Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 722

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. PROFESSIONAL PAPER October 22, 1918

A STUDY OF HEART-ROT IN WESTERN HEMLOCK

By

JAMES R. WEIR, Forest Pathologist, and ERNEST E. HUBERT
Scientific Assistant, Office of Investigations in Forest Pathology

CONTENTS

WASHINGTON
GOVERNMENT PRINTING OFFICE
1918

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 722

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. | PROFESSIONAL PAPER | October 22, 1918

A STUDY OF HEART-ROT IN WESTERN HEMLOCK.

By JAMES R. WEIR, *Forest Pathologist*, and ERNEST E. HUBERT, *Scientific Assistant, Office of Investigations in Forest Pathology.*

CONTENTS.

INTRODUCTION.

From the fact that the experience and methods of the European countries have been worked out and are at present practiced under an entirely different set of conditions, forestry in America is confronted with the necessity of formulating its own fundamentals as regards forest organization, working plan, and general silvicultural procedure in the virgin forests of the Northwest. Since a large number of the basic principles of an ideal forest organization depend upon a proper understanding and appreciation of the progress of decay in the forest and the general deterioration of the stand and of individual trees, the problem is largely one of a pathological nature. The need of reliable figures from which an adequate conception of the loss to the forest through the death and disease of individual trees or stands and through various other causes instrumental in reducing the maximum annual increment is self-evident when any attempt is made to establish a rotation or cutting age for any one species. It is necessary also to concentrate the collection of these data upon a single tree species or upon a single type in order to secure

63424°—18—Bull. 722——1

figures which can be applied to the practical operations of forestry. Meinecke,[1] in a recent paper on this subject, has clearly expressed the need of concentrated work upon single tree species, with a special aim to secure accurate data adaptable to practical use. In order to make a beginning in supplying the fundamental knowledge for a solution of some of the more vital problems bearing on the regulation of the forest with regard to the peculiarities and activities of the more economic fungi, a series of detailed studies has been instituted, beginning with the western hemlock (*Tsuga heterophylla*). In the present study, an attempt has been made to secure for two principal types of the typical stand all available data bearing on the relationship of decay to the many factors concerned in its inception, development, and spread, and to determine, if possible, which of the factors concerned in the life history of western hemlock has the greatest influence in the development or retardation of decay.

PRESENT STATUS OF WESTERN HEMLOCK IN THE TRADES.

The regulation of hemlock in the northwestern forests is probably one of the most difficult silvicultural problems with which foresters have to deal. Not only has this species for many years in some parts of the West been considered little more than a "weed" in the forest, to be removed in as expedient and thorough a manner as possible, but a widespread prejudice on the part of the lumber trade has kept the products of western hemlock much in the background.

The common occurrence of heart-rot, the susceptibility to fire and frost, etc., have also led to a much advanced theory of a general decadence of this really valuable species. Western hemlock can not be considered in any sense a decadent tree, as is evidenced by its splendid height and diameter growth in localities where it reaches its best development. There are approximately 90,000,000,000 feet board measure of western hemlock in the United States and Alaska, and most of this is found in Washington and Oregon.[2] Only recently have the millmen placed hemlock upon the market under its rightful name. In 1908, 90,000,000 feet of western hemlock were reported cut, and this increased to 248,000,000 feet in 1910.[2] The rapid increase in cut tends to show that the true value of western hemlock is hereafter to be recognized and that the prejudice against its name is gradually disappearing.

Several mill owners with whom the subject of the soundness and durability of hemlock lumber has been discussed state that too frequently the lumber decays rapidly after being sawed. This is not

[1] Meinecke, E. P. Forest pathology in forest regulation. U. S. Dept. Agr. Bul. 275, 62 p. 1916.

[2] Hanzlik, E. J., and Oakleaf, H. B. Western hemlock; its forest characteristics, properties, and uses. *In* Timberman, v. 15, no. 12, p. 25. 1914.

due to a poor physical quality of the wood, but usually arises from the fact that great difficulty is experienced in determining the actual extent of the advance decay from the more evident heart-rot when the trees are bucked and scaled in the woods. Some of the logs go to the mills to all appearances sound, but in reality with a part of the log in the incipient stages of decay. Consequently, when the log is sawed into boards they check or completely fall into a dry crumbly decay when exposed to drying conditions for any considerable length of time. Such conditions cause a discrimination against western hemlock by those who have witnessed this deterioration after sawing. A better understanding of the real causes underlying this result and a true conception of the usefulness of hemlock wood will aid greatly in removing such objections as the trades now hold against lumber sawed from this species of tree.

ECHINODONTIUM TINCTORIUM.

THE FUNGUS AND ITS HOSTS.

With few exceptions, as will be shown, *Echinodontium tinctorium* E. and E. (figs. 1 and 2) is the cause of practically all the heart-rot so widely prevalent in hemlock throughout the Northwest. Being the only hydnaceous fungus of its kind and the only member of its genus, something of its history should be given. The fungus was first described as *Fomes tinctorium* by J. B. Ellis from the original specimens collected in Alaska by J. G. Swan. The teeth were broken from these specimens, and Ellis mistook the pits or scars for pores and called it a Fomes.[1] The fungus was next collected at Jansville, Idaho, by C. V. Piper, who sent it to Lloyd. Lloyd published it as *Hydnum tinctorium.*[2] In a letter to the senior writer, Lloyd states that Ellis suggested that the fungus might well be the type of a new genus and should be called *Echinodontium tinctorium*. Lloyd used this name in his article and it was the first time the name was employed. In 1900, Hennings, of the University of Berlin, received some small specimens from Japan. Ignorant of the work of Ellis and Lloyd, he published the fungus as representing a new genus, calling it *Hydnofomes tsugicola.*[3] The name Echinodontium first published by Lloyd has become so thoroughly established in forestry circles that any attempt to depose priority and use any other names, which in some respects are far more applicable, for instance, Hydnofomes, would lead to some confusion in the ranks of practical foresters; hence the name given by Ellis and Lloyd will be used.

---

[1] Ellis, J. B. New fungi, mostly Uredineæ and Ustilagineæ from various localities, and a new Fomes from Alaska. *In* Bul. Torrey Bot. Club, v. 22, no. 8, p. 362. 1895.

[2] Lloyd, C. G. Mycological notes, no. 1, p. 2–3. 1898.

[3] Hennings, Paul. Fungi japonici. *In* Bot. Jahrb. [Engler], Bd. 28, Heft 2, p. 268. 1900.

The chief gross character by which the fruiting organ of the fungus may readily be recognized is a hymenium consisting of numerous firm, thick, sharp-pointed teeth of a light-brown color (figs. 1 and 2). The upper surface is almost black in old specimens (figs. 3 and 4), usually of a lighter color when young, and concentrically zoned, each zone representing a year's growth. In a growing condition the outer zone is white or brown, context solid, and of a Mars-orange to orange-rufous color.[1] The minute characters of the fruiting organ are: Spores hyaline, broadly ellipsoid, 4 by 6 μ, teeth covered with

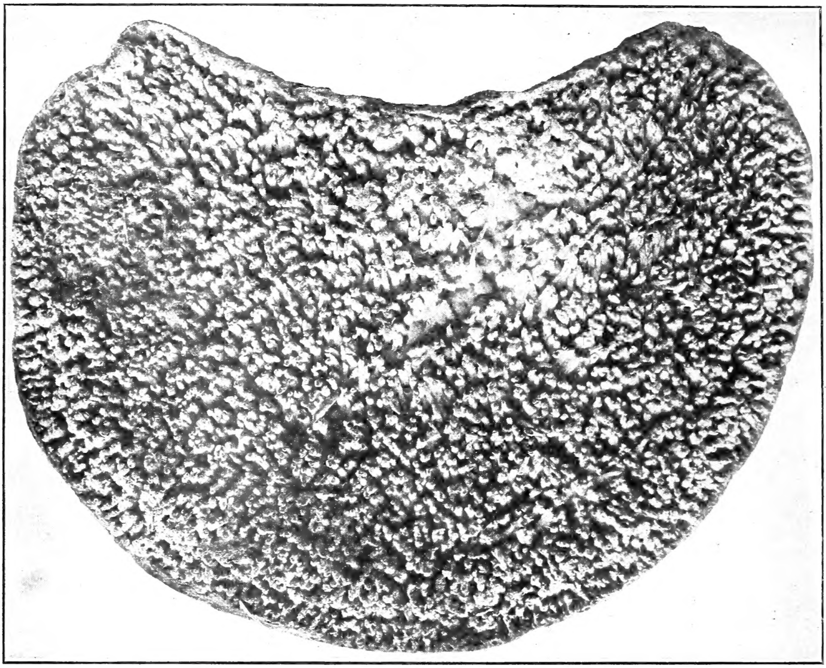

FIG. 1.—Sporophore of *Echinodontium tinctorium* on hemlock. Bottom view, showing fresh hymenium or spore-producing surface.

short colorless setæ or microscopic spines. The hymenium of the young growing fungus is by no means toothed in the beginning but is typically dædaloid, a character often misleading to the uninitiated when the interior has not been examined.

On account of its tinctorial property, the powdered fungus mixed with tar or oil is used by the Indians as a war paint. The fungus is likewise employed by the Indians of Alaska for medicinal purposes and as a dye. For the latter reason it has received the common name of Indian-paint fungus. Since an oily alkaloid has been detected by the analysis of the fungus, there is a possibility of its

[1] Ridgway, Robert. Color Standards and Color Nomenclature, pl. 2. Washington, D. C., 1912.

possessing therapeutic properties of some value. Tannin has been found in considerable quantities in the fungus.

From specimens preserved in the Laboratory of Forest Pathology at Missoula, Mont., the host range of *Echinodontium tinctorium* is as follows: *Tsuga heterophylla*, *T. mertensiana*, *Abies grandis*, *A. concolor*, *A. lasiocarpa*, *A. nobilis*, *A. magnifica*, and *A. amabilis*. The fungus has not been reported on *A. venusta*. Its occurrence on *A. arizonica* is reported by Hedgcock.[1] In the very rarest of cases *E. tinctorium* occurs on *Picea engelmanni* and *Pseudotsuga taxifolia*. The fungus rarely occurs on any but its common hosts and is only of economic importance in the consideration of problems relating to the genera Abies and Tsuga. The specimens which reached Berlin from Japan grew on *Tsuga diversifolia*.

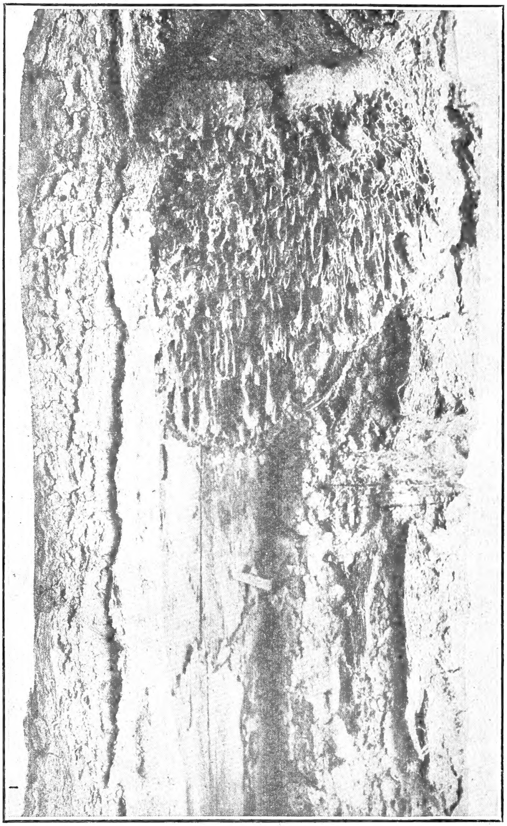

FIG. 2.—*Echinodontium tinctorium* growing out of a blaze, which was the source of infection. Note the spines on the fungus.

