soils. It may be more strictly true to say that the plants in the new sawdust soil were a little less vigorous than the plants in the other three soils, but the difference would scarcely attract notice.

PLATE NO. 15---ALFALFA.

Palouse Soil No. 1.
Old Sawdust Soil No. 2.
New Sawdust Soil No. 3.
Coniferous Soil No. 4.

PLATE NO. 16---WHITE CLOVER.

Palouse Soil No. 1.
Old Sawdust Soil No. 2.
New Sawdust Soil No. 3.
Coniferous Soil No. 4.

DESCRIPTION OF PLATES NOS. 17 and 18.

The Corn (Zea mays)
The Hairy Vetch (Vicia sativa)

The corn plants made the made vigorous growth in the Palouse soil, pot No. 1. The plants in the coniferous soil, pot No. 4, did not do well. And the influence of the one-third per cent of coniferous soil is shown in the illustration of the plants grown in pots Nos. 2 and 3, which meant that there was just that amount less of available food for their growth.

The illustration of the vetch are self-explanatory. The plants show the same growth in all the four soils, with possibly a little weight in favor of those in the coniferous and Palouse soils.

PLATE NO. 19---CELERY.

Palouse Soil No. 1.
Old Sawdust Soil No. 2.
Coniferous Soil No. 3.
New Sawdust Soil No. 4.

PLATE NO. 20---STRAWBERRY.

Palouse Soil No. 1.
Old Sawdust Soil No. 2.
New Sawdust Soil No. 3.
Coniferous Soil No. 4.

DESCRIPTION OF PLATES NOS. 21 and 23.

The Rose (Rosaceae)
The Bean (Leguminosae)

The plate makes clear the fact that the coniferous soil, used pot 1, is well adapted to rose culture. In the new sawdust and old sawdust soils the plants are seen to be less vigorous, than the plant in the coniferous soil, althou[gh] their growth is fair. The Palouse soil, used in pot 4, by its poorly developed plant proves itself, on the contrary, wholly unsuited to the growth of roses.

The bean plants seemed to be in their proper elem[ent] in the Palouse, old sawdust and coniferous soils, as pictured on Plate No. 23, pots Nos. 1, 2 and 3. The plant in pot 4, on the contrary, made a slow growth, and its color was of a light, sickly-looking yellow.

PLATE NO. 21---ROSE.

Coniferous Soil No. 1.
New Sawdust Soil No. 2.
Old Sawdust Soil No. 3.
Palouse Soil No. 4.

PLATE NO. 23---BEAN.

Palouse	Soil No. 1.
Old Sawdust	Soil No. 2.
Coniferous	Soil No. 3.
New Sawdust	Soil No. 4.

DESCRIPTION OF PLATES NOS. 24 and 25.

Barley (Hordeum).

Plate No. 24 shows the relation of the four soils, in respect to their effect upon barley plants, three months after the seed was sown. The plants in the Palouse soil, pot No. 1, exhibits the best growth. The growth of the plants in the other soils was less and less good in the rotation given in the numbering of the pots; No. 2, old sawdust, No. 3 new sawdust, No. 4 coniferous.

Plate No. 25 was made just as the barley was heading out. The same relation as to the effect of the soils upon the progress of the plants, shown in the description of Plate 24, continued in the later growth.

PLATE NO. 24---BARLEY.

Palouse	Soil No. 1.
Old Sawdust	Soil No. 2.
New Sawdust	Soil No. 3.
Coniferous	Soil No. 4.

PLATE NO. 25---BARLEY.

Palouse Soil No. 1.
Old Sawdust Soil No. 2.
New Sawdust Soil No. 3.
Cnniferous Soil No. 4.

DESCRIPTION OF PLATES 26 and 27.

The Oats (Avena sativa)
The Wheat (Triticum vulgare)

In the growth and development of the oats the same relation in respect to soils is manifest as was shown in the culture of the barley. That is, the Palouse soil in promoting growth, ranks first, old sawdust second, new sawdust third, and coniferous fourth.

Again, the plate shows that in the growth of wheat the Palouse soil brings the best results, and that the other soils follow in rotation, similar to that maintained in the development of the oats and the barley.

PLATE NO. 26---OATS.

