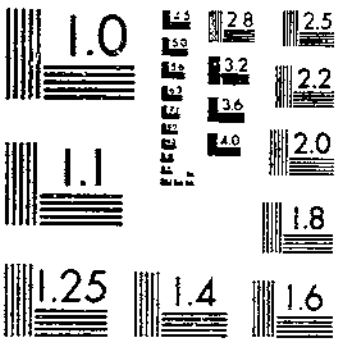
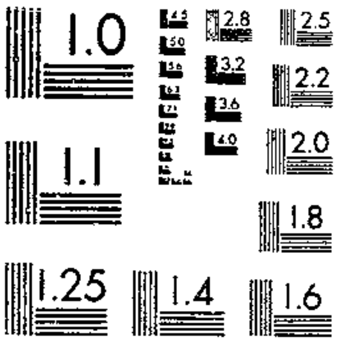
TB 132 (1929) USDA TECHNICAL BULLETINS UPDATA
DECAY OF SLASH OF NORTHERN WHITE PINE IN SOUTHERN NEW ENGLAND
SPAULDING, P 1 OF 1

START



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

TECHNICAL BULLETIN No. 132 — JULY, 1929

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

DECAY OF SLASH OF NORTHERN WHITE PINE IN SOUTHERN NEW ENGLAND

By PERLEY SPAULDING

Senior Pathologist, Office of Forest Pathology, Bureau of Plant Industry[1]

CONTENTS

INTRODUCTION

In this bulletin are presented the results of preliminary investigations of the decay of slash[2] of northern white pine[3] (*Pinus strobus* Linnæus) in southern New England. The center of operations was the Harvard Forest, Petersham, Mass., because of abundance of material in that vicinity. The investigations were extended over the following towns: Greenwich, Dana, Barre, Petersham, Athol, Winchendon, and Ashburnham, Mass.; Rindge, Jaffrey, Dublin, Marlboro, Troy, and Fitzwilliam, N. H.; and Alfred, Me. About 70 selected wood lots with white-pine slash were examined, and it is believed that sufficient data have been taken to permit the drawing of tentative conclusions, which may be of value in future cuttings of this species.

Data were taken on only the rotting of white-pine slash left on the ground by the usual logging operations. It was necessary to examine slash of all ages up to 20 or more years and to examine it on various slopes, soils, and forestry sites. In the area covered, the lumberman

[1] Investigation conducted in cooperation with the Northeastern Forest Experiment Station, Forest Service, U. S. Department of Agriculture, and the Harvard Forest.
[2] The word "slash" is used in this bulletin to mean all the débris left after logging.
[3] White pine as used in this bulletin means northern white pine. Sudworth's Check List, edition of 1927, is followed for the common and scientific names of the trees.

47370—29——1

leaves the slash in irregular piles or windrows of varying compactness and size, according to the density of the stand that is cut. Very little is scattered.

USUAL PROGRESS OF ROT OF WHITE-PINE SLASH

The usual course of the rotting of white-pine slash may be briefly outlined as follows:

FIRST YEAR.—The leaves and small twigs dry out. Insects work most intensively under the bark on the lower side of the slash. Very early stages of rot begin.

SECOND YEAR.—A few leaves drop. The bark begins to loosen from the wood, especially where the insects have worked. In favorable situations rot caused by *Lenzites sepiaria* Fries appears, and fruiting bodies are formed. This process is decidedly slower than in eastern Texas on *Pinus palustris* Miller, where large pockets of rotted wood form and fruiting bodies mature within five months of the felling of the tree (*31*).[4] Rot of sapwood by *Polystictus abietinus* (Fries) becomes apparent in the larger pieces of slash, which have thick layers of sapwood. This agrees with the findings of Boyce, in Klamath County, Oreg., where sap rot of western yellow pine (*Pinus ponderosa* Lawson) appeared principally in the second season after cutting (*3*).

THIRD YEAR.—The leaves nearly all fall and mat together about midway down in the piles. Where insects have worked, the bark is mostly loose and falling from the wood. The pockets of wood rotted by *Lenzites sepiaria* increase noticeably in number and size in the top slash.

FOURTH YEAR.—The bark practically all falls from the wood. Sap rot by *Polystictus abietinus* is well under way. The top slash is dry and brittle. Fruiting bodies of *Poria cinerascens* (Schw.) Bres. and *Corticium* spp. appear on the bottom slash next to the ground.