GEOGRAPHIC DISTRIBUTION.

In view of the fact that many of the more serious wood-destroying fungi are distributed over the world, it is interesting to note that the geographic range of *Echinodontium tinctorium* is limited. Except the specimens from Japan, it has not been found outside of western North America. To judge by specimens on hand in the Laboratory of the Office of Investigations in Forest Pathology of the Bureau of Plant Industry and as reported by others, the range of this fungus in North America extends from Alaska to northern Mexico and as far eastward as the limits of the range of grand fir and hemlock on the western slopes of the Continental Divide in Canada and Montana.

[1] Hedgcock, G. G. Notes on some diseases of trees in our National Forests. *In* Phytopathology, v. 2, no. 2, p.78. 1912.

The fungus is most abundant and of greatest consequence in western Montana, Idaho, Oregon, Washington, and British Columbia.

THE DISEASE CAUSED BY ECHINODONTIUM TINCTORIUM.

OUTWARD SIGNS OF THE DISEASE.

To be able to recognize or discriminate between the more dangerous and less harmful diseases should be a part of the everyday knowledge of the forest officer in charge of the marking. The following statements will be of some value in this respect.

The decay-producing fungus proper is the mycelium in the wood, not the "conk" (fig. 5) without. The appearance of a fruiting body

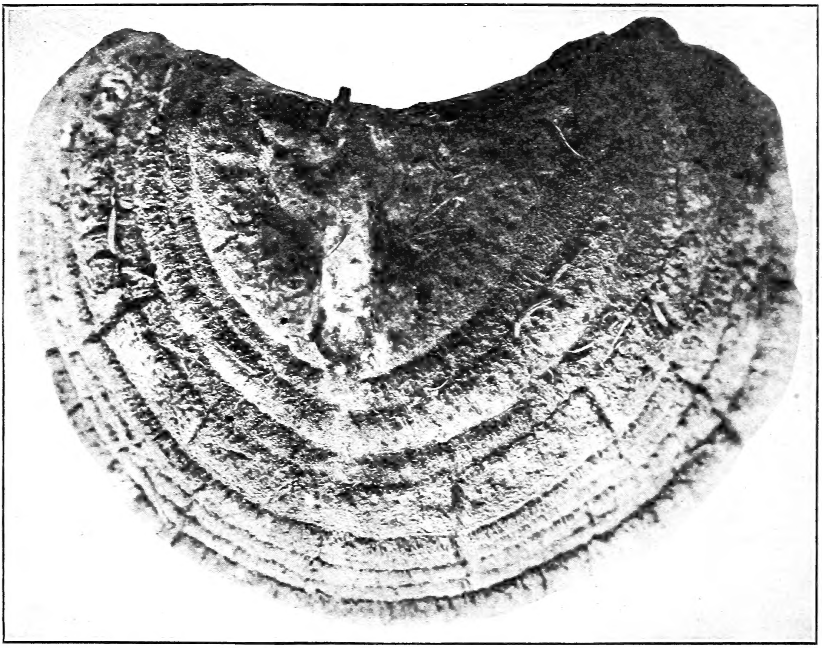

FIG. 3.—Sporophore of *Echinodontium tinctorium*, showing upper surface.

is in most cases an index of the intensive development of the fungus, at least within a certain volume of the tree infected. It means that a good part of the food materials of the heartwood at that point are exhausted. A single average-sized sporophore situated on the first 16 feet of the trunk for all practical purposes may be taken to indicate an unmerchantable condition of the heartwood of all points below and into the next 16-foot log above the first. A sporophore situated well up on the trunk may be taken to indicate undesirable material throughout the main part of the tree. Little need be said concerning the presence of more than one sporophore. It will be observed that the largest usually has smaller ones above and below it.

This generally indicates that the largest sporophore marks the area of greatest decay and that the decay has traveled both ways. In any case, trees bearing more than one sporophore situated some distance from each other are not merchantable and should be cut down and burned or fire-girdled.

The presence of sporophores on the tree is an indication of a fairly advanced stage of decay throughout a good portion of the tree. On the other hand, the absence of sporophores does not always indicate soundness. A few cases may occur where the tree is so old in decay that the sporophores have died and fallen away. The discoloration of the bark at the point of attachment or the hole left by the rotting

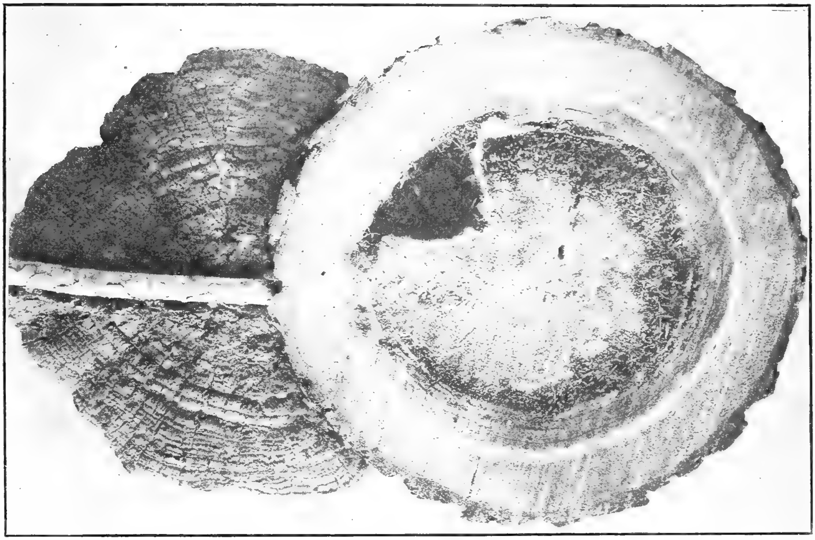

FIG. 4.—An old sporophore of *Echinodontium tinctorium* on hemlock. Top view, showing the zonation and the relation to intensive decay.

branch may readily be noted. The old sporophores, which have a remarkable resistance to decay, may be observed on the ground at the base of the tree. Pounding on the tree is a fairly accurate method of determining soundness, down to a particular stage of rot. In doubtful cases, remarkably accurate results may be obtained by pressing the ear firmly against the tree while pounding. Previous to this, the bark should be removed over a small area in order to secure an uncushioned sounding point.

Probably the most practical method for the average marking officer, in the absence of visible defects, is the presence of red color a half inch or so within the dead branch stubs. This reddish coloration of the rot *E. tinctorium* is an index of an advanced stage, and its appearance so far out on the dead branch as to be detected by merely breaking off the branch is a sure sign of the typical rot within. The red color may not show at the base of every branch, in which case several may be examined. If the red color does not show after the knot has been opened with the corner of an ax, the branch may still show a yellowish dry-rot or the usual flinty consistency of a naturally pruned branch has given way to a loosened condition of its annual rings. This may be taken to indicate an initial stage of the rot only at this point, however, for the heartwood of the tree may be entirely decayed, due to the fungus having entered at another point. Knocking off

FIG. 5.—Sale area after logging (private logging operations), showing defective hemlocks left standing, a waste of valuable material and a menace to the surrounding forest. Note the "conks" on the trunks.

a few dead branches with an ax does not require much time and is a very good method to use in such a case.

In general, individual trees growing under suppressed conditions or a type developing in a close stand can be expected to disclose a large amount of decay, especially when growing on moist river-bottom sites. The slope type of stand must be judged more carefully, and it is often the case that in vigorous stands an infected tree will yield the first two logs sound while the upper portion of the trunk will be in the last stages of decay. Under such conditions sounding by blows will not be found practicable, but the presence high on the trunk of many branch stubs, dead branches, and sporophores will always indicate the true condition. Moist sites of various slopes and exposures are generally found to produce a greater development of decay, and invariably the older trees in such stands are badly infected. This is indicated by the data secured from lumbermen given in the pages that follow. The early formation of branch stubs through the premature dying of the lower crown due to overshading can always be depended upon as an indication of existing decay, and it will usually be found that the center of infection is located in that portion of the trunk bearing the largest number of dead branches or branch stubs. The presence of many branch stubs, the presence of branch stubs showing unmistakable rot colorations, the appearance and number of sporophores, many injuries (including frost cracks), old age, and unmistakable signs of reduced vigor are all very reliable indications upon which a marking officer may learn to base his judgment for the determination of decay in western hemlock.

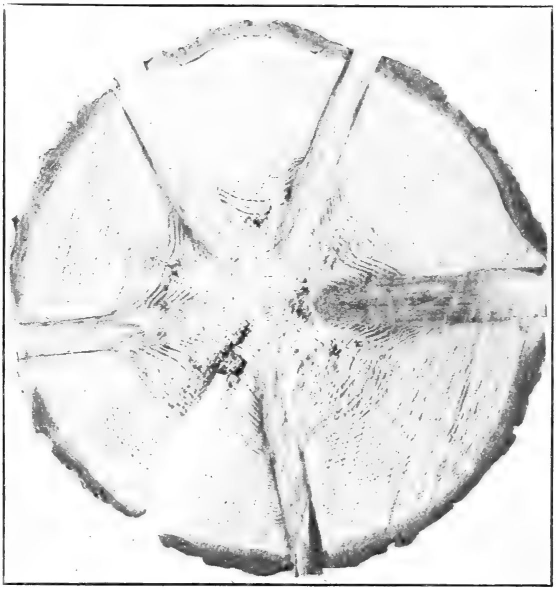

FIG. 6.—Cross section of a young hemlock, showing heart-rot at a whorl of branch stubs. In this case there are five dead branch stubs, all of which were possible agencies in conveying the disease into the heartwood.

GENERAL CHARACTERISTICS OF THE ROT.

The spores of *Echinodontium tinctorium* upon germination penetrate the host mainly through the dead broken branches or branch stubs (figs. 6 and 7). This has been confirmed by the data taken in the study of the relation of injuries to decay. A few infections are traceable to fire and logging scars, frost cracks, or other injuries. In a few instances, on areas other than those upon which data were secured, it has been found that the burls on hemlock caused by *Razoumofskya tsugensis* were points of infection.

The hyphæ on germinating follow the central nonresinous heartwood zone of the branch stubs and continue inward to the main heartwood of the tree (fig. 8), spreading more or less uniformly up and down the trunk from the point of infection. The decay is characterized in hemlock and grand fir by its uniformity in occupying the heartwood (figs. 4 and 8). In alpine fir the rot in cross section takes on a somewhat stellar development, due principally to the concentration of the hyphæ along certain of the medullary rays.

In badly decayed living trees it is invariably the case that the rot not only occupies the entire heartwood of the trunk but the heartwood of the branches as well (fig. 9), extending in some of the larger ones a distance of several feet,[1] causing the formation of sporophores at some distance from the trunk.