Palouse Soil No. 1.
Old Sawdust Soil No. 2.
New Sawdust Soil No. 3.
Coniferous Soil No. 4.

PLATE NO. 27---WHEAT.

Palouse	Soil No. 1.
Old Sawdust	Soil No. 2.
New Sawdust	Soil No. 3.
Coniferous	Soil No. 4.

DESCRIPTION OF PLATES NOS. 28 and 29.

The Lettuce (Lactuca sativa).

Plate No. 28 shows the lettuce plants as they grew in the pots. No very clear idea can be obtained from this plate of the relative size of the plants in the different soils. It can be seen to some extent, however, that the plants in pots 1, 2 and 3, that is, in the Palouse, old sawdust and new sawdust soils, are much larger than the pla in the coniferous soil, pot No. 4.

The difference is brought out more distinctly in Plate No. 29, which pictures the relative sizes of the leave and roots. The plant in the Palouse soil, pot 1, has the largest leaves and the greatest amount of roots. These roots are small and fine as distinguished from the roots of the plants in the other soils which are coarser and less numerous.

PLATE NO. 28---LETTUCE.

Palouse	Soil No. 1.
Old Sawdust	Soil No. 2.
New Sawdust	Soil No. 3.
Coniferous	Soil No. 4.

PLATE NO. 29---LETTUCE.

Palouse	Soil No. 1.
New Sawdust	Soil No. 2.
Old Sawdust	Soil No. 3.
Coniferous	Soil No. 4.

DESCRIPTION OF PLATES NOS. 30 and 31.

The Radish (Raphanus sativus).

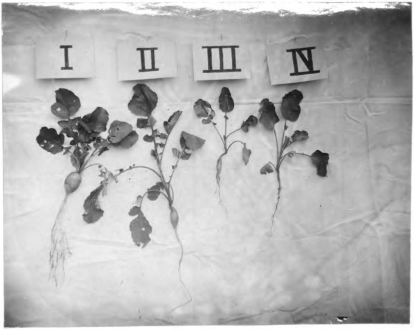
Plate No. 30 gives the picture of the plants as they appeared in the pots, growing in the different soils. Pot No. 1 exhibits the best developed top growth. The Palouse soil is thus again shown to be most effective. The second best soil for the top growth of the radish is the new sawdust. The two remaining soils vary little in the amount of top growth they developed, as shown in pots No. 3 and No. 4.

Plate 31 shows the Palouse soil to be first in rank, also for root growth, while the new sawdust ranks second, and the other soils are about equal in development of the roots. The roots in the Palouse soil, as usual, are much finer and more numerous than the roots in the other soils.

PLATE NO. 30---RADISH.

Palouse	Soil No. 1.
New Sawdust	Soil No. 2.
Old Sawdust	Soil No. 3.
Coniferous	Soil No. 4.

PLATE NO. 31---RADISH.



Palouse	Soil No. 1.
New Sawdust	Soil No. 2.
Old Sawdust	Soil No. 3.
Coniferous	Soil No. 4.

DESCRIPTION OF PLATES NOS. 34 and 35.

The Parsnip (Pastinaca sativa).

Plate No. 34 is an illustration of the growth reached by the plants in the different soils, in the four pots, from the time of seeding. Here again, the best development will be observed in the plant in the Palouse soil. The plant in the old sawdust soil ranks second in growth as pictured, while the plants in the other two soils seem very much alike.

In Plate No. 35 the relative sizes of leaves and root systems of the parsnips in the different soils prove that the Palouse soil is most favorable for their growth. That is, compared with the plants in the other soils, the leaves of the parsnip in the Palouse soil are larger and its root system in that soil is much better developed, larger and finer.

PLATE NO. 36---CARROTS.

Palouse Soil No. 1.
Old Sawdust Soil No. 2.
New Sawdust Soil No. 3.
Coniferous Soil No. 4.

DESCRIPTION OF PLATES NOS. 38 and 39.

The Beet (Beta vulgaris).