FIFTH YEAR.—The top slash of small branches is weakened by the numerous pockets of rotted wood made by *Lenzites sepiaria*, and the upper branches begin to break up. Sap rot by *Polystictus abietinus* is well advanced and general. Fruiting bodies of Poria, Stereum, and Corticium become quite plentiful next to the ground.

SIXTH YEAR.—Later stages of sap rot are general near the ground. Heart rot[5] by *Lenzites sepiaria* is well under way in the smaller branches.

SEVENTH YEAR.—The slash piles begin to flatten by the now-rapid breaking up of the top branches, at the pockets of *Lenzites sepiaria* rot, into pieces 1 to 2 feet long.

EIGHTH YEAR.—The fallen leaves are rotted but retain their shape. The twigs begin to fall from the branches.

NINTH YEAR.—The flattening of the piles accelerates. The sapwood around the bases of the branches in the main trunks has rotted and lost most of its strength. Heart rot by *Lenzites sepiaria* in the top slash is pronounced, and the fallen pieces of branches begin to disintegrate.

TENTH YEAR.—The slash piles are well flattened. The branches fall from the trunks.

ELEVENTH TO FIFTEENTH YEARS.—The larger part of the slash is well rotted. Pieces of the smaller top slash remain dry and brittle without rotting noticeably.

SIXTEENTH TO TWENTIETH YEARS.—Most of the slash disintegrates and forms a layer of mold in which are imbedded remnants of wood fibers. Small top slash persists for a number of years longer, especially pieces of the smaller branches one-fourth to 1 inch in diameter.

Table 1 shows the advance of decay symptoms with increasing age of the slash.

---

[4] Reference is made by italic numbers in parentheses to "Literature cited," p. 18.

[5] That *Lenzites sepiaria* rots heartwood is well known and has been stated plainly by different writers ([illegible]).

TABLE 1.—*Progress of rot of white-pine slash*

Condition of slash		Number of lots of slash of specified ages (years)																
Cause	Description	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Insects and fungi	Bark loosening		1	3	2	1												
	Bark falling			2	4	1	3	1										
	Bark nearly all fallen				2			5	1									
	Bark fallen						1	2	6	4	4							
Lenzites sepiaria	Rot begun		1	4	5	2			2									
	Pockets numerous				1		5	7	6	3	4	2	2	4	5			
	Heart rot begun						2	2	2	1	2	2	1	1				
	Heart rot advanced									2	1				5	1	3	3
	Piles flattening						1	3	3	2	2	2		2	2			
	Piles nearly gone												2		5	1	3	3
Polystictus abietinus	Rot begun		1	3	7	2			1									
	Rot advanced						5	6	6	2	3	2	2	2				
	Sapwood all rotted							1	5	4	4		2	4	6	1	3	3

FUNGI ROTTING WHITE-PINE SLASH

In discussing the fungi found rotting the slash of white pine there are two relations of the fungi to the slash that must be considered: (1) Relation of the different fungi to the age of the slash; and (2) relation of the different fungi to environmental factors, which are determined by the position of the slash in the piles. The first relation is also quite certainly a matter of environmental factors that are too obscure to attempt analysis with present knowledge. The best the writer can do now is to give his observations in the hope of ultimately acquiring knowledge that will show why certain fungi delay their appearance and why others appear promptly.

TABLE 2.—*Fungi found on white-pine slash of different ages*

[Specimens identified by J. R. Weir, formerly of the Bureau of Plant Industry, and L. O. Overholts, Pennsylvania State College. The specimens marked ? were in poor condition and could not be identified positively. + indicates the presence of a fungus]

Fungus	Occurrence of fungi on slash of specified ages (years)												
	2	3	4	5	6	7	8	9	10	11	12	13	14
Coniophora arida Fries ?				+									
Corticium cinerascens Berk													+
Corticium confluens Fries							+						
Corticium galactinum (Fr.) Burt							+						
Corticium lacteum Fries			+				+			+			+
Corticium sulphureum (Karst.) Bres								+		+			
Hymenochaete tabacina (Sow.) Lev						+							
Lenzites sepiaria Fries	+	+	+	+	+	+	+						
Merulius aureus Fries													+
Merulius himantioides (Fr.) Burt							+						
Odontia abietina Karsten								+					
Peniophora carnosa Burt									+				
Peniophora cremea Bres								+					
Peniophora gigantea (Fr.) Mass	+												
Peniophora sanguinea (Fr.) Bres			+										
Polyporus albidus (Sch.) Fries					+								
Polyporus destructor Schrader ?							+	+			+		
Polyporus fragilis Fries		+	+	+		+	+		+			+	
Polystictus abietinus (Fries)	+	+	+	+	+	+	+						
Poria cinerascens (Schw.) Bres			+		+	+			+	+	+	+	
Poria crocipora Berk. ?										+			
Poria lenis (Karsten) Bres							+						
Poria luteo-alba Karsten					+			+					
Stereum karstenii Bres								+					
Stereum sanguinolentum Alb. and Schw	+			+									
Trametes isabellina Fries						+							