The advance rot of *Echinodontium tinctorium* is very difficult of detection and unless accompanied by small brownish discolorations or by reddish or brownish streaks can not be detected without a very close examination. In the early stages of the decay the wood assumes a faint yellowish, spongy texture. Sometimes this stage is intensified by the presence of small, hardly discernible brownish areas, which later develop into the typical rot. The extension of the advance rot beyond the typical rot varies greatly according to the conditions. Some accurate data are at hand to determine the average height of the advance rot beyond the typical rot. Such data will be found very useful to scalers in determining the amount of cull to deduct from the gross scale in order to cut out all the advance rot which might later develop into the crumbly decay complained of by dealers in hemlock lumber. Meinecke[2] states that in the white fir (*Abies concolor*) of this region the advance rot produced by *E. tinctorium* extends about 2 to 6 feet beyond the typical rot. From the data collected on more than 200 hemlocks of all ages and sizes an extension of 1 to 5 feet has been found to be general. A single figure

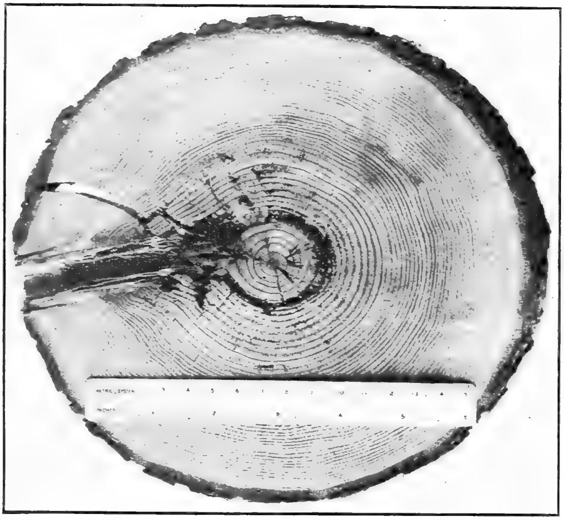

FIG. 7.—Section of hemlock, showing a branch stub as a means of first infection of heart-rot. The decay has commenced spreading into the heartwood from the end of the branch tissue.

[1] Weir, J. R. Destructive effects of Trametes pini and Echinodontium tinctorum. *In* Phytopathology, v. 3, no. 2, p. 142. 1913.

[2] Meinecke, E. P. Forest-tree diseases common in California and Nevada, p. 52. 1914. Published by U. S. Department of Agriculture, Forest Service.

can not be used to express this relation, since it varies with all the factors influencing the progress of the decay. As a rule, it would be safe to add to the linear estimate of the cull 1½ feet beyond the last recognizable punky area or area showing the slightest yellowish discoloration. The typical rot (figs. 4, 8, and 9) is readily recognizable and has a characteristic reddish brown to brownish yellow color, often spotted with areas of a more vivid rust color and occasionally showing streaks or lines of a dark red to reddish brown hue. Its texture is very pronounced and this, combined with its color, forms the basis for the scaler's common name for the defect "stringy brown-rot." In the last stages of decay the heartwood is entirely disorganized, giving place to large cavities in the butt logs and sometimes in the logs above. The stringy nature of the rot can be readily seen in this stage and also in the ends of logs badly but not hollow

FIG. 8.—Longitudinal section of an old sporophore of *Echinodontium tinctorium* on hemlock, showing its relation to branch stubs.

rotted, especially in the grass-stubble effect (figs. 4 and 10) produced by the sawing. The brick-red color of the sporophores is often found distributed through the typical rot and in the branch stubs in the final stages of decay.

AREAS STUDIED AND FIELD METHODS USED.

The areas selected for study lie in the drainage basin of the Priest River in Idaho. Throughout this region western hemlock is rather evenly distributed, extending downward from the subalpine zone into the upper limits of the yellow-pine zone. The species attains its best development on damp north slopes and is found greatly suppressed when growing as an understory in the dense bottom stands.

One of the factors promoting the development of forest-tree fungi of the region is the high annual precipitation. The dry periods of the year are comparatively short, so that the sporophores of perennial fungi may never at any time be entirely dried out. During the late fall, extending into December and coincident with the formation of new fruiting surfaces of the Indian-paint fungus, rain falls almost constantly. The average annual precipitation is between 20 and 30 inches, increasing rapidly with elevation, reaching a maximum of more than 40 inches in the higher slopes.

In the spring of 1915 investigations were begun on the river-bottom and slope sites of the Priest River valley in Idaho. The general altitude of the region is about 2,450 to 2,500 feet. The meanderings of the Priest River in former times created a number of

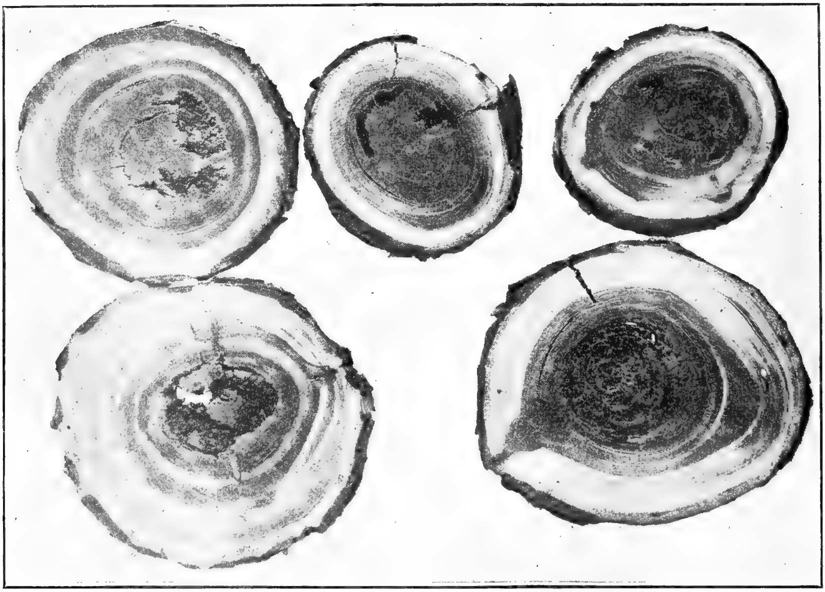

FIG. 9.—Cross sections of a hemlock branch in which heart-rot extended 10 feet out from the trunk, showing how the larger branches may be affected.

swamps and bayous, which are filled with water during the greater part of the year. The interlying areas are poorly drained.

The whole region is one of dense forests, composed of western white pine (*Pinus monticola*), western red cedar (*Thuja plicata*), western larch (*Larix occidentalis*), Engelmann spruce (*Picea engelmanni*), Douglas fir (*Pseudotsuga taxifolia*), western hemlock (*Tsuga heterophylla*), grand fir (*Abies grandis*), western yew (*Taxus brevifolia*), western birch (*Betula occidentalis*), and cottonwood (*Populus trichocarpa*).

The soil is a moist sandy loam, with much alluvial material and not well drained on the river-bottom sites. There is a great depth of humus, litter, and needles. On the above-described site, ten separate plats were laid out, comprising 5.7 acres. The river-bottom and slope types were first selected for investigation, for the reason that at these elevations and under the existing conditions grand fir and hemlock are heavily diseased. The plats represented a variety of age classes, mixtures, and successions.

The investigations on grand fir and hemlock were carried out simultaneously, but the data on the former are reserved for a future report. The influences of site and elevation on the distribution and amount of decay were considered, and the data were consequently divided according to the two sites indicated. In order to get the percentage of rot of hemlock and grand fir, a clean cut of these species

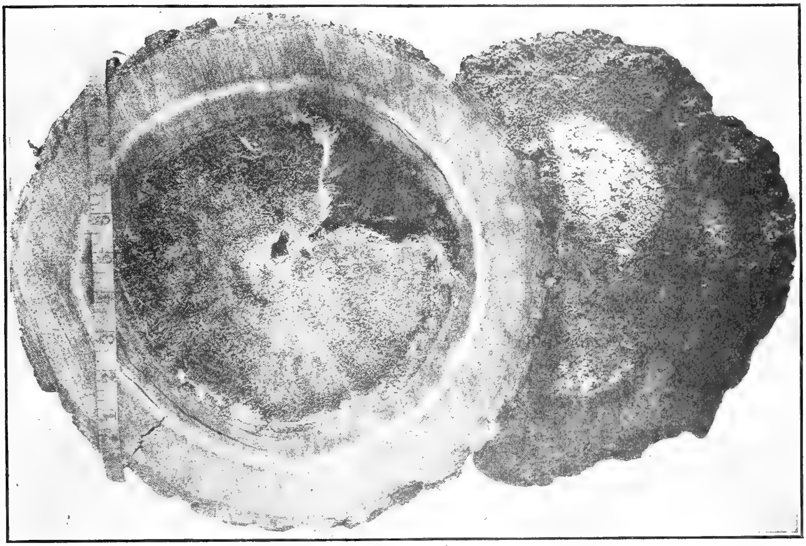

FIG. 10.—Section through a trunk of hemlock, with an old sporophore attached. The stringy nature of the heart-rot and the grass-stubble effect due to sawing are both characteristic.

was made. The trees were bucked in such lengths (16 feet and shorter) as to determine the transverse and longitudinal extent of the decay; also the point at which the decay was greatest. That section of the trunk containing the upper extension of the decay was fully dissected, in order to determine the exact upper limit. The diameter of the rot at each log end was measured and recorded. The rot in each tree was measured in detail. A full analysis of the stump was also made. A uniform stump height of 18 inches was maintained throughout. The age of the tree was determined at this point, and four years added to the age at the stump, giving the entire age.[1] Before the trees were felled, full notes on the external

[1] This average age at stump was secured by taking data on a number of seedling hemlocks in the same stand and determining the age corresponding to the stump height of the felled trees.

appearance relative to environment, etc., were recorded. Each tree was designated by a number. Altogether, 201 trees of western hemlock were cut on the ten areas, and about an equal number of grand fir. The hemlocks considered in this study are numbered from 1 to 201. No selection of trees was practiced, but all trees on the areas laid out were cut.

Aside from a few cases of secondary decay, the cause of which could not be definitely determined from a chemical and anatomical study of the rot alone, the occurrence on hemlock of the more common fungi of the associated species was practically nil. In a few cases the rot of *Trametes pini* and *Polyporus schweinitzii* was found in hemlock, but since the merchantable parts of the same trees were wholly decayed by *Echinodontium tinctorium*, all decay of the species on the areas is attributed to the latter. This is equivalent to saying that practically 100 per cent of all cases of decay in living hemlock were due to *E. tinctorium*. This is by no means an unusual condition for the region. In fact, the finding of any other fungus working as a first agent of decay in hemlock is a rarity.

METHODS USED IN PRESENTING DATA.

The methods used in preparing the data for presentation and comparison are the result of an attempt at standardizing such factors as, in ordinary field observations, are usually determined by an ocular method not involving exact measurements. Any attempt at standardization of such factors as are included under "Seriousness of injury," "Degree of vigor," or "Crown rating" is bound to meet with difficulties. So long as the same standard is used consistently throughout the work, a slight amount of arbitrary standardization will not in the least reduce the value of the results.

The total volume of the tree, less the stump, inside of the bark was first secured in cubic feet by means of the paraboloid formula,[1] $V=(BH\div 2)$, and the table of basal areas.[2] The diameter (inside of the bark) at the stump was used to secure the above figure. The total volume of rot in the tree, less the stump, was secured in cubic feet by a similar method. As an experiment to determine the shape of the rot column, the outlines of the rot column of several infected hemlocks were plotted on coordinate paper. It was found that these rot outlines conformed closely to the general outlines of the trees. It was also found that the formula used to secure the volume of rot more nearly included all the rot found within the trunk than did the Smalian method. The dissection of the trees and the plotting of a few of them on coordinate paper showed that the formula as

[1] Graves, H. S. Forest Mensuration, ed. 1, p. 88. New York, London, 1906.
[2] Graves, H. S. Op. cit., p. 430.

here used allowed for such rot as was to be found outside of a straight line drawn from points on the rot sections appearing at both ends of the logs and such rot as was found extending outward from the heartwood along the branch whorls. The advance rot is included in the total rot in every case. The rot percentage was secured from the two given volumes.

