UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 799

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

Washington, D. C. PROFESSIONAL PAPER November 10, 1919

A STUDY OF THE ROTS OF WESTERN WHITE PINE.

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LOSSES DUE TO FUNGI.

The estimated stand of western white pine (*Pinus monticola*) in British Columbia, Oregon, Washington, Idaho, and Montana is about 23,685 million feet B. M., valued at approximately $102,875,000. The average loss due to the activities of fungi in western white pine for the entire white-pine belt, based on data from logging operations in northern Idaho, is 1,658 million feet B. M.[1] This figure, on a basis of the above given valuation, shows a loss of $7,201,250 from this cause alone. These figures, taken as an average condition throughout the merchantable range of the species, indicate the loss from decay to be enormous. The limited area occupied by merchantable white pine, the adaptability of its wood to a wide range of uses, and the ease with which it is worked so establish its value as a timber tree that it becomes imperative to investigate any cause of financial loss in the species, the amount of this loss, the

[1] Based on the recorded data, which give 6.9 as the average rot percentage for the entire area upon which the data were collected. The actual loss due to rot would no doubt be greater if figured on a basis of cull percentage or actual volume discarded, according to scalers' practice.

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relation of various factors to the rots, and the means by which the loss may be reduced. This, in short, states the purpose of this bulletin.

LOCAL PATHOLOGY OF WESTERN WHITE PINE.

With the exception of the principal fungus (*Echinodontium tinctorium*) attacking western hemlock and grand fir, all fungi occurring on other trees of the western white-pine type attack white pine to a greater or lesser degree. Until it is determined that the interrelations of these fungi vary with different species of trees the conditions for fungous development may be considered very favorable. The western white-pine type of forest is described as having western white pine as the key tree and forming approximately 15 per cent or more of the stand. In some parts of its range (northern Idaho) in young stands western white pine forms as much as 50 per cent or more of the stand. The other species in the mixture are grand fir and western red cedar, the predominant trees of the type, and Douglas fir, western larch, western yellow pine, and lodgepole pine. In many of the mixtures of the western white-pine type, the white pine, although intermediate as to tolerance, very rapidly gains on its associates and eventually overtops them or may even drive them from the stand. One of the results of this suppression of associate species is to promote the activities of fungi in the associate species, which in turn react on the white pine. Fully stocked or even pure stands of western white pine may be found extensively attacked. In the fully stocked stands the trees do not prune readily, causing the development of larger and older dead branches which are open to breakage and infection at an earlier age and also affecting the grade of lumber of the tree. In the pure stands, much suppression naturally results and fungous diseases are just as prevalent as in a mixed stand. Suppression in white pine is not always brought about by overcrowding or by adverse conditions on sites having little protection. Needle fungi may cause retardation by destroying the needles. *Lophodermium pinastri*, in its ascigerous stage and also in its pycnidial stage (*Leptostroma*), is a very common needle fungus throughout the white-pine type and is a factor to be considered in suppression. Mistletoes rarely attack white pine within its merchantable range and may be overlooked as a cause of suppression.

The three main wood-destroying fungi[1] for the areas studied are *Trametes pini*, *Polyporus schweinitzii*, and *Fomes annosus*. The first-named fungus, as the most important, is particularly active in western white pine throughout its merchantable range.

[1] Weir, J. R., and Hubert, E. E. Forest disease surveys. U. S. Dept. Agr. Bul. 658, 23 p., illus. 1918.

The sporophore (conk) of *Trametes pini* (ring-scale fungus) is brown, woody, usually stratified, and varies in shape and thickness. The usual form in the Northwest is a thin shell or scallop shaped structure, but it may become hoof shaped or resupinate, depending upon the position of the substratum or point of exit. Owing to the tendency of the mycelium to spread more rapidly vertically than horizontally in individual annual rings, a cross section of an infected tree shows the decay in the form known as ring-rot. The wood when first invaded by the mycelium of *Trametes pini* assumes a deeper reddish brown than when normal. It first becomes visibly characteristic with the appearance of pits in the wood lined with cellulose fibers. This is the well-known "honeycomb" stage and is the most characteristic stage of the rot. The decay, as indicated above, is not uniformly distributed in the heartwood, but the rot column may vary in location within the tree. This is also due to the fact that several separate infections may occur in the same tree, the diseased areas being separated by sound wood. As a butt rot, the general form of the rot column is conical, tapering at the upper limits. In the upper parts of the tree the rot column may be conical in both directions from the area of greater decay or from the point of first infection. The range of the vertical extent of the rot column in the tree may be from a few feet to the entire length of the tree when acting as a trunk rot and from 5 to 6 feet as a typical butt rot. External signs of the decay are the fruiting bodies, swellings of the trunk in a region of earlier infections, especially at branch whorls, due to the tendency of the tree to heal the old "punk knots," resin flow at swelled whorls or other points on the upper trunk, brownish punky material in old branch knots from which old sporophores have fallen, hollowness or punkiness indicated by soundings on the trunk, and the presence of various injuries.

Polyporus schweinitzii (velvet-top fungus) is usually not as conspicuous as the ring-scale fungus, owing to the fact that the sporophore rarely appears on the trunk but usually develops on the roots near by, and it may be partly obscured by the forest mold. It often appears a considerable distance away from the base of the tree. The fruiting body is in most cases stalked, the segments of the top incurving and colored a deep, rich brown. The margins when in a growing condition are of a lighter color. It sometimes appears from old wounds on the trunk in the form of brackets with or without a lateral stalk. The under side of the pileus is yellowish green, which turns reddish if injured. The fungus usually produces a uniform heart-rot of the butt of the tree. It enters the roots and decays the heartwood and may travel in this manner from root to root to neighboring trees. The decay produced is a light reddish brown in early stages, but in its typical stage it becomes reddish brown, brittle and crumbly when dry, with a tendency to break into cubical blocks. The rot has sometimes the characteristic odor of turpentine. The rotted wood is carbonized by the action of the fungus and the cellulose is reduced.

The rot caused by *Trametes pini* is characterized by the delignification of the wood cells attacked. White patches of unreduced cellulose are left. The decay produced by *Polyporus schweinitzii* seldom advances beyond the first log and is usually not more than 5 to 6 feet up. The form of the rot column is conical from the base of the tree upward.

Fomes annosus (root Fomes) on the areas studied was least important. The sporophores of this fungus are generally found close under the surface attached to the roots and hidden by the forest mold. They are brown above, with a white spore surface and usually very irregular in outline. The early stages of decay range in color from lilac to reddish. In the typical stages the annual layers are separated by the more rapid decay of the summer wood. In a radial section white-pitted areas with black centers may be prominent. Finally the wood is converted into a spongy mass. The fungus causes a resin flow from the base of the tree and the roots. A fine felty mycelium is present under the bark in the early stages of decay. The rot column is uniformly circular in advanced stages and may extend from 6 to 8 feet into the first log.