RELATION OF FUNGI TO AGE OF SLASH

In Table 2 are shown the fungi found on the different-aged slash. As it is impossible to indicate the relative frequency of the different species with any accuracy, this is not attempted. *Lenzites sepiaria* probably rots more slash than any other fungus, although its fruiting bodies are not especially abundant at any time. Next in frequency is *Polystictus abietinus*, which fruits more abundantly upon the material upon which it is working. The other fungi occur rather infrequently, none being more than common in single lots of slash.

Attention should be called to the fact that each of the various fungi has its definite season in the year for fruiting, just as our crop plants do. Certain soft-textured ones, which are eagerly attacked by some of the insects and as a consequence soon disappear, quite surely attack white-pine slash and fruit upon it, but none of them have yet been found. They are probably rather infrequent in occurrence.

RELATION OF FUNGI TO ENVIRONMENTAL FACTORS

The fungi that attack white-pine slash may be divided readily into three groups, according to their location in the piles of slash: (1) Those rotting the upper, well-exposed slash; (2) those working in the middle slash; and (3) those attacking the lower slash under the matted leaves and near the ground or in contact with it.

Lenzites sepiaria works only in well-exposed slash. This is probably largely due to its high optimum growth temperature, which is above that of most wood-rotting fungi. Falck (*7, 8*) determined this point to be 35° C. decidedly higher than for *Coniophora cerebella* (Persoon) or *Merulius lacrymans* (Jacquin) Schum. Snell (*28*) found that the optimum growth temperature for mycelium of *Lenzites sepiaria* was 30° to 34°. Fritz (*11*) found it to be about 35° and decidedly higher than those of several other common wood-rotting fungi. Humphrey and Siggers[6] found it to be between 32° and 36°. Coupled with the high-temperature toleration is a toleration or necessity for relatively little water and much air, both of which naturally accompany the high temperatures in slash exposed to the sunlight. It is the principal and almost the only top-slash destroying fungus for white pine. At first it forms rather limited pockets of rotted sapwood in slash exposed to the full sunlight. The rotted wood is carbonaceous, brown, and falls into small cubical pieces, which readily crumble between the fingers. (Fig. 1.) The fruiting bodies of this fungus are rather scarce, but it appears that the rot continues until in the eighth to tenth years nearly all of the sapwood except a thin external layer (which becomes casehardened when decortication takes place) and some of the heartwood are well rotted. Much of the flattening of the piles is due to the breaking of the top branches, one-fourth to 2½ inches in diameter, where they are weakened by pockets of rot made early by *L. sepiaria*. The branches thus break into pieces 1 to 2 feet long. In late stages of rot the whole interior of branches up to about 3 inches in diameter is rotted by the same type of decay. Fruiting bodies are found occasionally on rotted branches of this size up to about the eighth year,

---

[6] HUMPHREY, C. J. and SIGGERS, P. V. TEMPERATURE RELATIONS OF WOOD-DESTROYING FUNGI. 1927. [Manuscript report.]

so that there seems to be no doubt that this fungus is responsible for the rot. This rather sharp limitation of *L. sepiaria* to the smaller slash is also true of it in New Mexico and Arizona in slash of western yellow pine (*Pinus ponderosa*) (*21*) and in Arkansas in slash of shortleaf pine (*P. echinata* Miller) (*22*).

On the whole, although it is limited commonly quite closely to the smaller slash, *Lenzites sepiaria* appears to disintegrate as much slash of the white pine as all the other species of fungi together. The flattening of the piles of slash begins with the rotting of the heartwood of the branches by *L. sepiaria* and progresses with it.