The basis for classifying the seriousness of injury is given as follows:

0 = No injuries.
x = 1 to 4 branch stubs, no frost cracks, and very few miscellaneous injuries (less than 2).
xx = 5 to 9 branch stubs, one frost crack, and a superficial blaze, logging scar, or other slight injury.
xxx = 10 to 15 branch stubs, not more than 2 frost cracks, deep blazes, logging scars or fire scars, and slight lightning injury.
xxxx = 15 or more branch stubs, more than 2 frost cracks, and heavy injuries (injured and broken top, severe lightning, and other injuries).

The grouping of trees according to the crown class has, in general forestry practice, been almost entirely done by ocular estimate. In the present study the four gradations of the crown class were taken from Forest Service Bulletin 61[1] and were used with the crown size in composing the standard for crown rating. The actual size of the crown and the crown class are used to determine this rating. The crown sizes in square feet (length by width of crown) for each age class are grouped together, the largest and smallest sizes compose the extremes of the large and the very small crown divisions, respectively, the remainder ranging in order of size between these two. The group is then divided into four equal classes: Large, average, small, and very small. The individual trees are then given their respective crown rating according to the following outline:

(1) Crown size, large. (Crown class 1.)
(2) Crown size, average. (Crown class 2.)
(3) Crown size, small or one sided. (Crown class 3.)
(4) Crown size, very small. (Crown class 4.)

The vigor of a tree is indicated by the size and condition of its crown and by the favorableness or unfavorableness of the position it occupies, as well as by the narrowness of the sap zone and the fineness of its annual rings. The injuries which the tree receives during the course of its development also play an important part in influencing its vigor. The rating for vigor has therefore been based upon the following three factors, in the order of their importance: (1) Width of average ring in sap, (2) crown rating, and (3) the degree of injury. This rating for vigor at least comes nearer registering the true condition than a mere ocular estimate. The fixing of the standard or average width (as in *oo* where the width is 0.12 to 0.19 inches) was

[1] Terms used in forestry and logging. U. S. Dept. Agr., Bur. Forestry Bul. 61, 53 p. 1905.

secured from a careful checking of all the data and from the table by Hanzlik and Oakleaf [1] giving the average annual diameter growth for western hemlock as obtained under average conditions in western Washington.

Rating of Vigor.

o=Thrifty.—Width of average ring in sap 0.20 inches and up; 1 in crown rating; classed as 0 or x under degree of injury.

oo=Fair.—Width of average ring in sap 0.12 to 0.19 inches; 2 in crown rating; classed as x or xx under degree of injury.

ooo=Poor.—Width of average ring in sap 0.04 to 0.11 inches; 3 in crown rating; classed as xx or xxx under degree of injury.

oooo=Low.—Width of average ring in sap 0.03 inches and less; 4 in crown rating; classed as xxx or xxxx under degree of injury.

Other methods specially adapted to develop certain data will be found explained under the headings which follow.

The size of the average ring in the sap is the most important factor in the vigor determinations. The injury ratings (as *x* or *xx*) in the *oo* vigor class are intended to give a certain leeway in so far as the injuries found on the trees are concerned. Many trees have an *x* rating for injury, yet the vigor as indicated by crown size and by width of average ring in sap indicates a thrifty tree. A similar leeway is given the other vigor classes.

INFECTION AGE.

In studying the life history of a particular type, such as the river-bottom type of western hemlock, it becomes evident in the course of the work that certain age classes within that type represent a definite stage in the development of decay. This has been brought out by Meinecke [2] in his work on white fir (*Abies concolor*). The factors governing the entrance and development of a fungus in its host tend to determine a certain average age which indicates the age of first infection, an age at which the stand is most liable to first infection by the fungus and below which the infection rarely occurs.

Judging from Meinecke's [3] discussion of the age of infection, he defines it as the age at which "infection rarely leads to more than negligible decay unless the tree is handicapped by quite unusually severe conditions." An attempt has here been made more accurately to define this average age. The youngest trees only were used and of these only those which were infected. This age is briefly outlined as the average age of the youngest trees open to first infection by the fungus.

---

[1] Hanzlik, E. J., and Oakleaf, H. B. Western hemlock; its forest characteristics, properties, and uses. *In* Timberman, v. 15, no. 12, 1914, p. 25–33, tab. 3.

[2] Meinecke, E. P. Forest pathology in forest regulation. U. S. Dept. Agr. Bul. 275, p. 47–48. 1916.

[3] Meinecke, E. P. Op. cit., p. 48.

Table I represents all the trees of the 41 to 62 age class, inclusive, taken from plats classed in the river-bottom and southwestern-slope types. The 15 and 9 youngest trees of each site (river bottom and southwestern slope), respectively, were used to secure an average age representing the infection age. This age for each tree was secured by means of the formula, $A_1 = A - (V \div V_1)$, where A_1 equals age of first infection, A equals age of tree, V equals volume of rot of the tree, and V_1 equals the average annual increase in rot volume for the age class in which the tree is included. This last figure is obtained from Table II. It was attempted to use the first 15 trees of the southwestern-slope type. This gave an infection age of 70 years but included trees as old as 99 years, while the oldest tree of the river-bottom type was only 62 years. In using 9 trees, the oldest tree of the slope site is 75 years, giving a more equal comparison.

TABLE I.—*Data relating to the infection age of heart-rot in western hemlock on plats of the river-bottom and southwestern-slope types.*

Age.	Tree No.	Volume of rot.	Approximate value for $V \div V_1$.	Probable age of infection.[1]	Number of infected trees (basis).
River-bottom type: [2]		*Cubic feet.*	*Years.*	*Years.*	
46 years	82	0.07	2	44	
48 years	83	.03	1	47	
54 years	84	.06	2	52	
54 years	85	.68	19	35	
55 years	86	.32	9	46	
55 years	87	0	0	0	
56 years	88	.36	10	46	
57 years	89	.27	8	49	13
57 years	90	.19	5	52	
58 years	91	.44	13	45	
60 years	92	0	0	0	
61 years	93	.59	17	44	
62 years	94	1.11	32	30	
62 years	95	1.13	32	30	
62 years	96	.12	3	59	
Average				44.5	
Slope type: [3]					
54 years	1	0	0	0	
57 years	2	.07	4	53	
60 years	3	0	0	0	
62 years	4	0	0	0	
67 years	5	0	0	0	4
70 years	6	.17	9	61	
72 years	7	.51	26	46	
75 years	8	.11	6	69	
75 years	9	0	0	0	
Average				57.3	

[1] Formula: $A_1 = A - (V \div V_1)$. $V_1 = 0.035$.

[2] Site description.—River-bottom flat, very moist; soil not well drained; stand very dense. Almost all individuals of the tolerant species, such as western hemlock and grand fir, were overtopped or suppressed.

[3] Site description.—Southwestern slope, partly flat; old-age class of a white-pine type in which the hemlock has become a climax species; soil fairly moist and well drained; stand not overcrowded.

Table I shows that the average infection age for the river-bottom type is 44.5 years and for the southwestern-slope type 57.3 years. It thus appears from a comparison of the results shown in this table

63424°—18—Bull. 722——3

that the average infection age for the slope type is higher than that for the river-bottom type. This is undoubtedly due to the fact that the environmental factors in the river-bottom type are more favorable to early attack by the fungus. Crowded stands, much shade and suppression, and a higher percentage of atmospheric and soil moisture all presumably contribute to the earlier infection in the stands situated along the river bottoms.

It is to be understood that the figures as given in the tables that follow are not to be taken as absolute. The small numerical basis for some of the data, especially in Table I and part of Tables II and III, and other sources of unavoidable error, make it plain that the figures given are to be interpreted as indicative of the true conditions and not as an absolute analysis. The general tendencies must first be ascertained and the methods for determining them developed before absolute figures are presented.

TABLE II.—*Average annual increase in the volume of heart-rot in infected western hemlock trees of the several age classes, on plats of the river-bottom and southwestern-slope types.*

Age class.	Average age.	Interval between age classes.	Average volume of rot (cubic feet). As measured.	Average volume of rot (cubic feet). Annual increase between age classes.	Number of infected trees (basis).
River-bottom type:	*Years.*	*Years.*			
46 to 56 years	52		0.27	0	6
57 to 62 years	60	8	.55	.035	7
63 to 70 years	66	6	.82	.045	32
71 to 80 years	75	9	2.23	.16	39
81 to 90 years	86	11	3.62	.13	19
91 to 102 years	95	9	4.04	.05	7
104 to 126 years	114	19	4.21	.01	6
All age classes			2.25	.07	116
Slope type:					
54 to 70 years	62		.12		2
72 to 75 years	74	10	.31	.02	2
90 to 99 years	94	20	1.42	.06	6
101 to 120 years	110	17	14.31	.81	6
134 to 160 years	149	38	16.89	.07	9
162 to 179 years	172	23	19.16	.10	11
184 to 200 years	193	21	46.62	1.31	12
207 to 225 years	216	23	46.56	[a] .62	13
226 to 306 years	254	38	73.43	.71	12
All age classes			24.30	.46	73

[a] Interpolated.

RELATION OF DECAY TO SITE AND TO AGE.

Western hemlock, which ranges in decay from 50 to 100 per cent of trees infected in some localities and quite generally so over large areas where the species occurs in nearly pure stands, may be entirely free from its principal disease (heart-rot, caused by *Echinodontium tinctorium*) in some regions.

In order to determine the distribution of *Echinodontium tinctorium* and the extent of the damage produced by it as influenced by various environmental factors, a series of questions was prepared and submitted to the timber and mill owners in all parts of the Northwest. In response to a total of 151 letters sent out, 44 replies dealing with hemlock were received. A certain number of the replies were confined to grand fir alone. The replies to the questions were prepared by experienced scalers and cruisers, to whom the writers desire to express their thanks for the careful attention and willingness shown to further the progress of the investigation. In most cases the "conks" (figs. 1, 2, 3, and 4) of the fungus chiefly responsible for the decay in hemlock for the region were sent by the recipients of the letters. In practically every instance the fungus was *E. tinctorium*. Many of the northwestern regions not covered by these letters were visited; hence it was possible to gain a fairly accurate knowledge of the range and destructiveness of this disease along with the data on other phases of the study. Since the questions given out dealt with a variety of factors, the information thus obtained is submitted under the various sections of this paper covering the particular point under discussion. Four of the questions concerned the influence of site on the distribution and prevalence of decay.