FIELD STUDIES OF THE ROTS IN WESTERN WHITE PINE.

Field studies of the principal rots of a particular species of tree which aim to develop results of practical importance must necessarily be based on data taken from a large number of felled trees. It was decided that 100 trees of each age class for each of the two types of site would be a sufficiently large number to insure the best results. Seven age classes were determined upon as follows: 41 to 60, 61 to 80, 81 to 100, 101 to 120, 121 to 160, 161 to 200, and 201+ years. These are the age-class divisions used by the Forest Service in silvicultural practice in district 1. The two types of site, slope and bottom, were used, under each of which the seven age classes were ranged. Figuring 100 trees per age class and 7 age classes for each of the two types of site gives a total of 1,400 trees upon which accurate data on each tree are required in order to be fairly certain of the results.

Previous to the opening of the summer logging operations, all information relative to the age classes, sites, and locations of the various sale areas scheduled for cutting in the western white-pine type in northern Idaho and western Montana during the field season of 1916 were secured. With this information plans were outlined and arrangements made to secure data on as many of the areas as were necessary in order to comply with the outline previously given. Thanks are due to the officers of the Cœur d'Alene National Forest for their helpful cooperation throughout the season.

In all, seven separate sale areas and one private cutting were covered in the study, and data were secured from each. The Lindberg, Honeysuckle, and Cathcart chances, or sale areas, are located within the drainage of the Little North Fork River. The Tent, Silver, and Boro Creeks sale areas are located in the drainage of the main Cœur d'Alene River, near Nelson, Idaho. The Bennett-Miner chance is located on the slopes adjacent to the North Fork of the Cœur d'Alene River, 20 miles above Prichard, Idaho. The private cutting is located near Priest River, Idaho, and is on the Humbird Lumber Company's land. All of the sale areas, with the exception of the private cutting on the Priest River, are located within the general drainage of the Cœur d'Alene River in the Cœur d'Alene National Forest of Idaho. All the areas studied are typical of the western white-pine type of forest.

Data were secured on the trees soon after the trees had been felled and before any of the logs had been removed by the skidding teams. In this manner it was possible to obtain data on a large number of trees each day. The entire tree was always available, and references to all the trees cut on that portion of the sale area included within the study were covered by the data. No selection of individual trees or groups of trees was practiced, the aim being to record accurate information on the general run of the stand according to age class and site. The sawing of the trees into standard log lengths of 8, 12, 14, and 16 feet by the logging crews offered splendid opportunities to obtain the rot dimensions and other data. The infected culled logs of merchantable size were opened up sufficiently to disclose the rotted area. The top portions of the tree beyond the merchantable limit were cut open by the data crew to determine the exact extent of the rot in cases where the rot ran into the top. Cooperation with the logging contractors and foremen aided greatly in keeping ahead of the skidding teams.

For data on the younger age classes not found on the sale areas, special permission was obtained to cut certain small areas of the younger trees on adjacent areas.

The trees on both the sale areas and the young age-class plats were numbered consecutively as they were measured and recorded, the number being placed on the stump, so that no duplication of trees occurred. Similar extensive and intensive data were obtained for the white-pine study as were secured for the hemlock study,[1] and all available factors were taken into consideration in the final results. Forest descriptions were written for each sale area, and notes were made of the moisture and shade conditions existing on each.

The data obtained from a total of 1,417 trees, of which 135 were grand fir (*Abies grandis*), were first arranged according to site and age class. While in the field it was found that the number of trees needed in the two youngest age classes could be considerably reduced from the 100-tree standard. It was found that the trees on the 41 to 60 age class in both types of sites, slope and bottom, were uniformly free from visible decay. Owing to this condition and to the fact that young white pines of this age class are too small to be merchantable and should not be cut needlessly, it was decided to reduce the number of trees required. In the 61 to 80 age class it was found that the rots were in the beginning stages, and 60 trees per age class for each type of site were considered sufficient. In all the other age classes the number of trees was either above or but slightly below the 100 mark, except in the 121 to 160 age class on the slope sites, where the number was doubled in order to make a comparison between a similar age class and site for two widely separated sale areas, and in the 201+ age class, where it was impossible to find more than the recorded number of trees. There was, fortunately, one sale area which furnished a fairly large number of trees of the very old age class (201+).

Tables were prepared from the data collected, and these will be presented in the order of their consideration in the text. The volumes were figured by means of the Smalian formula. In these tables the word "Infected" as used at the head of certain columns is intended to cover all trees visibly infected. Early stages of infection not determinable by field observations and not measurable as recognized cull are not included.

RELATION BETWEEN ROT AND VARIOUS FACTORS.

AGE.

In Table I are found the data which show the relation between the rot volume and the age class of the stand. These data are separated under heads of "Bottom sites" (upper part of table) and "Slope sites" (lower part of table), and the data under each head are grouped according of the seven principal age classes.

Trunk-rot, indicated in the table by the initials T. R., represents mainly *Trametes pini*. Butt-rot, indicated by the initials B. R., represents *Trametes pini* when acting as a typical butt-rot, but in-

[1] Weir, J. R., and Hubert, E. E. A study of heart-rot in western hemlock. U. S. Dept. Agr. Bul. 722, 39 p., illus. 1918.

cludes *Polyporus schweinitzii* and *Fomes annosus* as well, and *Armillaria mellea* is sparingly represented.

In comparing the slope sites with the bottom sites it is well to keep in mind that the differences in these comparisons are made even more striking by the fact that the average age of the slope type of sites is greater by 14 years than that of the bottom type.

In Table I the average total volume per age class shows a steady increase for both types of site. The trunk-rot for both types also shows a definite increase from the 41 to 60 to the 201+ age class, the bottom sites indicating a greater percentage of rot than the slope sites. The bottom sites for the 61 to 80 age class show 0.8 cubic feet as the average volume of rot and 85 cubic feet for the 201+ age class, as compared to the slope sites, which have 0.055 cubic feet for the 61 to 80 age and 72 cubic feet for the 201+ class. The figures for the average rot volume for the butt rots on the two types of site vary considerably and do not show any consistent increase between the youngest and the oldest age classes. The 161 to 200 age class on the bottom sites runs extremely high, which may be due to the fact that the site from which these trees were taken was very favorable to butt-rot and supported a great deal of *Polyporus schweinitzii.* On the slope sites the average is less for the 161 to 200 age than for the class preceding it. This again must be accounted for by the local environmental differences present in the various areas upon which the trees included in this study were found growing. This is especially true of the 201+ age class on the bottom sites, in which no butt-rot is recorded and where the rot is almost entirely due to *Trametes pini* acting as a distinct trunk-rot.

The " T. R. + B. R." column gives figures for the combined rots, and in general indicates an increase in rot volume and in rot percentage with increased age.