The larger pieces of slash, 2½ inches or more in diameter, and mostly intermediate in location in the piles, are sap-rotted by *Polystictus abietinus*. This produces a diffuse light-yellow fibrous rot, which in its late stages has small lens-shaped pockets resembling those made by *Trametes pini* (Brot.), but with no white lining of cellulose fibers as with that fungus. (Fig. 2.) *P. abietinus* attacks only partially shaded slash and fruits more commonly on the lower sides of the rotted pieces. It requires considerably more moisture in the

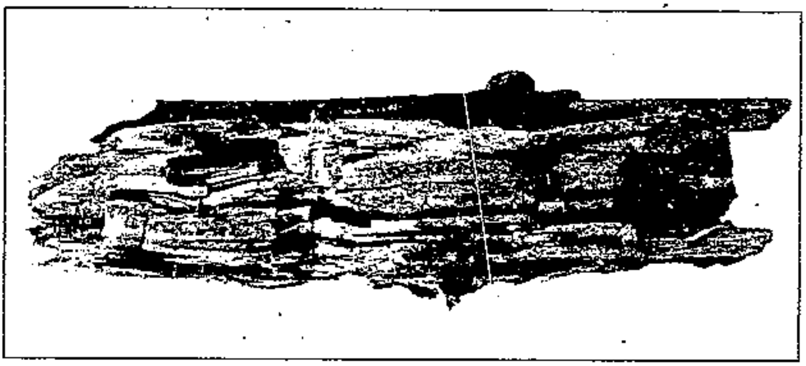


FIGURE 1.—A 3-inch branch of white pine well rotted by *Lenzites sepiaria*. The external layers of the wood are quite sound and hold the interior rotted parts together. Approximately two-thirds natural size

wood than *Lenzites sepiaria*. Long (*21*) working in Arizona and New Mexico, found that it requires more moisture than the other common fungi in slash of white fir (*Abies concolor* (Gordon) Parry). In scattered slash it works well down to the ground. In piles it begins to attack in the middle zone. The falling and matting together of the leaves about half way down in the piles excludes almost all of the light and, except on dry soils, creates beneath a water-logged condition which is inimical to this fungus. Fruiting bodies of this fungus may appear as early as the second year and are common as late as the fifth. They seem to be formed on the same piece of slash for not more than two consecutive years, probably because the available sapwood is then well rotted. *P. abietinus* is second only to *L. sepiaria* in the quantity of white-pine slash that it rots.

After about five years the lower slash, which is decidedly wet as a rule, and from which nearly all light is excluded by the fallen needles, bears sporophores of various species of Poria, Merulius, Stereum, and Corticium, as well as considerable sterile mycelium of different kinds. A few of the fungi that occur most frequently appear to aid in the disintegration of the slash. Among these are *Polyporus albidus* (F. P. 43827 [7]), *P. destructor* (F. P. 43818), *P. fragilis* (F. P. 43802), *Poria cinerascens* (F. P. 43806), *P. cinerescens* Bres. (F. P. 43897), *P. crocipora* ?, *P. lenis* (F. P. 43824), *P. luteo-alba* (F. P. 43801), *Trametes isabellina* (F. P. 43826), *Merulius aureus* Fries (F. P. 43820), *M. himantioides* (F. P. 43807), *Corticium berkeleyi* Cooke, *C. byssinum* (Karsten) Burt, *C. confluens* (F. P. 43808), *C. galactinum* (F. P. 43803), *C. lacteum* (F. P. 43822), *C. seriale* (F. P. 43821), *C. sulphureum* (F. P. 43804), *Hymenochaete tabacina* (F. P. 43825), *Odontia abietina* (F. P. 43823), *Peniophora carnosa* (F. P. 43819), *P. gigantea* (F. P. 43988), *Stereum karstenii* (F. P. 43805), *S. sanguinolentum* (F. P. 43800, 43985).

When the rot is in an advanced stage, one can not say that a certain fungus alone has caused all of the decay that is near its fruiting bodies. Cultures, which would yield mixed growths, would not materially help to determine this point. The wood rotted by several