The belief that conditions of soil, moisture, exposure, and altitude greatly influence the distribution and prevalence and the amount of decay caused by a particular fungus in the forest is supported by the data thus obtained. Out of 44 different observations covering a great range of territory, including the entire economic range of the tree in the United States, only three observers report a uniform distribution of decay in hemlock for all conditions. All other replies indicate great differences in the amount of heart-rot as influenced by soil, slope, and elevation. The topography and soil of those regions from which a uniform condition of defect is reported are so uniform in themselves that no great variation could be expected. The question of the influence of the site on the prevalence of the fungus *Echinodontium tinctorium*, it appears, depends on the moisture condition of the soil and its porosity and not upon soil quality. The fungus may occur on hemlock growing on any type of soil, but occurs to a greater extent on trees growing on wet, undrained sites. This is found to be true at any elevation, showing very clearly that the excessive moisture conditions of the site are highly favorable to the development of the principal attacking fungus. The answers indicate that the soundest hemlock is usually associated with a rich, well-drained soil. In wet, shallow soil the root system can not attain its normal position but must stay near the surface. If the soil is sufficiently loose to enable the roots to penetrate deeply, but is undrained, as in semiswamp, bottom sites, decay is prevalent and a retardation of growth also results. No relation between the composition of the soil and the prevalence of the fungus has been observed. Hemlock growing on lime, sand, or clay soils as a base for the regular humus layer exhibits no greater proclivity to fungus attack than do other species. Of the total answers received, 41 stated definitely that the least defective hemlock was found at the upper elevations and slopes and upon well-drained soils. The most defective stands were en-

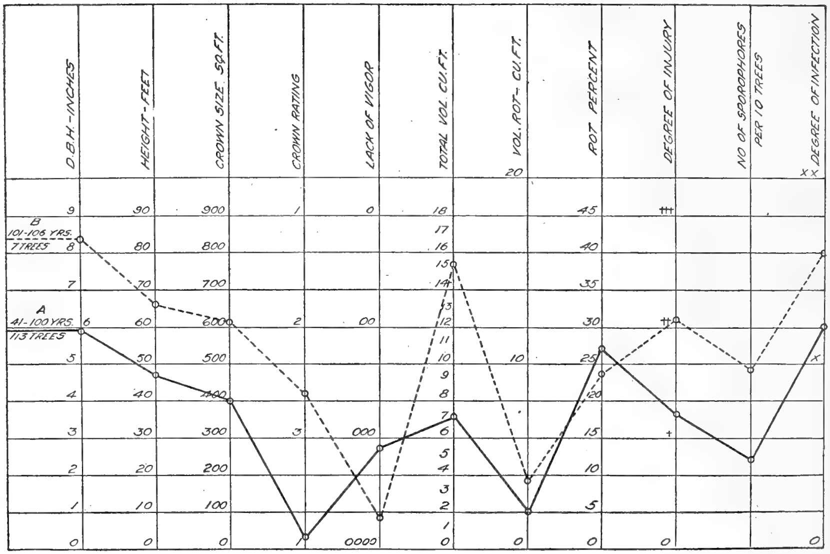

FIG. 11.—Diagram showing the relation of various factors to the age classes of western hemlock on plats of the river-bottom type.

countered at lower elevations, on flats and bottom sites, and upon poorly drained soils.

As the tree grows older it reaches a certain period in its life at which its vigor seems to have rached its maximum, after which time the vitality of the tree ebbs. This is often spoken of merely as old age and is the resultant lowering of vigor due to the increased unfavorable environment of its surroundings. Many factors enter into this relationship, competition with younger and sturdier trees for light, water, and food being the principal ones. Not the least of these factors is the effect of cumulative injuries received throughout its life. Many writers on forest pathology have expressed this opinion, and the data following (Table IV) convey a like conclusion. Von Schrenk[1] states that "it has been pointed out that as trees grow older they become

[1] Schrenk, Hermann von. Some diseases of New England conifers: A preliminary report. U. S. Dept. Agr., Div. Veg. Phys. and Path. Bul. 25, p. 51. 1900.

more liable to insect and fungus attack. An old tree has many vulnerable points, such as old branches and wounds," and naturally these injuries open the tree to more and greater infections. Hartig [1] does not believe that old age is a natural inherent condition, but says: "In itself, the feebleness of old age is not a natural condition attributable to internal causes. The older a tree is, so much the more numerous are the dangers through which it has had to pass, and so much the greater is the number of its injuries and wounds through which parasites and saprophytes can find an entrance into its inte-

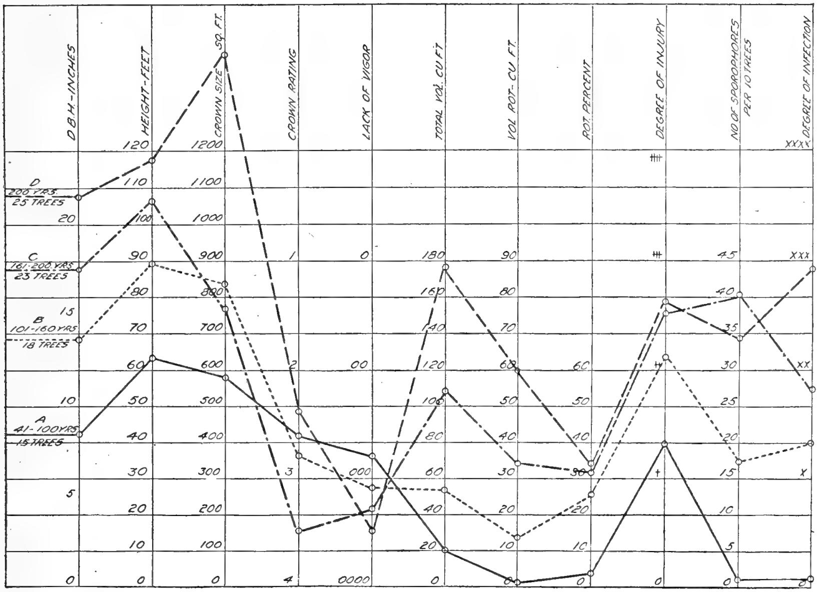

FIG. 12.—Diagram showing the relation of various factors to the age classes of western hemlock on plats of the southwestern-slope type.

rior." From the data secured by questions sent to a large number of lumbermen in the Northwest, it was found that a majority of the answers received indicated that the older age classes of hemlock were very much more defective than the younger. Möller [2] has shown that, with the increase of age in stands infected with *Trametes pini*, there was a corresponding increase in the percentage of trees infected, and the data given in Table III and figures 11 and 12 also show plainly that with increasing age there is a definite increase in the amount of decay.

---

[1] Hartig, R. Textbook of the Diseases of Trees. Translated by William Somerville, p. 7. London and New York, 1894.

[2] Möller, A. Über die Notwendigkeit und Möglichkeit wirksamer Bekämpfung des Kiefernbaumschwammes Trametes pini (Thore) Fries. *In* Ztschr. Forst. u. Jagdw., Jahrg. 36, Heft 11, p. 677-715, 2 pl. (partly col.). 1904.

TABLE III.—*Averages computed from field data relating to heart-rot in western hemlock based upon trees of the several age classes on plats of the river-bottom and southwestern-slope types.*

Type and age classes.	Number of trees (basis).	Diameter breast high.	Height.	Crown size (height by width).	Crown rating.	Lack of vigor.	Volume (cubic feet).		Rot percentage.		
							Total.	Of rot.	For class.	For stand.	
										Total.	Infected trees.
River-bottom type:		*Inches.*	*Feet.*	*Square feet.*	*Degree.*						
41 to 100 years.	113	5.9	47.0	400.0	3.9	3.1	7.1	1.9	27.1	26.6	96.7
101 to 160 years	7	8.4	65.7	609.5	2.6	3.4	15.3	3.6	23.6		
Slope type:											
41 to 100 years.	15	8.4	62.6	574.2	2.6	2.8	19.8	.62	3.1		
101 to 160 years	18	13.6	88.9	833.3	2.8	3.1	52.6	13.20	25.1		
161 to 200 years	23	17.5	106.0	761.6	3.5	3.3	107.6	33.50	31.1	30.8	90.1
201 years and over	25	21.5	117.0	1,458.6	2.4	3.5	175.5	59.40	33.8		

From the viewpoint of the natural increase in heartwood due to larger size, etc., coincident with age, it is presumed that the amount of decay would increase proportionately. The figures obtained in the case of the southwestern-slope type show this to be not only true in this respect, but the proportion of the volume of decay to the total volume of the tree is also much higher. In the river-bottom site (Table III) the average volume of rot increases from 1.9 cubic feet in the 41 to 100 year age class to 3.6 cubic feet in the 101 to 160 year age class. In the southwestern-slope type (Table III) a better comparison between age classes can be made. Here a definite increase in rot volume from the 41 to 100 year age class to the 201 year and older age class is evident. Table II also shows an irregular increase in the average annual increase in rot volume between age classes, though the general trend of the figures in Table II shows a gradual increase from the younger to the older trees up to the age class 81 to 90 years, after which a gradual decline is noted. This fact might possibly reflect the rate of growth of the tree and therefore of the heartwood and indicate a dropping off in rot activity simultaneously with a slowing up of the annual growth.

RELATION OF DECAY TO VIGOR, CROWN RATING, SIZE, AND VOLUME.

Decay in western hemlock is the main factor of depreciation outside of fire. No other destructive agency operates upon this tree to cause so much waste and none is so difficult to control. The preceding data have shown how the tree, especially when growing in river-bottom sites, is subject to attack by this fungus at an early age, and for the youngest age classes the river-bottom type shows a greater average volume of rot than the southwestern-slope type. In the data secured from lumbermen of the Northwest it is found that a high rate of decay is general in western-hemlock and grand-fir stands and especially so in low, poorly drained bottoms. The hemlock and also the grand fir reacts more favorably in the sites where the factors concerned in the growth of the tree are less favorable to the advance of the attacking fungus.

The relation which such factors as vigor, crown rating, size, and volume bear to the inception and progress of decay has never been thoroughly demonstrated. A difficult part of this task lies in obtaining comparable figures to indicate the rating for lack of vigor, the crown rating, the degree of infection, and the degree of injury. By standardizing these factors on numerical data, a basis for comparison has been secured. In the first part of Table III are arranged the averages of 120 trees, taken from the various plats worked as growing on the river-bottom site. In this table the total height represents a measurement from the ground to the tip of the tree. The crown size is given as the product of the height of the crown by the width. The crown rating and lack of vigor are determined from the field sheets, according to the standard outlines given. Similarly, the total volume and the volume of rot determine the rot percentage. In the column "Lack of vigor," the figures represent the relative numerical values, determined in the following manner: All trees (18) of the 101 to 160 age class were grouped together (second part of Table III). Three of these trees had a lack of vigor represented by 00, 10 trees by 000, and 5 trees by 0000. 3(00) equals 6(0), 10(000) equals 30(0), and 5(0000) equals 20(0), which gives a total of 56(0). This figure divided by 18 gives 3.1(0), which is indicated by 3.1. This gives a numerical basis for the relative values of lack of vigor in plotting the graphs. A similar method was applied to the data in the column under crown rating, and the results secured were used in the plotting of the graphs (figs. 11 and 12). This method was also used in the "Average degree of injury" column in Table IV and in plotting points for the graphs in figures 11 and 12.

The process was applied to the trees of the various plats which were growing upon the southwestern-slope sites, and the resulting data are arranged in the second part of Table III. Pathological graphs were then constructed from each of the two parts of Table III, using all the factors concerned and arranging the units in such a manner as to secure the least confusion in following the individual graphs. In the graph in figure 11, constructed from the figures relating to river-bottom plats in Table III, the first points to be noted are that the diameter, height growth, crown size, total volume, and volume of rot all increase with the increase in age. This is found to be true also in figure 12 (with the exception of crown size), which graphically expresses the data given for plats of the southwestern-slope type in Table III. In searching for those factors most prominent in their relations to the degree of infection and included within the first eight factors of the graph, there is apparently no one which stands out. The factors of height, diameter, crown size, total volume, and lack of vigor show increase with increased age, so that no special importance can be attached to these in so far as any one directly influences the rate of decay. The data herein given are not sufficient proof that vigor is the one outstanding factor influencing decay; since vigor is expected to decrease with increased age, the parallelism of increased decay and decreased vigor can not be interpreted as a direct influence exerted by vigor. No doubt vigor plays an important part in the speeding up or slowing down of the rate of decay in a tree, if only this relation could be determined accurately and definitely.