Table I shows computations of the average annual increase in rot volume between the age classes per infected tree. These figures are intended to serve as an approximation of the rate of increase in rot volume during the life of the stand and are used later to determine the infection age.

A study of the relation between sound and infected trees reveals the fact that as the age increased, the percentage of infected trees increased at a quite rapid rate. The bottom sites show the more rapid increase of the two types of site. It is significant to note that the proportions of trees infected for the bottom and slope sites are almost identical, being 55 per cent and 55.3 per cent, respectively. If, in order to remove to a certain extent the source of error due to the larger percentage of trees of the older age class on the slope sites, the averages of the percentages for the different age classes are compared, it is found that the bottom sites show a greater tendency toward favoring fungous development. The average percentage of infected trees for the bottom sites by this method is 52, and for the slope sites 47. On the bottom sites the rot percentage is 7.8, and on the slope sites 6.1. These figures indicate that although a slightly larger percentage of trees was infected (55.3) and although the trees were considerably older on an average on the slope sites, the bottom sites carry the larger rot percentage. Considering the various areas upon which data were taken as a unit, the total volume of rot was found to be 13,359 cubic feet and the total volume of the stand 193,432 cubic feet. This gives a rot percentage of 6.9, or 7.0 figured on a basis of 1,282 sound and infected trees, ranging from the 40 years' growth to the veterans of 450 and more years.

TABLE I.—*Relation of rots to age classes in western white pine on sites of the bottom and slope types.*

[Abbreviations: T. R.=trunk-rot; B. R.=butt-rot.]

Age classes.	Age computations (years).			Average volume (cubic feet).							Number of trees (basis).				
					Rot per infected tree.							Infected.			
								Annual increase between age classes.							
	Average.	Interval between classes.	Percentage of rot for stand.	Total.	T. R.	B. R.	T. R.+B. R.	T. R.	B. R.	T.R.+B.R.	Sound.	T. R.	B. R.	T. R.+B. R.	Percentage.
Bottom sites:															
41 to 60 years	52	....	0	0.99	0	0	0	0	0	0	37	0	0	0	0
61 to 80 years	73	21	.16	30.7	.8	0	.8	.04	0	.04	58	4	0	4	6
81 to 100 years	88	15	.72	82.7	1.7	1.2	1.6	.06	.08	.055	73	38	5	43	37
101 to 120 years	113	25	1.67	150.9	4.2	2.4	4.0	.10	.05	.09	40	63	8	71	64
121 to 160 years	131	18	3.12	196.2	9.5	2.5	9.2	.29	.007	.29	43	83	3	86	67
161 to 200 years	180	49	15.67	203.0	19.0	281.3	33.6	.19	5.7	.50	4	68	4	72	94
201+ years	289	109	18.3	450.5	83.6	135.9	85.0	.59	0	.47	1	37	1	38	97
Total	125	....	7.8	......	18.1	61.6	21.6	......	......	......	256	293	21	314	55
Slope sites:															
41 to 60 years	48	0	0	2.7	0	0	0	0	0	0	50	0	0	0	0
61 to 80 years	65	17	.06	4.6	.03	.14	.055	.0015	.008	.003	56	3	1	4	7
81 to 100 years	91	26	.37	11.2	.19	.16	.17	.006	.001	.0045	74	11	13	24	24
101 to 120 years	110	19	.45	57.9	.8	.295	.6	.03	.007	.025	59	30	11	41	41
121 to 160 years	137	27	2.34	178.9	5.7	6.0	5.7	.18	.21	.19	61	156	18	174	74
161 to 200 years	164	27	2.36	237.3	7.3	5.1	6.7	.06	......	.04	17	61	21	82	83
201+ years	343	179	14.67	485.2	76.3	56.0	72.2	.38	.28	.36	1	55	14	69	98
Total	139	....	6.1	......	17.6	12.9	16.7	......	......	......	318	316	78	394	55.3

SITE.

The western white pine is found in situations which supply sufficient moisture and shade to fill the requirements of the tree. Moisture plays an important part in its establishment and development, and this is emphasized by the fact that the western white pine attains its best growth in the regions where rainfall is plentiful.

In order to get a first-hand impression of the characteristics of western white pine from the point of view of the logger, questionnaires were sent to a large number of lumber and logging concerns operating in the Northwestern States. Out of the total answers received 18 were selected in which the replies to the questions were complete. Most of these answers were received from companies operating in the States of Oregon, Washington, Idaho, and Montana.

In respect to site, most of these answers state that the rot is greatest in trees occurring on flat, low, and poorly drained land, and that the best sites, where trees are freer from rot, are well-drained slopes or benches. Altitudes ranging from 1,500 to 7,500 feet are given as most favorable to healthy stands, and conversely the greatest proportion of rot is found in stands at altitudes below 1,500 feet.

In Table I it is seen that the proportion of rot on the bottom sites (7.8 per cent) is somewhat greater than on the slope sites (6.1 per cent). Apparently, this difference is directly due to the site and corroborates what has already been said in reference to environment favorable to fungous development. The above comparison of rot percentages for the two types of site is made more exclusive when the figures for the percentage of infected trees for each type are considered. The difference, presumably, would have been still greater if the proportion of the trees on sites of the slope type in certain of the older age classes had not been so much greater than for sites of the bottom type. In Table II a comparison is made between two sale areas in the same forest but separated by a considerable distance. The trees occurring on the slope sites only were used, and these were restricted to the age class of 121 to 160 years. A glance at Table II will show that the trees from the Honeysuckle sale area averaged 132 years and those of the Silver Creek sale area 142 years, a difference of 10 years.

TABLE II.—*Comparison of two sale areas of western white pine of the 121 to 160 age class growing on slope sites, showing the relation of rots to site.*

[T. R.=trunk-rot, B. R.=butt-rot.]

Sale area.	Average age (years).	Total volume (cubic feet).				Volume of rot (per cent).			Number of trees (basis).			
		Stand.	Rot.			T. R.	B. R.	T. R. + B. R.	Total.	Sound.	Infected.	
			T. R.	B. R.	T. R. + B. R.						T. R. + B. R.	Percentage.
Honeysuckle.	132	22,172	323.5	96.1	419.5	1.45	0.43	1.89	122	36	86	70.5
Silver Creek.	142	18,095	536.6	1.6	538.3	2.96	.01	2.97	106	24	82	77.3

This indicates a greater number of the older trees of the 121 to 160 age class on the Silver Creek sale area than on the Honeysuckle area. Continuing the inspection of the data in the table it is seen that the total volume of rot, the rot percentage, and the precentage of infected trees for the combined rots are all greater in the case of the Silver Creek area. The difference of 10 years between the average age for the two areas is apparently responsible for the difference in the rot activity just noted and gives further evidence that, the site being similar, the age of the stand affects the amount and percentage of rot as well as the number of trees infected. Eliminating the difference in the average ages between the two sale areas, the slope sites of the two areas should yield more nearly equal values for total volume of rot, rot percentage, and percentage of infected trees.