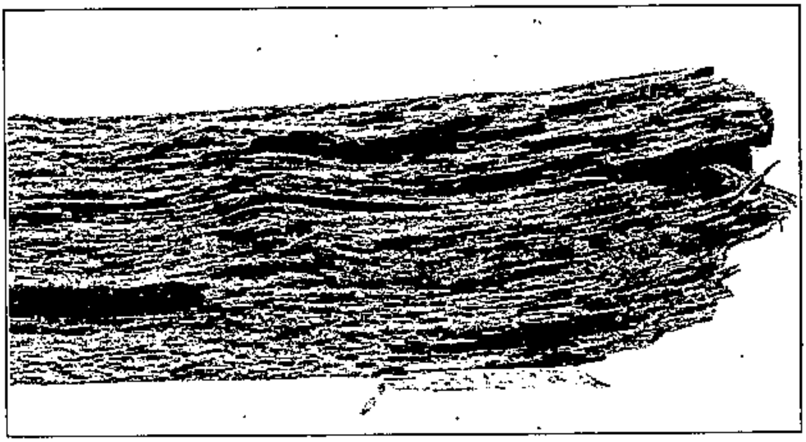


FIGURE 2.—A small section of white-pine trunk sap rotted by *Polystictus abietinus*. Note the numerous small pockets separated by stringly, rotten wood. Approximately natural size

of these fungi is of the same general type—somewhat coarse, cubical, carbonaceous, friable, and brown. Without sporophores it is difficult if not impossible to distinguish them clearly. However, fruiting bodies of any kind of fungus are relatively scarce on slash of white pine under all conditions.

INFLUENCE OF VARIOUS FACTORS UPON ROTTING OF WHITE-PINE SLASH

TYPE OF SLASH

The character of the growth of the trees furnishing the slash distinctly influences its decay. Slash from typical well-grown white pine with relatively small short branches is attacked vigorously and rots relatively quickly. Slash from trees with large, long branches in

[7] F. P. followed by a number means that a specimen of the fungus indicated is filed in the study collections of the Office of Forest Pathology under that serial number.

which there is much red heartwood resists decay for a maximum length of time.

It was found that slash left from cordwood cutting, which is 2 inches or less in diameter, resists decay for a maximum time. In old piles of all sizes of slash, if any pieces still persisted, they were usually pieces of small branches one-fourth to three-fourths of an inch in diameter. This seems to be caused by the early decortication of such small branches and their thorough drying out before fungi can get established in the wood. They appear to remain unaffected by fungi after they are once dry.

SITES, SLOPES, AND SOILS

While the number of lots (70) of slash studied is rather small for the purpose, they are enough to indicate general trends for the more important factors controlling rot of the slash. Tabulation and comparison of the data show the following:

No conclusion can be drawn as to the effect of forestry sites upon rot of the slash, because of the occurrence of most of the lots examined upon Site II.[8] Very few lots of slash were seen on Sites I and III.

The slope upon which slash lies distinctly influences its rate of decay. It has been found that northern and western slopes retard decay and southern and eastern slopes favor it.[9] This is evident especially in the early stages of rot both by *Lenzites sepiaria* and by *Polystictus abietinus*.

The range of soils in the lots examined was relatively small. All would be classed as sandy with varying admixture of humus. No material difference in rate of decay could be ascribed to the type of soil independent of moisture. This is probably accidental and because forestry Sites I and III are not well represented in the region examined.

Partial shade, either from one side or from partial canopy, where the soil is not distinctly wet, favors rapid decay of slash. This was distinctly shown upon thin, dry soil and on well-drained alluvial soil.

HEAT

In the consideration of temperature, water, and air or oxygen, one must keep very clearly in mind the fact that, in wood, they are so completely connected with one another that regulation of one inevitably affects the others. Increase in temperature usually means decrease in water content and a simultaneous increase in air content. Change of the water content means an inverse change in the air content, and vice versa.

The observed facts, that small white-pine branches resist decay longest, apparently because of early thorough seasoning throughout their entire thickness, that larger pieces of slash frequently have their outer layers casehardened, and that on hot, summer days the temperature under the bark, even where the wood within was waterlogged, was noticeably warm to the fingers, led to the idea that

---

[8] Three sites are considered to include all conditions.

[9] The slopes here referred to are gentle and located in relatively dry situations, so that moisture is somewhat deficient for the best development of the fungi.

extremely high temperatures in midsummer may decidedly retard decay of slash that is fully exposed to the sun. That such retardation actually occurs is shown by the fact that partial shade usually favors rapid decay. Two sources of heat are to be considered—the action of the direct rays of the sun, and the heat reflected from the soil.