The total rot percentage for the entire stand of the bottom type is 26.6, as compared with 30.8 per cent for the slope type. This slight difference in the percentage of total rot for the two types (where a greater difference might be expected) is significant and is no doubt due to the fact that under each site are grouped all the trees, ranging from the youngest to the oldest. A comparison of the percentages of infected and uninfected trees for the two sites shows a striking difference in results from different methods of presenting the amount of infection in a stand. In the river-bottom type, 97 per cent of the trees were infected and 27 per cent of the wood decayed. In the slope type, 90 per cent of the trees were infected and 31 per cent of the wood decayed. A comparison of these figures indicates that ease of infection is the factor in which the bottom type exceeds the slope type and the rate of spread of decay in the trunk is less speeded by bottom location, if at all. The latter belief seems to be borne out by the fact that the rate of spread in the bottom type must necessarily have been slow, since the stand was composed of comparatively young trees of small heartwood content.

In the slope type the environment is favorable to the full development of tree growth, with an environment equally unfavorable to the development of fungi. The reverse is true of the river-bottom type. This is evidenced by the facts brought out in Table III (figs. 11 and 12), which show that decay is more pronounced in the river-bottom type than in the other. The graphs also show that in the 41 to 100 year age class (Table III) the conditions for the best development of the health of the trees were far below those for the 101 to 160 year age class.

RELATION OF DECAY TO INJURY AND TO SPOROPHORES.

The relation of injuries to decay in respect to furnishing entrance points for infection has been accepted with little opposition, and in many instances in culturing fungi it has been found that the opening of the protective tissues of the host plant was necessary in order to produce infection. A portion of the field data was obtained with the principal object of determining the part played by the degree of injury. All injuries were noted as to size, height on tree, side of tree affected, total number, and condition (whether healed or not healed); whenever possible the age when the injury was inflicted and the time taken to heal were also noted. A special effort was made to determine, if possible, the particular injury causing the original infection. This was generally taken to be at the point on the trunk where the oldest sporophore appeared. Table IV gives summaries for the river-bottom and southwestern-slope types, respectively, based upon an age-class division of the trees.

TABLE IV.—*Relation of injuries causing heart-rot to the age and to the total stand of western hemlock trees on plats of the river-bottom and southwestern-slope types.*

Type and age class.	Infection traced to—								Uninfected trees.		Average degree of injury.	Number of trees.
	Branch stubs.		Frost cracks.		Broken tops.		Miscellaneous injuries.					
	Number of trees.	Per cent.	Number of trees.	Per cent.	Number of trees.	Per cent.	Number of trees.	Per cent.	Number.	Per cent.		
River-bottom type:												
41 to 100 years	103	91.2	1	1.0	3	2.6	[a] 2	1.7	4	3.5	1.19	113
101 to 160 years	7	100.0	0	......	0	......	0	......	0	......	2.05	7
Total	110	92.5	1	.1	3	2.5	2	1.6	4	3.3	1.14	120
Slope type:												
41 to 100 years	9	60.0	1	6.7	0	......	0	......	5	33.3	1.3	15
101 to 160 years	12	66.6	0	......	1	5.7	2	11.1	3	16.6	2.1	18
161 to 200 years	16	70.0	1	4.0	3	13.0	3	13.0	0	......	2.5	23
201 years and older	22	88.0	0	......	2	8.0	1	4.0	0	......	2.6	25
Total	59	72.8	2	2.6	6	7.4	6	7.4	8	9.8	2.1	81

[a] Windfall scars.

Table IV shows that by far the greatest percentage of infection was attributed to branch stubs (figs. 6, 7, and 8).

This amounted to 92.5 per cent in the river-bottom type and 72.8 per cent in the slope type for the total stand in each type. Broken tops come second, and miscellaneous injuries, such as windfall and logging scars, etc., reached a percentage of 7.4 in the slope type and 1.6 in the river-bottom type. Grouped under miscellaneous causes were such injuries as blazes, logging, windfall and fire scars, lightning, etc., and a considerable amount of sapsucker injury. The first infection was not attributed to a certain injury unless the development of a sporophore on it (fig. 2) showed this to be the most apparent point of infection. The relative degree of injury as determined upon a basis of age class is shown in figures 11 and 12, taken from Table IV under the head of "Average degree of injury." This shows an increase in degree of injury with an increase in the degree of infection and with increased age. With increase in age the cumulative chances for infection due to injuries of all kinds, and especially to branch stubs, increase appreciably, and it is but natural that the older trees bearing many injuries and a high degree of injury should show an equally high degree of infection.

The two types of stand compared on the basis of the amount of injury are found to vary but little in the general relation between the degree of infection and the degree of injury. In both types the groups of higher rot percentage also show a higher degree of injury, and similarly the groups of lower rot percentage show a smaller degree of injury. In both sites the infections traced to branch stubs bore the largest percentage and the frost cracks the smallest. Broken tops in both instances came second in importance.

In the southwestern-slope type (Table IV), the percentage attributed to broken tops was larger than in the river-bottom type (Table IV), due to the more exposed location and to the older stand. Infections traced to branch stubs in the slope type equaled 72.8 per cent of the total, while in the river-bottom type it equaled 91.5 per cent. It would appear that in spite of the younger age class the river-bottom type developed more infection-producing branch stubs than the other. A reason for this may be found in the fact that the crowded, suppressed condition of the river-bottom stand was much more favorable to the infection of branch stubs than the other more open type of stand. The high proportion of branch-stub infections to injury infections can be partly explained by the fact that the trees of the river-bottom type, being younger, had fewer injuries.

In the slope type the largest amount of injury was found in the oldest age class (201 years and older), and in the river-bottom type it was also found in the older age class (101 to 160 years). In the slope type 10 per cent of the trees were uninfected, and in the river-bottom type a much smaller percentage (3) was uninfected, showing by this comparison a more favorable environment for the attacking fungus in the river-bottom sites.

The slope type exhibited more frost cracks, broken tops, and miscellaneous injuries to the stand than the river-bottom type, which is due partly to the older age and partly to the more exposed situation. The wind plays an important part in both the formation of frost cracks and in the broken-top condition of many of the trees. It was particularly interesting to note that most of the oldest and largest frost cracks were found to have formed in the hollows between the root spurs. This seems to be more general in the slope type, where the exposure to high winds and the height of the trees (in connection with low temperature) appears to play an important part in their formation. The swaying of the trees by the wind when the low temperature has set up a stress within the tissues of the lower trunk would cause the cracks to form at right angles to the swaying movement and in the root-spur hollows, where the least resistance to splitting was to be encountered. The swaying of the tree alone sets up varying forces of strain and rupture in the lower part of the tree, and when the tissues are contracted or prevented by low temperatures from adjusting themselves, a frost crack eventually occurs.

Sporophores of fungi, if they develop at all, appear after a certain period has elapsed from the time of first infection. This period, up to the present time, has not been determined for most of the xylophilous fungi, at least not for *Echinodontium tinctorium*. Such determination would involve a considerable amount of careful inoculation work upon trees absolutely free from fungous infection, which in the case of wood-destroying fungi would extend over a period of several years. The relation which sporophores bear to the development of decay in the host and to the degree of infection can more easily be determined. A careful field study of the tree in question with reference to recording all possible data relating to the sporophores has developed several interesting facts. Little work has been done along this line tending to give actual figures as a basis for conclusions. The data collected are grouped under the two parts of Table V for the river-bottom and slope types, respectively. Under the heading "Position on tree," the sporophores were grouped to indicate whether the northerly growing sporophores were more numerous than those growing on the southerly side of the tree. The remaining columns in Table V are self-explanatory with the exception of the column headed "Relative position along trunk." This refers to the vertical position of the largest sporophore with respect to the other sporophores on the same tree. For example, tree No. 50 had a total of five sporophores, of which the third one from the ground was the largest. This condition was expressed by the figures 3–5, indicating that the position of the largest sporophore was in the center of the group. This method was used throughout, and the resulting figures were used to determine whether the largest sporophore was found more commonly in the center or toward either end of the group.

The river-bottom type with reference to its sporophore data (Table V) is in general very similar to the slope type. Out of a total of 119 trees, 70 (59 per cent) were sporophore-bearing trees. On these 70 trees a total of 149 sporophores were found, of which 131 (88 per cent) were living and 18 (12 per cent) were dead, giving an average of 1.8 live sporophores to a tree and 1 dead sporophore to every 4 trees. These figures show a much larger percentage of live sporophores than those of the slope type. Almost all (96 per cent) of the largest were living, which was equally true of the sporophores in general. The average height from the ground is 8.7 feet. The northwest to north-northeast grouping held 53 per cent of the total sporophores, the southwest to south-southeast grouping 27 per cent, the east 9 per cent, and the west 11 per cent. Most of the sporophores are grouped on the northern aspect of the trunks, with a smaller percentage on the southern. Upon dividing the sporophores into groups corresponding to the eight principal points of the compass, it was found that most of them (23 per cent) were on the northwest side, the next largest on the south (18 per cent), and the smallest number on the southeast (3 per cent).

The figures in Table V, river-bottom type, relative to the number of sporophores are plotted in figure 11 and show the relation between the degrees of infection and the number of sporophores. To avoid the awkwardness of using such an expression as "1.3 sporophores" in the diagrams, it was thought proper to term this factor "Number of sporophores per 10 trees" and use the same figures after multiplying each by 10. This does not alter the comparative value of the figures. These data and the pathographs indicate how the increase in the number of sporophores keeps pace with the increase in the degree of infection.

In the southwestern-slope type (Table V), out of a total of 81 trees 54 (67 per cent) bore sporophores in varying numbers. These 54 trees carried a total of 210 sporophores, of which 141 (67 per cent) were alive and 69 (33 per cent) were dead, giving an average of 2.6 live and 1.2 dead sporophores per sporophore-bearing tree. More than half (60 per cent) of the largest were living. These data indicate that the number of sporophores increases with increased age and with increase in the degree of infection as expressed by the rot percentage. This holds true for all the age classes except the oldest, which is found to have a smaller total number of sporophores and a smaller number per 10 trees than the 161 to 200 age class. This may be due to the fact that the maximum sporophore production has been reached in the 161 to 200 age class and to the further fact that on old trees the older sporophores are often found to have dropped to the ground. An average of all the figures relative to the vertical position of the largest sporophore gave a figure which placed it at or very near the middle point. This would seem to indicate that the decay spreads more or less in both directions up and down the trunk from the point of original infection; consequently the sporophores are produced on either side of the largest as the decay progresses. This is, of course, not true in every case, but the average condition is found to be such.