Another interesting point brought out in Table II is the variation in the amount of butt-rot for the two areas. Very little butt-rot is found upon the Silver Creek area (1.6 cubic feet) in comparison to that found on the Honeysuckle area (96.1 cubic feet).

In Table III comparisons are made between the rot percentages of trees occurring on the slope and bottom sites of the same sale areas. This method of comparison removes all possible variations which might be due to comparisons of plats occurring upon widely separated areas. In general, the figures show a higher rot percentage in trees occurring on the bottom sites than in those growing on the slopes.

On the Bennett-Miner sale area plat 1 was laid out upon the slopes and plat 2 on the bottoms. The bottom sites have a greater average by 38 years and also a greater rot percentage by 6 than the slope sites. In comparing the slope and bottom sites of the Silver Creek plat 1 area it is seen that the difference in average age is only 4 years, while the difference in rot percentage is approximately 5. Again, in comparing the Honeysuckle plat 1 with the Honeysuckle plat 4 area the difference in average age is 7 years and that of the rot percentage 4.5. The greatest difference in rot percentage is found in comparing the Humbird area with the Tent Creek area, between which are found differences of 39 years in average age and 7 per cent in the rot. This last comparison is not as dependable as the ones preceding, since the slope and bottom areas compared were taken from two widely separated sale areas. Similar criticism also applies to the comparison of the Honeysuckle plat 3 with the Silver Creek plat 2 area, which comparison indicates the possibility that the difference in average age may not be entirely responsible for the small rot percentage in the Honeysuckle plat 3 area. Comparing the same Honeysuckle plat 3 area with the Honeysuckle plat 1*a* area it is seen that a difference in rot percentage of 0.538 is more than balanced by a difference of 50 years, which latter is no doubt accountable for the larger rot percentage found on the slope sites.

Table I shows that for each type of site the rot percentage gradually increases from the youngest to the oldest age class, reaching 18 per cent in the bottom sites and 14.7 per cent on the slope sites. Comparing similar age classes of the two types of sites, the figures for rot percentage on the bottom sites run consistently higher than those of the slope sites.

TABLE III.—*Comparison of bottom and slope sites of different sale areas of western white pine, showing the relation of rots to site, independent of age classes.*

Sale area.	Bottom sites.				Sale area.	Slope sites.			
	Plat No.	Number of trees (basis).	Average age (years).	Rot (per cent).		Plat No.	Number of trees (basis).	Average age (years).	Rot (per cent).
Bennett-Miner	2	15	379.1	20.53	Bennett-Miner	1	71	340.6	14.62
Silver Creek	1	18	146.4	8.01	Silver Creek	1	100	142.2	2.98
Honeysuckle	3	70	72.0	.002	Silver Creek	2	149	79.0	.63
					Honeysuckle	1*a*	16	122.0	.54
Do	1	347	111.0	5.23	do	4	33	118.0	.70
Humbird		120	159.6	9.32	Tent Creek		241	120.7	2.19
Total		570			Total		712		

In comparing the average volume of rot for the two types of site in Table I a striking contrast is found between the butt-rot volumes. The average butt-rot volume on the bottom sites is found to greatly exceed the average volume for the slope sites, the average volume of trunk-rot is approximately equal, while the average volume of combined rots is shown to be somewhat larger on the bottom sites.

INFECTION AGE.

The average infection age, as defined in a previous work,[1] represents the average age of the youngest trees in the stand open to first infection by fungous enemies. It is the average age at which the stand is most liable to first infection and below which infection rarely occurs. Subsequent to this age infection is to be guarded against, as the chances of infection, up to a certain point, will continue to increase with the increase in age, number of injuries, etc.

In this bulletin the term *age of earliest infection* is used in place of "average infection age." It is believed the newer term will more accurately convey the meaning intended.

On the bottom sites, Table IV, the age of the earliest infection for the combined trunk and butt rots can be placed approximately in the 61 to 70 age class, since the first tree with visible decay is found in the 71 to 80 age class and is 73 years old. It must be remembered that actual infection is expected to take place some time before visible

[1] Weir, J. R., and Hubert, E. E. A study of heart-rot in western hemlock. U. S. Dept. Agr. Bul. 722, 39 p., illus. 1918.

decay is present in the tree examined, and this fact would tend to place the age of earliest infection somewhat below the age of the tree at the time visible decay is noted.

TABLE IV.—*Relation of rot to age classes, with reference to the infection age of western white pine on sites of the bottom and slope types.*

Age class.	Bottom sites.					Slope sites.				
	Average age (years).	Number of trees (basis).			Average rot per infected tree (cubic feet).	Average age (years).	Number of trees (basis).			Average rot per infected tree (cubic feet).
		Total.	Infected.	Percentage infected.			Total.	Infected.	Percentage infected.	
41 to 50 years	48	16	0	0	0	45	33	0	0	0
51 to 60 years	56	21	0	0	0	56	17	0	0	0
61 to 70 years	66	21	0	0	0	63	48	2	4	.035
71 to 80 years	80	41	4	10	.79	74	12	2	17	.075
81 to 90 years	85	80	26	33	1.78	85	46	10	22	.213
91 to 100 years	94	36	17	47	1.38	95	52	13	25	.145

In Table IV the youngest trees found visibly infected on the slope site are in the 61 to 70 age class, and the age of the earliest infection would be found in the 51 to 60 age class. The youngest tree on the slope sites found to have visible decay is 61 years old. From these data it appears that the age of the earliest infection would be found between the ages of 50 and 60 years, and to be reasonably safe it may be placed at approximately 50 years.

Most of the answers received from the logging companies in reference to the question of the age at which western white pine is first infected give 50 years as the approximate age below which very little infection occurs.

It is apparent that factors other than that of site influence the percentage of infections as expressed by the figures in Table I. On the bottom site (Table I), the 61 to 80 age class, with an average age of 73 years, has only 6 per cent of the total trees infected, as compared to 7 per cent on sites of the slope type for a similar age class with an average age of 65 years. Density of stand and injuries such as fire scars could well be responsible for the increased infection of the trees on the slope sites. Farther along in the table it is found that for the bottom sites in the 81 to 100 age class, averaging 88 years, the percentage of infected trees is 37 as compared to 24 for the slope sites with a similar age class, averaging 91 years.

On both the slope and bottom types of site it is found that the 41 to 60 age class is entirely free from visible infection; that is, no measurable rot recognizable to the naked eye was found in these trees. This fact alone would indicate that an age of earliest infection placed at 50 years would be as nearly correct as the practical application of such an age demands. The site, apparently, is not the determining factor as to the earliest age when infection may take place. The earliest visible infection for the groups of trees included in this study was found in a tree on the slope type of site, 61 years old. Table I shows that in the 61 to 80 age class the greater percentage of infected trees is found on the slope sites, while the bottom sites have the larger rot percentage.