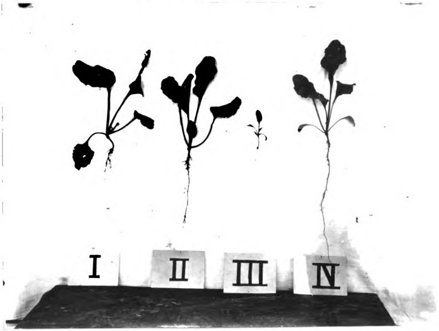
The plants of the beet, as exhibited in Plate No. 38, made about the same top growth in three of the soils, the Palouse, the coniferous, and the old sawdust, in pots No. 1, No. 2, and No. 3. In the new sawdust soil a plant much smaller than any in the other soils was produced, as is shown in the plate.

The root systems of this vegetable as variously developed in the different soils are illustrated in Plate No. 39. The illustration proves that in the relation of the roots of the beet to the soils the coniferous and old sawdust soils are more favorable than the other two soils for the development of its root system. The roots of the plant in the Palouse soil, as shown, are fine and few in number.

PLATE NO. 38---BEET.

Palouse Soil No. 1.
Coniferous Soil No. 2.
Old Sawdust Soil No. 3.
New Sawdust Soil No. 4.

PLATE NO. 39---BEET.



Palouse Soil No. 1.
Coniferous Soil No. 2.
New Sawdust Soil No. 3.
Old Sawdust Soil No. 4.

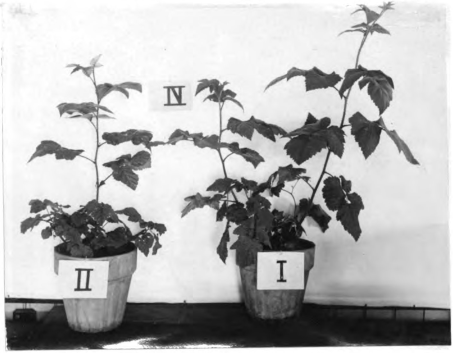
DESCRIPTION OF PLATES NOS. 40 and 41.

The Blackberry (Rubus villosus).
The Raspberry (Rubus strigosus).

Plate No. 40 shows the blackberry grown in two soils, the Palouse, pot No. 1, and the coniferous, pot No. 2. In the Palouse soil, as shown in the illustration, the plant made a slightly better growth. Yet the plant in the coniferous soil, as will be seen, did well, and proved satisfactorily the adaptability of coniferous soil to blackberry culture.

The raspberry in the Palouse soil, it will be noticed in Plate 41, grew higher than the plant in the coniferous soil. But a comparison of the total growth as shown in the two pots will prove it to be about the same in both. The conclusion that the one soil is about as good as the other for the growth of the raspberry seems to be fairly reached.

PLATE NO. 40---BLACKBERRY.



Palouse Soil No. 1.
Coniferous Soil No. 2.

PLATE NO. 41---RASPBERRY.

Palouse Soil No. 1.
Coniferous Soil No. 2.

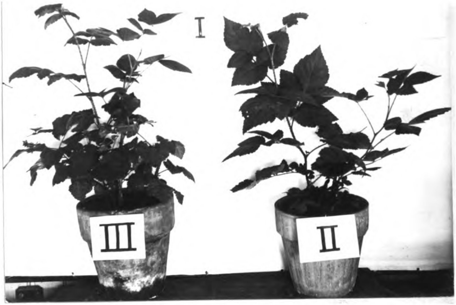
DESCRIPTION OF PLATES NOS. 42 and 43.

The Loganberry (Rubus (?)).
The Potatoes (Solanum tuberosum).

Plate No. 42 represents the loganberry as grown in the Palouse soil and in the coniferous soil. There is too little difference between the plants as developed in the two soils, for comparison. The growth is clearly about the same in both pots. The leaves appear somewhat larger on the plant in pot 2, but this may be attributed to the better position of its leaves for illustration.

The top growth of the potatoes was explained in the description of Plate No. 12. Plate No. 43 shows the root systems in the different soils. In the coniferous and old sawdust soils will be seen a large and coarse root system in which very few tubers were developed. In the Palouse and new sawdust soils, with a much smaller and finer root system, more tubers were produced, as appears in the illustration.

PLATE NO. 42---LOGANBERRY.



Palouse Soil No. 2.
Coniferous Soil No. 3.

PLATE NO.43---POTATOES.

Palouse	Soil No. 1.
Old Sawdust	Soil No. 2.
New Sawdust	Soil No. 3.
Coniferous	Soil No. 4.

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