TABLE V.—*Summary of sporophore data relating to heart-rot of western hemlock trees on plats of the river-bottom and southwestern-slope types.*

Age class.	Number of trees (basis).	Number of trees bearing sporophores.	Sporophores: Number alive.	Sporophores: Number dead.	Sporophores: Total number.	Sporophores: Average number per tree.	Sporophores: Largest: Average age.	Sporophores: Largest: Condition: Alive.	Sporophores: Largest: Condition: Dead.	Sporophores: Largest: Size.	Sporophores: Largest: Relative position along the trunk.	Sporophores: Smallest: Size.	Sporophores: Position on tree: Average height.	Sporophores: Position on tree: Northwest to north-north-east.	Sporophores: Position on tree: Southwest to south-south-east.	Sporophores: Position on tree: East.	Sporophores: Position on tree: West.	Infection traced to—: Branch stubs.	Infection traced to—: Broken tops.	Infection traced to—: Frost cracks.	Infection traced to—: Miscellaneous injuries.
River-bottom type:							*Yrs.*			*Inches.*		*Inches.*	*Feet.*								
41 to 100 years	112	64	118	14	132	1.2	6.6	61	3	9 by 6 by 4	Lower	1 by 1 by 1	8.3	67	38	12	15	105	2	0	1
101 to 160 years	*a* 7	6	13	4	17	2.4	10.0	6	0	8 by 6½ by 3	Middle	3 by 2½ by 1½	13.1	12	3	1	1	7	0	0	0
Total, Number	119	70	131	18	149	......	......	67	3	9 by 6 by 4	......	1 by 1 by 1	......	79	41	13	16	112	2	......	1
Total, Per cent	......	58.8	87.9	12.1	......	......	......	95.7	4.3	......	......	......	......	53	27	9	11	97.4	1.7	......	0.9
Average per sporophore-bearing tree.	......	......	1.80	*b* .25	2.1	......	*c* 7	All.	......	5 by 3½ by 2½	(*d*)	......	8.7	(*e*)	......	......	......	All.	......	......	......
Slope type:																					
41 to 100 years	15	1	1	0	1	.07	9.0	1	0	8 by 5 by 3	Middle	......	9.5	......	......	......	1	8	......	1	......
101 to 160 years	18	11	21	10	31	1.70	8.5	9	2	9 by 5 by 5	do	3 by 3½ by 1	30.6	14	12	0	5	13	1	0	2
161 to 200 years	23	20	63	29	92	4.00	15.1	10	10	16 by 8 by 8	do	3 by 3 by 2	40.4	40	24	12	16	16	4	1	2
201 years and older	25	22	56	30	86	3.40	12.8	13	9	11 by 11 by 5	......	3 by 2 by 2	45.3	26	21	16	23	23	2	......	......
Total, Number	81	54	141	69	210	......	......	33	21	16 by 8 by 8	Middle	......	......	80	57	28	45	60	7	2	4
Total, Per cent	......	66.6	67.1	32.9	......	......	......	61.1	38.9	......	......	......	......	38.1	27.1	13.3	21.5	82.2	9.6	2.8	5.4
Average per sporophore-bearing tree.	......	......	2.6	1.3	4.0	......	*f* 13	All.	......	7 by 6 by 4	Middle	......	39.9	(*e*)	......	......	......	All.	......	......	......

a Sporophore data lost on one tree, which therefore was not included.
b One to every four trees.
c Average age of largest sporophores.
d Between middle and lower.
e All northerly.
f Average age of largest sporophores.

The distance from the ground of the largest sporophore ranges from 4.5 feet in the case of younger suppressed trees to 78.5 feet in the case of a large 300-year-old veteran. The average height indicated 39.9 feet. The grouping of the sporophores in respect to their cardinal positions on the tree gave some very interesting figures. The largest number of the sporophores (38 per cent) was found in the northwest to north-northeast grouping, 27 per cent in the southwest to south-southeast, and 21.5 and 13.5 per cent in the west and east groupings, respectively. Upon dividing the sporophores into groups corresponding to the eight principal points of the compass, it was found that 25 per cent were on the north side, the next largest on the west (21 per cent), and the smallest number on the southwest (4 per cent). The data for the slope type show the largest number on the northerly side of the tree. No such overwhelming percentage was secured as in the work of Möller,[1] who assembled data on the sporophores of *Trametes pini* (Brot.) Fr. and found that 45.8 per cent of the sporophores appeared on the west side of the tree and 89.4 per cent on the westerly side. This westerly side included all sporophores listed in the north, south, and west columns.

Figure 12, the southwestern-slope type, represents in the respective column the sporophore data taken from Table V. The same relation is found to exist between the degree of infection and the total number of sporophores as is found in the river-bottom type. The number of sporophores per 10 trees ranges from 13 in the 41 to 100 age class to 24 in the 101 to 160 age class, exhibiting a considerable increase between the two. In the slope type a similar rate of increase can be noted, which is constant between all the age classes except the two oldest.

THEORY OF INFECTION.

Suppression caused by shade combined with a crowded condition of root spacing as well as crown spacing tends to reduce vigor appreciably. A poorly drained soil having a large amount of soil moisture is another factor to be considered in this connection.

Upon the vigor of a tree depend all its vital functionings, its ability to enlarge and elevate its crown toward better lighting, to secure raw material and manufacture food, to compete with its neighbors, to quickly heal wounds, and to resist attack by fungous enemies. The predisposition or inherent susceptibility of a tree to disease is not considered a sufficient cause for the extensive attack and development of a fungus in that tree. It is believed that low vigor or a

[1] Möller, A. Über die Notwendigkeit und Möglichkeit wirksamer Bekämpfung des Kiefernbaumschwammes Trametes pini (Thore) Fries. *In* Ztschr. Forst. u. Jagdw., Jahrg. 36, Heft 11, p. 677–715, 2 pl. (partly col.) 1904.

natural weakness in healing injuries, producing resin, etc., combined with environmental factors is responsible for the intensive and extensive fungous activity within this species of tree. At the same time it must be borne in mind, especially in the case of hemlock, that such a natural trait as the absence of any great amount of protective resin must be considered as playing an important part in the entrance of the disease. The foregoing data have clearly shown that one fungus is responsible for almost the entire amount of heart-rot found in western hemlock, that the river-bottom type exhibits more decay than the other (comparing the youngest age class), that this type also exhibits a remarkably early decay, and that as a whole a large amount of heart-rot is found in hemlock at early periods in its life.

Dense stands growing in moist, poorly drained soils develop a large number of suppressed or low-vigor trees. This is more commonly the case when the stand is overtopped by older trees of other species. The low vigor due to the overshading of the lower crown causes the early and numerous formation of shade-killed branches. These in time produce branch stubs which are believed to be responsible for most infections by *Echinodontium tinctorium.* The shading of the crown, especially the lower crown, not only causes the eventual formation of branch stubs but produces a moisture and shade condition favorable to the germination and entrance of the fungus. As a theory of infection for hemlock types, this is corroborated by the fact that in thinnings made by cutting out the more merchantable species the secondary crowns formed rapidly and vigorously by an enlargement and thickening of the regular crown. This fact, coupled with the observation that very few living sporophores were found 10 years after the thinning, strengthens the theory.

DISCUSSION OF RESULTS.

As a preliminary to the discussion of the main points brought out in the foregoing pages, it is essential to review briefly the main silvicultural characteristics of the tree in question. It will then be easier to point out the importance of the various factors influencing decay and to arrive at certain conclusions regarding the action of the fungus *Echinodontium tinctorium* during its life history on the host.

The western hemlock, as indicated by its distribution, requires a cool and moist climate for its development, and an important fact in this connection is its splendid maximum development along the western slope of the coast ranges, where it receives an annual rainfall of from 70 to 100 inches.[1]

---

[1] Allen, E. T. The western hemlock. U. S. Dept. Agr., Bur. of Forestry Bul. 33, p. 10. 1902.

Its moisture requirements seem to be the principal limiting factor of its distribution, since it is found growing on a variety of soils. Its altitudinal range extends from sea level in Alaska, British Columbia, Washington, and Oregon to an altitude of 6,000 feet, and in Idaho and western Montana it is found at a maximum altitude of 5,000 feet. It is always at its best in cool moist draws or north slopes. Regions with a relatively high humidity favor its development, although at some of the higher altitudes the humidity is much less than in the bottom-land sites.

A very tolerant species, it is found to thrive in Idaho and Montana in the white-pine type, generally in a mixed stand. Referring to its tolerance, Sudworth[1] says it is "very tolerant of shade throughout life, especially in seedling stages. In later life vertical light is necessary for best growth. Allowed overhead light, it recovers remarkably well from long suppression and renews rate of growth. Prolonged suppression in dense shade greatly checks growth. It thrives in cool, open, humid places with abundant soil moisture."

No natural thinning takes place under normal conditions, and in mixed stands the pruning of the lower branches is a slow and imperfect process. Shade causes the lower branches of the crown to die, and these remain on the trunk until broken by wind, windfalls, or other causes. This condition leaves the tree with a large number of branch stubs open to infection by fungous spores.

Hemlock in its green condition contains 40 to 60 per cent of its own dry weight of moisture,[2] a relatively large amount compared to the other trees of the region. This fact has a direct bearing upon the action of the fungus in the heartwood and accounts for the water-logged condition of the base of the tree which is often encountered in stands growing on poorly drained soils.

In summing up the points brought out by this study the most pronounced results are found in the variations in the action of the decay in the two types studied. A glance at the plat descriptions given for each type (Table I) will show the variation in slope and exposure as well as the marked difference in soil and atmospheric moisture. The river-bottom type, growing as a dense suppressed stand on a heavy undrained soil in close proximity to the river and to its numerous sloughs, presupposes its greater susceptibility to the attack of the fungus. In the absence of trees of an older age class it can only be assumed that the rot percentage would increase with age. The fact that the rot percentage in the older age class was lower does not invalidate this assumption in view of the small number of trees it

[1] Sudworth, G. B. Forest trees of the Pacific Slope, p. 95. 1908. Published by U. S. Department of Agriculture, Forest Service.

[2] Hanzlik, E. J., and Oakleaf, H. B. Western hemlock: its forest characteristics, properties, and uses. *In* Timberman, v. 15, no. 12, 1914, p. 25–33, tab. 3.

contains. The total percentage of infected trees as well as the total rot percentage of this type in comparison to the slope site bear out this statement (Table III). The relation of moist sites to the degree of infection of a stand has been noted by Hartig,[1] who says: "The climatic conditions peculiar to a given district may render it especially liable to outbreaks of certain diseases. Thus, in alpine districts proximity to lakes and narrow valleys specially predisposes to certain fungoid diseases, because the moist air of such places favors the fructification of fungi in a high degree." The loss of vigor due to the unfavorable environmental conditions and principally due to suppression by shade is responsible to a certain extent along with other factors in the rapid and universal spread of the decay on this site. Meinecke [2] states: "The relative extent of decay by *Echinodontium tinctorium* is far greater in slow-growing, suppressed white firs than in thrifty ones." And in discussing the susceptibility of hemlock to injury Hanzlik and Oakleaf [3] state: "Broken branches and injuries to the bark account largely for the spread of conk (*Trametes pini*) and the stringy brown-rot (*Echinodontium tinctorium*), these being more abundant in overmature stands and in suppressed stands overtopped by mature growth."

That on the river-bottom type the trees are decayed at an earlier age, is brought out by a comparison of the data given. The river-bottom type in comparison with the slope type exhibits not only extensive decay at an earlier age and a younger age of infection but a larger number of branch stubs and sporophores for similar age classes for the stand. The data secured from the lumbermen of the northwestern region also aid in determining the fact that hemlock is more defective on lower elevations, on bottom or flat sites, and on poorly drained soils.

In making use of pathological data in the determination of pathological cutting ages for a stand, the rot percentages as given here for separate age classes of the stand are of some value. With the rot percentages as a basis (indicating the ratio of the rot volume to the total volume of the stand for each age class), the forester can determine a cutting age for that stand, using all the economic and silvicultural factors to aid him in a correct determination. The average annual increase in rot volume between age classes can also be used to advantage in determining the rapidity of increase in rot volume. Forest pathology can thus serve to furnish pathological data for particular stands, which data can be applied by the practical forester

[1] Hartig, R. Textbook of the Diseases of Trees. Translated by William Somerville, p. 10. London and New York, 1894.

[2] Meinecke, E. P. Forest-tree diseases common in California and Nevada, p. 27. 1914. Published by U. S. Department of Agriculture, Forest Service.

[3] Hanzlik, E. J., and Oakleaf, H. B. Op. cit.

in a solution of such forest-regulation problems as are appreciably influenced by the presence of decay in the stand. When once the forester reaches the point in his calculations upon a proposed sale where he can determine a certain rot percentage as the maximum to be considered in a stand in order to secure the required amount of sound material at a minimum cost, with this rot percentage as a basis it will be comparatively easy to compute the cutting age of that stand.

METHODS OF CONTROL.