INJURIES.

Since injuries play the principal rôle in the infection of living trees, it is important to consider them in relation to the various factors such as age and site and especially in relation to the rot volume. In Table V are given the data for bottom and slope sites, respectively, showing the relation of injuries to age class and to site, as well as indicating the percentage of infection traced to the various kinds of injury. The determination of the particular injury which was primarily responsible for the initial infection of the tree was most difficult in many cases, and no doubt a few of the individual decisions may be classed as doubtful. In the main such factors as the appearance of sporophores and the location of the largest ones, the region of greatest decay within the trunk, and the overwhelming occurrence of butt-rot in trees having large fire scars at the base give substantial evidence for the determination of most of the injuries responsible for infection.

The basis for the determination of the degree of injury rests on the following standard:

- 0 = No injuries.
- x = 1 to 60 dead branches, no frost cracks, and very few miscellaneous injuries (less than 2).
- xx = 61 to 120 dead branches, one frost crack, and a superficial blaze, logging scar, or other slight injury.
- xxx = 121 to 180 dead branches, not more than 2 frost cracks, deep blazes, logging scars, or fire scars; slight lightning injury.
- xxxx = 181 to 250 and more dead branches, more than 2 frost cracks, and heavy injuries' (injured and broken top, severe lightning, and other injuries).

Dead branches were considered of prime importance in determining the degree of injury for individual trees. Fire scars proved an exception in a certain group of trees where the fire had caused injuries at the base, and these injuries were believed to be primarily responsible for the entrance of the fungus. These trees were of an age class bearing many dead branches. The younger trees had fewer dead branches than the older ones. Frost cracks were entirely absent in the younger age classes, so that no difficulty was experienced such as would arise in case a tree was found having only 60 dead branches and bearing 2 frost cracks. The older trees bore the few frost cracks found, and these trees had numerous dead branches.

In rating the averages for the various age classes x was given the valuation of 1, xx of 2, etc. In this manner averages such as 0.32 and 2.9 were computed (see Table V), indicating the average degree of injury.

TABLE V.—*Relation of injuries to age and to total stand of western white pine on sites of the bottom and slope types.*[1]

Age class.	Infection traced to—								Total trees with injuries to which infection was traced.		Degree of injury.	Total number of trees.
	Branch stubs.		Broken tops.		Frost cracks.		Fire scars and other injuries.					
	Number.	Per cent.[2]	Number.	Per cent.[2]	Number.	Per cent.[2]	Number.	Per cent.[2]	Number.	Per cent.[3]		
Bottom sites:												
41 to 60 years	0	0	0	0	0	0	0	0	0	0	0.32	37
61 to 80 years	3	75.0	0	0	0	0	1	25.0	4	6.5	1.74	62
81 to 100 years	23	53.5	0	0	0	0	20	46.5	43	37.1	2.09	116
101 to 120 years	50	70.4	0	0	0	0	21	29.6	71	64.0	2.6	111
121 to 160 years	68	79.1	0	0	1	1.2	17	19.7	86	66.7	2.9	129
161 to 200 years	65	90.3	0	0	2	2.8	5	6.9	72	94.7	2.6	76
201+ years	32	84.2	0	0	2	5.3	4	10.5	38	97.4	3.0	39
Total	241	76.7	0	0	5	1.6	68	21.7	314	55.0	2.4	570
Slope sites:												
41 to 60 years	0	0	0	0	0	0	0	0	0	0	0	50
61 to 80 years	3	75.0	0	0	0	0	1	25.0	4	6.66	.16	60
81 to 100 years	15	62.5	0	0	0	0	9	37.5	24	24.4	.7	98
101 to 120 years	26	63.4	0	0	0	0	15	36.6	41	41.0	1.41	100
121 to 160 years	137	78.7	0	0	1	.6	36	20.7	174	74.0	2.7	235
161 to 200 years	47	57.3	0	0	3	3.6	32	39.0	82	82.8	2.68	99
201+ years	67	97.1	0	0	0	0	2	2.9	69	98.6	3.77	70
Total	295	74.8	0	0	4	1.0	95	24.1	394	55.3	1.9	712

[1] Percentage of total trees (infected and sound) bearing injuries to total trees in stand = 70.
[2] Percentage based on total number of infected trees.
[3] Percentage based on total number of trees.

Table V shows certain interesting results. On both types of site the infections traced to branch stubs bear the largest percentage over infections traced to other injuries, with 77 per cent for the bottom sites and 75 per cent for the slope sites. Broken tops as sources of original infection were not found, although a considerable number of broken-top trees were recorded and some of these trees gave evidence that a certain amount of infection took place through the exposed tip. In nearly every case it was found that infection in the lower part of the trunk had taken place some time previous to the breakage of the top, as indicated by the difference in the stage of development of the two rotted areas. On the bottom sites approximately 2 per cent of the infections were traced to frost cracks and 22 per cent to miscellaneous injuries, which latter included fire scars, blazes, windfall scars, etc. On the slope sites only 1 per cent of the infections were traced to frost cracks and 24 per cent to miscellaneous injuries. On the slope sites a larger percentage of infection traced to miscellaneous injuries is found than is recorded for the bottom sites. This is due principally to the larger number of basal fire scars recorded for the trees on the slopes. On both types of site a steady increase of the total number of trees with injuries is recorded, ranging on the bottom sites from 0 in the 41 to 60 age class to 97 per cent in the 201+ class. On the slope sites the percentage ranges from 0 in the 41 to 60 age class to 99 per cent in the 201+ class. Comparing the entire stand of each type of site it is seen that the percentage of total trees infected is 55 on the bottom sites and 55.3 on the slope sites. A more correct comparison of the amount of injury found in the stands of each type of site is made by contrasting the percentages of total trees, both sound and infected, bearing injuries. For the bottom sites this percentage is 90 and for the slope sites 70, indicating that a larger number of trees on the bottom sites bore injuries. This difference may be partly due to the presence of a larger number of branch stubs on the trees of the bottom sites. These data clearly indicate the increasing danger of infection through injuries with the increase in age for both sites.

From a study of Table V it appears that frost cracks as sources of infection are more common in the older age classes and not present at all in the younger. The recorded field data show that frost cracks were more frequent in the older trees, which accounts for the preceding statement.

The degree of injury for the two types of site shows a fairly steady increase with increased age and a slight difference in degree of injury for the total stand of the two types of site. The bottom sites have but a few tenths greater degree of injury.

Table V shows that 10 to 30 per cent of the trees are without injuries. These trees are principally in the youngest age classes and bear no dead branches.

SPOROPHORES.

Most of the sporophores encountered in the western white-pine study were those of *Trametes pini*. Very few sporophores of *Polyporus schweinitzii* or of *Fomes annosus* were found attached to the trees. Most of the *Polyporus schweinitzii* fruiting bodies developed on the ground at the base or near the host, and the logging operations nearly always disturbed these from their original positions. A very few sporophores of *Polyporus schweinitzii* were found attached directly to the base of the tree. The data in Table VI, therefore, are principally from field notes on one fungus, *Trametes pini*. In this table it will be noted that the 41 to 60 age class is omitted, since no rot and therefore no sporophores were present on the trees of this class. On the bottom sites out of a total of 533 trees approximately 30 per cent were found bearing sporophores. On these sporophore-bearing trees a total of 604 sporophores were recorded, of which 561, or practically 93 per cent (92.8), were alive and 43, or over 7 per cent (7.2), were dead, giving an average of 35 sporophores to every 10 trees for the live sporophores, 3 to every 10 trees for the dead sporophores, and an average of 38 sporophores both dead and alive for every 10 trees. An average of 11 sporophores both dead and alive for every 10 trees is found when all the trees of the six age classes are considered. Of the largest sporophores, which varied in size up to 6 by 6 by 8 inches, 92 per cent were found alive and 8 per cent dead. The average of the ages of the largest sporophores is approximately 15 years, and the average height on the trunk is 5.1 feet.

TABLE VI.—*Summary of field notes relating to sporophores on western white pine on sites of the bottom and slope types.*

Age class.	Number of trees (basis).	Number of trees bearing sporophores.	Sporophores.																	
			Number.				Largest.						Number for each position on the tree.							
			Alive.	Dead.	Total.	Average per tree.	Average age.	Condition. Alive.	Condition. Dead.	Sizes.[a]	Relative position along trunk.	Average height on tree.	North.	South.	East.	West.	Northeast.	Northwest.	Southeast.	Southwest.
Bottom sites:							Years.			Inches.		Feet.								
61 to 80 years	62	2	7	0	7	0.11	5.0	2	0	1 by 2 by 2.	Bottom.	0.8	0	2	1	4	0	0	0	0
81 to 100 years	116	25	71	3	74	.63	5.3	24	1	4 by 3 by 5.	Middle	1.8	13	10	11	23	1	5	3	4
101 to 120 years	111	46	145	11	156	1.4	13.3	42	4	3 by 5 by 5½.	Top	2.0	18	9	14	45	10	7	4	5
121 to 160 years	129	56	273	20	293	2.2	28.5	49	7	6 by 6 by 8.	do	4.5	55	30	57	53	34	11	8	22
161 to 200 years	76	21	47	9	56	.74	19.6	20	1	4 by 6 by 8.	do	6.4	0	13	13	15	0	0	2	10
201+ years	39	9	18	0	18	.46	23.0	9	0	2 by 4 by 6.	do	32.5	0	0	8	8	0	0	0	0
Total:																				
Number	533	159	561	43	604	1.1	15.1	146	13	6 by 6 by 8.	Top	......	86	64	104	148	45	23	17	41
Percentage	......	29.8	92.8	7.2	......	......	......	91.8	8.2	......		......	16.3	12.1	19.7	28.0	8.4	4.4	3.3	7.8
Average[b]	......	......	[c] 3.5	[d] .27	[e] 3.8	......	[f] 15.1	All.	......	......	Top	5.1	......	......	......	West.	......	......	......	......
Slope sites:																				
61 to 80 years	60	0	0	0	0	0	......	......	......	......	......	......	......	......	......	......	......	......	......	......
81 to 100 years	98	0	0	0	0	0	......	......	......	......	......	......	......	......	......	......	......	......	......	......
101 to 120 years	100	7	15	0	15	.15	8.6	7	0	3 by 3 by 3.	Bottom.	2.4	......	1	10	......	1	1	1	......
121 to 160 years	235	105	405	25	430	1.83	11.24	101	4	6 by 4 by 7.	Middle	3.3	93	45	61	76	23	26	21	57
161 to 200 years	99	23	57	5	62	.62	16.7	21	2	4 by 6 by 6.	do	5.1	12	20	4	9	4	4	4	2
201+ years	70	9	18	6	24	.34	17.3	7	2	6 by 10 by 10	do	35.5	......	......	......	14	2	1	1	5
Total:																				
Number	662	144	495	36	531	.8	12.3	136	8	6 by 10 by 10	Middle	......	105	66	75	99	30	32	27	64
Percentage	......	21.7	93.2	6.8	......	......	......	94.4	5.6	......		......	21.1	13.2	15.1	19.9	6.0	6.4	5.4	12.9
Average[b]	......	......	[g] 3.4	[h] .25	[i] 3.6	......	[f] 12.3	All.	......	......	Middle	5.5	North.	......	......	......	......	......	......	......

[a] The size of the smallest sporophore found wherever the presence of large sporophores is noted was 1 by 1 by 1 inch. [b] Per sporophore-bearing tree. [c] 35 to every 10 trees. [d] 3 to every 10 trees. [e] 38 to every 10 trees. [f] Average age of largest sporophores. [g] 34 to every 10 trees. [h] 25 to every 10 trees. [i] 36 to every 10 trees.

In classifying the sporophores according to the positions occupied on the trunk of the host it was found that the largest percentage of them (28 per cent) developed on the west side of the tree, with the smallest percentage (3.3) on the southeast side. Most of the largest ones were found near the upper end of the group on each tree.

On the slope sites, out of a total of 662 trees 22 per cent were found bearing sporophores. In this connection it must be remembered that a much higher percentage of the trees on the slope sites was in the 120 to 160 age class, which bore the maximum number of sporophores. The sporophore-bearing trees carried a total of 531 sporophores both dead and alive, of which 495, or over 93 per cent (93.2), were alive and 36, or nearly 7 per cent (6.8), were dead. These figures give an average for the total stand of 34 live sporophores to every 10 trees, 2.5 dead sporophores to every 10 trees, and 36 live and dead sporophores to every 10 trees. Considering all of the trees of the six age classes given and not limiting the figures to sporophore-bearing trees alone, an average of eight sporophores both dead and alive was found for every 10 trees. Of the largest sporophores, which varied in size from 1 by 1 by 1 to 6 by 10 by 10 inches, 94 per cent were found alive and 6 per cent dead. The average of the ages of the largest sporophores is recorded as approximately 12 years and the average height on the trunk was 5.5 feet. Most of the sporophores on this site were found grouped on the north side of the trunks, 21 per cent being on the north side and the smallest, or 5 per cent, on the southeast side. Most of the largest ones were found at about the middle of each group of sporophores.