The methods of control applicable to such types as are here under discussion can be little other than extensive. The foregoing data, owing to the small number of trees included in some of the age classes and to apparently unavoidable errors, are not to be taken as exact in determining the cutting age but are given merely as an aid to this determination. Intensive control methods can not be applied to logging operations where extensive logging methods are practiced. Methods such as can be readily incorporated into the usual routine of logging operations and conforming to the practice of the Forest Service are the only ones which can hope to fill the need for forest sanitation among the all-practical lumbermen and foresters. Intensive control can be practiced to a limited extent only upon such sales areas as warrant the additional cost.

The control of wood-destroying fungi is not a matter comparable to the curative treatment of human disease, but is solely dependent for its success upon prevention. With few exceptions there is no help for a stand after it is once attacked by the fungus; hence, if preventive measures are to be effective they must precede the infection, or at least precede the period when the production of spores endangers the remaining healthy trees. There are several methods applicable to the hemlock type, and these can be grouped under two heads, sanitation clauses in timber sales [1]. and pathological rotations. Under the first come such suggestions as girdling, killing by burning of infectious cull material and piled brush, thinning, and the direct cutting and burning of infected material. Under the second appear such methods based upon a study of the area in question as would lead to a cutting cycle aiming to secure the maximum amount of sound material with a minimum risk of future infection and at a minimum of cost. Each particular sale area has its individual variations affecting the pathological condition of the stand. The species in the mixture and the relative percentage of each, the slope and exposure, the moisture conditions, the cost of logging, the value of the species in the stand (in fact, all the environmental and economic factors) have to be taken into consideration before an attempt can be made to determine a method of control.

[1] Meinecke, E. P. Op. cit., p. 62. 1914.

A pathological survey of sales areas made with the object in view of determining the best method of incorporating sanitation clauses or of establishing pathological cutting ages would be an important step toward a practical and effective means of reducing the total amount of good timber going to waste every year in our forests. Girdling by the ax as a method of removal of infected trees left standing on a sale area is not to be recommended as an effective means of control. If the situation allows of no better method, then the girdling should proceed, the utmost care being exercised in severing all the transporting tissues. The recuperative ability of hemlock in regard to the healing of wounds is very great (fig. 13). Merely cutting a cleft in the outer sapwood, leaving the chip in

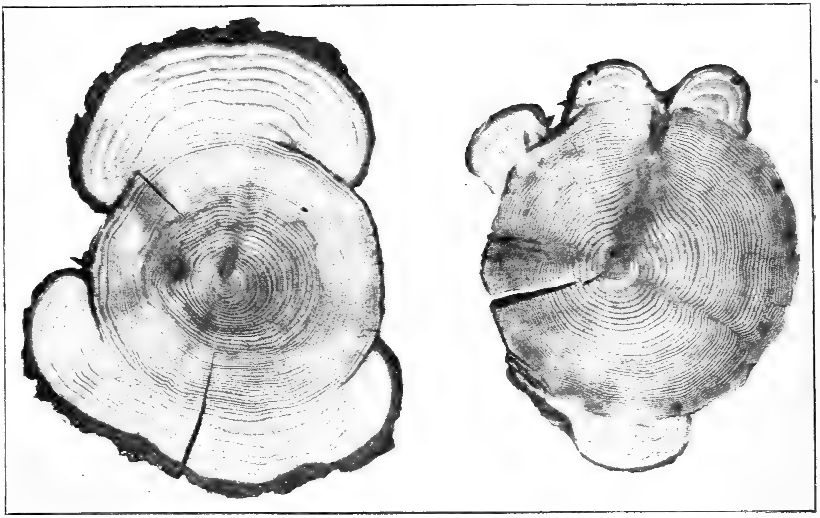

FIG. 13.—Cross sections of grand fir (at left) and western hemlock (at right), showing the result of imperfect girdling by the use of an ax.

place, will not suffice. The wound is very apt to heal, and even if it does not the tree may continue to live for years because the transporting tissues have not been actually severed. It is to be remembered that the wood of hemlock, owing to its nonresinous nature, probably retains its ability to conduct water and food substances longer than that of many of its associates; hence it will be found necessary to insist upon thorough girdling. Some notable instances of the longevity of even thoroughly girdled hemlocks and firs have come to notice in which the trees continued to live for five to eight years although the bark and part of the wood had been removed entirely around the tree for a foot or more. Trees under the shock of this wounding will sometimes produce as much seed in the year following as during several years of normal life. This point is important in connection with the girdling sometimes done for the purpose of removing seed trees of undesirable species.

In view of the need of a rapid destruction of fungus-infected trees, viz, those that may not be considered safe to leave on sales areas, there is much in favor of burning the trees severely and allowing them to stand. Girdling trees by fire is an old and successful practice. There should be sufficient loppings from the other merchantable trees that when piled about the base of the hemlocks and burned will effect their death without much injury to the forest soil or to the seeds of desirable species which may be embedded in the soil.

Thinnings whenever conformable to the conditions of the sales areas are of importance in greatly increasing the vigor and therefore presumably the ability to resist fungus attack in the remaining infected trees, and apparently reducing the number of viable and spore-producing fruiting bodies produced.

Under certain conditions where it is found practicable, a method of control by fire can be very effectively used. It has been observed that in cases where the down logs of hemlock were left in a sufficiently shaded and moist situation sporophores of *Echinodontium tinctorium* were developed, which were a source of infection to the remaining stand. The cutting of all infected trees and the piling and burning of all infectious cull material along with the brush will not only remove the fungus-infected wood but will prevent the formation of infection-spreading sporophores.

SUMMARY.

Western hemlock, a tree subject to prejudice by lumbermen and now beginning to find its place in the lumber markets, is abundantly distributed throughout the northwestern United States and western Canada.

It is found to be subject to a large percentage of decay, which is partly accountable for the prejudice against it.

Echinodontium tinctorium E. and E., the Indian-paint fungus, is responsible for practically all the decay in standing timber of western hemlock, causing a stringy brown-rot of the heartwood which extends to all parts of the tree.

In general, the sites and associations of western hemlock are favorable to the development of decay, and the moisture relation seems to play an important part in this respect. The absence of large quantities of resin, the tolerant habit of the species, the early and abundant formation of branch stubs, and the large number of spores produced yearly—all these are important factors in the rapid and extensive development of decay in the stand.

The fungus enters mainly through branch stubs. Frost cracks play a minor part as first-infection injuries. From the point of first infection, apparently coincident with the largest sporophore, the decay extends up and down the heartwood until all the susceptible heartwood is attacked. The extent of decay is found to increase with age. A high degree of injury, large numbers of sporophores, low vigor, and smaller crown sizes appear to develop more or less parallel with the increase in decay.

The environmental factors in the river-bottom type are more favorable to the early and extensive development of decay. A large percentage (97) of the total trees of the northern Idaho plats examined were found to be infected. Of 10 trees less than 60 years old and 3.5 inches in diameter breast high, 9 were infected.

The environmental factors in the southwestern-slope type are less conducive to early decay. The maximum development of the fungus is not reached until the stand is old.

A large number of sporophores are produced on both sites, the river-bottom site on a comparison basis of age class showing the greater number. The 48 trees over 160 years of age bore an average of 3.7 sporophores per tree.

Pathological cutting ages based upon data secured by thorough pathological surveys and adjusted to the economic factors concerned, if applied to all stands of hemlock, would aid greatly in checking the spread of the disease and would determine the cutting age of the stand before the increase in rot became too great for economic logging. In the present study this could be applied to the slope type only, since the trees of the river-bottom type are all below merchantable size.

A rigid sanitation clause inserted in all timber-sale contracts involving western hemlock should be aimed principally at the destruction by fire of all infectious cull material as well as all infected trees left standing. Girdling by the ax is not recommended.

These two control methods, when adapted to the situations they best serve, will pave the way to the sanitation of the western hemlock stands as well as other types of forests in the Northwest.

THE PRESIDENT TO THE FARMERS OF AMERICA.

[Extracts from President Wilson's message to the Farmers' Conference at Urbana, Ill., January 31, 1918.]

The forces that fight for freedom, the freedom of men all over the world as well as our own, depend upon us in an extraordinary and unexpected degree for sustenance, for the supply of the materials by which men are to live and to fight, and it will be our glory when the war is over that we have supplied those materials and supplied them abundantly, and it will be all the more glory because in supplying them we have made our supreme effort and sacrifice.

In the field of agriculture we have agencies and instrumentalities, fortunately, such as no other government in the world can show. The Department of Agriculture is undoubtedly the greatest practical and scientific agricultural organization in the world. Its total annual budget of $46,000,000 has been increased during the last four years more than 72 per cent. It has a staff of 18,000, including a large number of highly trained experts, and alongside of it stand the unique land-grant colleges, which are without example elsewhere, and the 69 State and Federal experiment stations. These colleges and experiment stations have a total endowment of plant and equipment of $172,000,000 and an income of more than $35,000,000, with 10,271 teachers, a resident student body of 125,000, and a vast additional number receiving instruction at their homes. County agents, joint officers of the Department of Agriculture and of the colleges, are everywhere cooperating with the farmers and assisting them. The number of extension workers under the Smith-Lever Act and under the recent emergency legislation has grown to 5,500 men and women working regularly in the various communities and taking to the farmer the latest scientific and practical information. Alongside these great public agencies stand the very effective voluntary organizations among the farmers themselves, which are more and more learning the best methods of cooperation and the best methods of putting to practical use the assistance derived from governmental sources. The banking legislation of the last two or three years has given the farmers access to the great lendable capital of the country, and it has become the duty both of the men in charge of the Federal-reserve banking system and of the farm-loan banking system to see to it that the farmers obtain the credit, both short term and long term, to which they are entitled not only, but which it is imperatively necessary should be extended to them if the present tasks of the country are to be adequately performed. Both by direct purchase of nitrates and by the establishment of plants to produce nitrates, the Government is doing its utmost to assist in the problem of fertilization. The Department of Agriculture and other agencies are actively assisting the farmers to locate, safeguard, and secure at cost an adequate supply of sound seed.

The farmers of this country are as efficient as any other farmers in the world. They do not produce more per acre than the farmers in Europe. It is not necessary that they should do so. It would perhaps be bad economy for them to attempt it. But they do produce by two to three or four times more per man, per unit of labor and capital, than the farmers of any European country. They are more alert and use more labor-saving devices than any other farmers in the world. And their response to the demands of the present emergency has been in every way remarkable. Last spring [1917] their planting exceeded by 12,000,000 acres the largest planting of any previous year, and the yields from the crops were record-breaking yields. In the fall of 1917 a wheat acreage of 42,170,000 was planted, which was

1,000,000 larger than for any preceding year, 3,000,000 greater than the next largest, and 7,000,000 greater than the preceding five-year average.

But I ought to say to you that it is not only necessary that these achievements should be repeated, but that they should be exceeded. I know what this advice involves. It involves not only labor but sacrifice, the painstaking application of every bit of scientific knowledge and every tested practice that is available. It means the utmost economy, even to the point where the pinch comes. It means the kind of concentration and self-sacrifice which is involved in the field of battle itself, where the object always looms greater than the individual. And yet the Government will help and help in every way that is possible.

It was farmers from whom came the first shots at Lexington, that set aflame the Revolution that made America free. I hope and believe that the farmers of America will willingly and conspicuously stand by to win this war also. The toil, the intelligence, the energy, the foresight, the self-sacrifice, and devotion of the farmers of America will, I believe, bring to a triumphant conclusion this great last war for the emancipation of men from the control of arbitrary government and the selfishness of class legislation and control, and then, when the end has come, we may look each other in the face and be glad that we are Americans and have had the privilege to play such a part.

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
10 CENTS PER COPY
▽