In comparing the two types of site some interesting figures are disclosed. The bottom sites, to begin with, have a larger percentage of sporophore-bearing trees and a slightly larger average number both of living and of dead sporophores per sporophore-bearing tree. In the 81 to 100 age class the bottom sites have 22 per cent of the total trees bearing sporophores, while for the slope site there are none. In the 101 to 120 age class on the bottom sites 41 per cent of the total trees were found bearing sporophores, with only 7 per cent in the slope sites. In the 121 to 160 age class are found the maximum figures. In this age class for the bottom sites 43 per cent of the total trees bore sporophores and for the slope sites 45 per cent. The average of the ages of the largest sporophores is also greater on these sites. On the other hand, the slope sites have a greater percentage of the larger sporophores alive than the bottom sites. It is very interesting to find that the percentage of live and dead sporophores to the total number of sporophores is practically the same for both types of site. This would seem to indicate that site does not appreciably affect the vitality of the sporophore, although it apparently affects the number of sporophores produced.

On the bottom sites it is observed that sporophores are recorded for all the age classes, including that of 61 to 80 years. In the slope sites both the 61 to 80 and the 81 to 100 age classes have no sporophores recorded. The first sporophores appear in the 101 to 120 age class. They increase in number in the 121 to 160 age class and decline in the 161 to 200 and the 201+ age classes. The column indicating the average number of sporophores per tree indicates this very clearly. The column recording the number of sporophore-bearing trees shows a similar increase, reaching a maximum in the 121 to 160 age class, and a rapid decline is noted in the two succeeding age classes. These data indicate a maximum of sporophore production attained in the 121 to 160 age class and show the rapidly decreasing numbers of sporophores present on the trees of the two oldest age classes. Two factors are responsible for the decline—first, the fact that the fungus in the tree has reached and passed its maximum development and so produced fewer new sporophores, and second, the fact that in the old-age classes the old sporophores are observed to have died, become loosened from the trunk, and dropped off. The relation of rot percentage to sporophores is evident when compared on a basis of site. On the bottom sites the rot percentage is nearly 8 (7.8, Table I), and an average of 1.1 sporophore per tree or 11 sporophores to every 10 trees is recorded. In the slope site the rot percentage is over 6 (6.1, Table I), and the average number of sporophores per tree is 0.8 or 8 sporophores to every 10 trees. The bottom sites show a greater rot percentage and a greater average number of sporophores per tree.

Another interesting point brought out by the table is the fact that on both types of site the smallest groupings of sporophores were found on the southeast side of the trees.

DISCUSSION OF RESULTS.

From the foregoing data it appears that age is the important factor in determining the amount of rot to be expected in a western white-pine stand. This factor of age is significant in the application of proper silvicultural methods to the care and disposal of the timber. From the forester's point of view two things stand out in considering the stand in relation to rots. The one is the age of earliest infection of the stand, or the period when infection by fungi can first be expected. This is undoubtedly controlled by the formation of heartwood and the appearance of injuries susceptible to infection. This infection age is found to be approximately 50 years for western white pine, and it indicates the period when the young stand is in need of the utmost protection against infection by fungous spores. Infection takes place in this tree earlier than at 50 years in certain individuals, and, of course, infection continues to take place in all stands after the 50-year period is reached, and no doubt at an increased rate.

The other consideration of importance to the forester is the period in the age of the stand at which the net increment of sound material passes its maximum. This period is more or less indefinite and difficult to express in actual age figures. It depends primarily upon what the forester considers the dividing line between a stand having sufficient sound material to pay a profit for logging and one having so much rot that logging would not be profitable or the profit a small one, all factors considered. From the viewpoint of annual increment the forester has determined that a rotation of 100 to 120 years for western white pine gives a maximum yield.[1] If this holds true, then it also appears that this will mean the cutting of the stand when the average rot percentage for the bottom sites is 1.7 and for the slope sites 0.5. Glancing at Table I it is seen that for both types of site an appreciable increase in the average annual increase in rot volume is recorded between the 101 to 120 and the 121 to 160 age classes.

In the sporophore summaries (Table VI) an apparent maximum point is reached in the 121 to 160 age class in respect to the number of sporophore-bearing trees and to the number of sporphores produced. The 101 to 120 age class would, therefore, represent the age class having, on the average, a stage of development of the rot below the maximum stage for sporophore production. These facts point to the 101 to 120 age class as a possible felling age from the pathological point of view, and it remains to discover whether an average rot percentage of 1.7 on the bottom sites and 0.5 per cent in the slope sites conforms to the most economical logging or whether a higher rot or cull percentage is possible without a sacrifice in the returns on the operation. The next higher age class (121 to 160) records a rot percentage of 3.1 for the bottom sites and 2.3 for the slope sites.

In the relation of age to injuries the data have shown that with increased age comes a greater degree of injury. This is evident for both types of site in all the age classes excepting the 161 to 200, which drops slightly below the preceding age class in degree of injury. It is so well understood that increased age brings cumulative risks of greater injury that a discussion seems unnecessary.

A steady increase in the number of trees with injuries to which infection was traced is noted with increase in age for both the bottom and slope types of site.

It is readily seen that age up to a certain limit has a definite relation to the sporophore production of a stand. If rot increases with

[1] Mason, D. T. Management of western white pine. *In* Proc. Soc. Amer. Foresters, v. 9, no. 1, p. 61. 1914.

age, then it follows that the production of sporophores will also increase as the decay develops to that stage where fruiting bodies are produced. It is also to be expected that when the period of maximum sporophore production is passed there will be a gradual decline in the numbers produced and also in the numbers retained upon the trunk. Fewer new sporophores are produced in the old-aged trees of the stand, and of the old sporophores already on the tree many die, become loosened from the trunk, and drop off. The data show for both types of site that there is an increase in the number of trees bearing sporophores and in the average number of sporophores per tree, from the 61 to 80 to the 121 to 160 age classes, inclusive, while a decrease is noted for the 161 to 200 and the 201 age classes. This indicates a maximum sporophore production in the 121 to 160 age class and a declining production for the age classes following.

Figures have been given which show that site plays an important part in the development of rot in a stand. The consensus of opinion among practical loggers is that low, flat, and poorly drained sites bear stands having the greatest amount of rot and that the sites where trees are freest from rot or where the rot percentage is small are well-drained slopes or benches. The comparison of slope and bottom sites in respect to rot percentage, both for age classes and for the total stand, indicates that a greater amount of rot is prevalent on the bottom sites. A comparison between trees taken from similar sites upon widely separated areas and having a difference in average age of 10 years shows a difference of 1 per cent in rot between these two areas. The percentage is greater on the area having the greater average age. The same indication is given by the figures for the percentage of infected trees. These data also furnish evidence of the influence of age upon the amount of rot to be found in a stand. Further comparisons of trees occurring on slope and bottom sites on the same sale areas also indicate that the trees on the bottom sites bear a greater percentage of rot than those on the slopes.

In respect to the influence of site upon degree of injury the data do not show conclusively that a greater degree of injury exists upon bottom sites. The bottom sites with 2.4 and the slope sites with 1.9 (Table V) leave too small a difference to attribute them to the influence of site. Apparently greater percentages of infections are traced to branch stubs on the bottom sites than on the slopes. This may be due to the formation of a larger number of dead branches on the bottom sites as a result of greater shade. Light more easily reaches the lower branches of trees growing on a slope than of trees growing on the bottom sites, providing the densities are about equal. This might be a possible explanation of the formation of a greater number of dead branches on trees of the bottom sites. Site is apparently responsible for a greater percentage of sporophores developing on the trees of the bottom sites. An average for the bottom sites gives a distribution of 11 sporophores to every 10 trees, while the slope sites have 8 sporophores to every 10 trees. The proportion of live and dead sporophores to the total sporophores is about equal on each type of site, 93 per cent alive and 7 per cent dead. The proportion of live and dead sporophores to the total, in the case of the largest sporophores, shows a percentage approaching that already given, also showing very little variation in respect to site. A greater number of sporophore-bearing trees are found upon the bottom sites.

METHODS OF CONTROL.

From the study of the data presented, it appears that the control of diseases in western white pine under the present stage of forestry in the Northwestern States will be a difficult matter and subject to extensive rather than intensive methods. The high economic value of the tree and the large amount of loss due to rot are two important factors which make it imperative that steps be taken at least to check the diseases and that attempts be made to reduce the annual loss of sound material brought about by the spread of the casual organisms.

There are two methods of control which present themselves as practicable under the present methods of forest management. These two methods work hand in hand. The first method is primarily based upon the rotation of the stand or the felling age. It is evident from a study of the data presented that if the stand is cut before any sporophores are produced, or before they are produced in any great numbers, the spread of the diseases will be effectively checked. The data show that a certain age class represents the period in the stand which develops a maximum of sporophores. This period in western white pine is represented by the 121 to 160 age class. This age class has 43 per cent of the total trees bearing sporophores for the bottom sites and 45 per cent for the slope sites. Both the next lower and the next higher age classes have smaller percentages for the two types of site than the 121 to 160 age class. If the felling age of western white pine is kept within the 101 to 120 age class there is every reason to believe that the infected trees will be cut down before they reach the age of maximum sporophore production. Most of them will no doubt be cut down before any fruiting bodies whatever appear. This is the most desirable result and is particularly true for the slope sites.

The second method is fundamentally concerned in the strict application of proper pathological marking rules and the consequent removal of all infected slash on the sale areas. The marking rules should provide definite instructions to fit each distinct sale area and should include the consideration of the classification of stands in the western white-pine type and the methods of cutting employed on each. The pathological marking rules should specify the cutting of all diseased trees on a sale area where selection cutting is employed and the retention on clean-cut areas of seed trees free from all root, butt, and trunk rots, as well as from rust and mistletoe. These two recommendations will insure a healthier second growth in the case of selection or improvement cuttings, and in the case of clean-cut areas will insure the reserved seed trees against windfall and windbreak due to fungous activity.[1] In the case of the clean-cut area the retention of sound seed trees will also prevent distribution of diseases by these trees. If seed trees other than western white pine are reserved, the selection of sound trees will prevent infection of young growth by the rust[2] and mistletoe[3] diseases which are peculiar to certain tree species, such as Engelmann spruce and western larch, found in stands of the western white-pine type. The removal of all infected slash left on a sale area after logging is an important part of the successful control of fungous diseases. In order to prevent the spread of the diseases which have caused rot in the trees of the stand all infected slash liable to develop sporophores should be disposed of in such a manner as to check the development of the fungus and thus prevent subsequent sporophore production, or it should be destroyed outright in some manner consistent with economic requirements.

SUMMARY.

Data obtained in a study of the rots of western white pine show the following conclusions as presented in this bulletin:

The three main wood-destroying fungi in the order of their importance are *Trametes pini*, *Polyporus schweinitzii*, and *Fomes annosus*. Most of the rot found in the tree is traceable to *T. pini*.

Trametes pini attacks all portions of the trunk, acting in some cases as a typical butt-rot. *Polyporus schweinitzii* is found to produce a typical butt-rot, and *Fomes annosus* is chiefly confined to the roots and butt of the tree.

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[1] Hubert, E. E. Fungi as contributory causes of windfall in the Northwest. *In* Jour. Forestry, v. 16, no. 6, pp. 696–714. 1918. Bibliography, pp. 713–714.

[2] Weir, J. R., and Hubert, E. E. Notes on forest-tree rusts. *In* Phytopathology, v. 8, no. 3, pp. 114–118. 1918.

——— ——— Notes on the overwintering of forest-tree rusts. *In* Phytopathology, v. 8, no. 2, pp. 55–59. 1918.

[3] Weir, J. R. Larch mistletoe: Some economic considerations of its injurous effects. U. S. Dept. Agr. Bul. 317, 25 p. 1916.

——— Some suggestions on the control of mistletoe in the national forests of the Northwest. *In* Forestry Quart., v. 14, no. 4, pp. 567–577. 1916.

It is found that an average rot percentage of 7 represents the proportion of sound wood rotted by these agencies in the stands of timber classified under the western white-pine type. This represents a loss of $7,201,250, or 1,658 million feet B. M., in the forests of British Columbia, Oregon, Washington, Idaho, and Montana.

The data indicate that the factor of age is prominent in determining the amount and stage of decay in a stand. The age of earliest infection was found to be approximately 50 years for the trees in general for the Cœur d'Alene region of Idaho.

Site is found to have a bearing upon the rot in the stand. The bottom site, in general, is found to be more favorable to the development of fungous diseases. Site, apparently, has no great effect upon the percentage of trees infected, both sites showing approximately the same percentage. A larger percentage of the slope trees were in the heavier infected age classes. This was not the case for the bottom sites, and therefore a direct comparison of the total percentage of trees infected gives figures which are higher for the slope sites than would otherwise be true. In general, a greater rot percentage, a greater percentage of infected trees, a greater amount of butt-rot, a greater degree of injury, and a larger average number of sporophores per tree are recorded for the bottom sites than for the slopes. This indicates that the bottom sites are more favorable to the development of fungous diseases.

With increased age up to a certain point comes an increase in the number of sporophore-bearing trees and an increase in the degree of injury.

The maximum production of sporophores is found to occur in the 121 to 160 age class. The 101 to 120 age class presents, in so far as the rot data show, favorable figures upon which to determine a pathological felling age.

The high economic value of the tree coupled with the large amount of loss annually sustained through heart-rotting fungi makes it highly necessary to attempt control methods.

The loss due to rots may be reduced by the application of control methods aiming to prevent the spread of the organisms causing decay.

Proper pathological marking rules and practical methods for the disposal of infected slash on sale areas are recommended as methods of control.

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