Merriam (*24*) apparently first attempted to outline life zones on the long-recognized, decisive influence of climate, and especially of temperature, in controlling the ranges of animals and plants. Zoologists and botanists very generally have accepted and recognized this influence as existing in all parts of the earth. More recently the Livingstons (*20*) and Zon (*43*) have shown that temperature has a very potent influence over the higher plants. It is difficult to determine what has been done on the effect of temperature on the growth of the fungi, as many data are scattered in a huge mass of literature in such a manner as to be found only after very prolonged search. A complete survey, therefore, is not attempted here. Stevens (*32*) seems to have been the first to make studies of the relation of temperature to the activities of a forest-tree fungus in the field. He found that *Endothia parasitica* (Murrill) And. and And. growing in the inner bark of *Castanea dentata* trees was plainly favored by the temperature of the Southern States as compared with those of New York and New England, but he made no attempt to determine the maximum temperature within the diseased bark.

It is well established that the surface of the soil attains commonly high temperatures when exposed to the full sunlight in summer. Climatologists (*15*) and ecologists (*37*) have given it especial attention. Among those investigators who have given definite data in this country are Tubeuf (*35*), Hartley (*17*), Bates and Roeser (*2*), and Toumey and Neethling (*34*). The latter give rather extensive data for Keene, N. H., where conditions are somewhat similar to those in the area where slash has been studied by the writer. The soil at Keene is described as varying from sandy loam through medium to coarse sand. It was found that surface soil temperatures of 122° F. were exceeded at times, and a maximum of 152° was reached. Removal of the duff made a difference of 20° to 26° in maximum temperatures, the bare soil reaching the highest temperatures.

Bark adhering to the wood has been considered an efficient insulator against heat. It sometimes appears to be a less efficient insulator than generally supposed. Hartig (*16*), investigating the temperatures within exposed living tree trunks in Bavaria, found that when the temperature of the outside air was 36° C. in shade, the subcortical temperature of 80-year-old spruces on the southwest side fully exposed to the sun was 55° C. Stevens (*33*) took readings at numerous places in New York and New England of the temperatures under which common fungi of small woody stems exist. Among these were readings of temperatures under the bark of dead Ribes twigs lying on the ground on May 26. The maximums ranged from 33° to 37° C. Again, maximums were noted in living and dead blackberry canes of 30° to 32° C., continuously from 9.30 a. m. to 1 p. m., when shade of surrounding vegetation intervened. The dead canes were practically of the same temperature as the living ones. On May 13, when the air temperature in shade was 10.5° to 13°, the maximum temperatures of twigs of *Betula lenta*, *B. lutea* (thin bark) and *B. alba* (thick bark) were respectively 30°, 36°, and 24°. Craighead (*5*), working in the Southern States, found that the temperatures of the upper sides of logs lying in full sunlight were as much as 60° (F.?) higher than that of the surrounding air. Graham (*13*, *14*), working in Minnesota, took the subcortical temperatures of logs of *Pinus strobus*, *P. banksiana*, *P. resinosa* and *Picea glauca*. He found that the maximum reached and even exceeded 50° under the dark-colored, smooth bark of white pine. The highest temperatures were attained under the smooth bark of white pine. Scaly bark was a much better insulator against heat than smooth bark. The temperature in rough-barked white pine exceeded 48° in 62 per cent of the days of July and August, 1920. Graham (*14*) also found that the temperature on six consecutive days in June, 1923, reached maximums ranging from 46° to 60°. By his various experiments he found that the subcortical temperatures of logs are directly and greatly influenced by the position of the log, the part of the log tested, the intensity of the solar radiation, the angle of incidence of the sun's rays, the color, thickness, and scaliness of the bark, the movement of the air, evaporation from the surface of the bark, etc.

At the writer's request, Gottlieb, (*12*) made readings, at Petersham, Mass., of the temperatures attained under the bark of white-pine slash varying in diameter from 0.3 to 9.7 inches. The slash used was felled six weeks before the readings were taken. The temperatures were taken by means of electric thermocouples on three full days and at random on several other days. It happened that the days chosen were not the hottest of the summer, although they were days of high air temperatures. Therefore the maximums can not be said to be maximums for the season, but may perhaps be called "frequent seasonal high temperatures." The readings were arranged in classes according to the diameter of the slash, each class having a range of 2 inches. A maximum temperature of 130° F. was reached. Figure 3 shows graphically the results for the three full days' readings. Temperatures were read from two to five different points in each size class of slash. The graphs are based on averages of the multiple readings. From 10 a. m. to 3.30 p. m., the hottest part of the day, the difference between the extremes for the different-sized slash ranged continuously from 13° to 29°. The slash of the 4 to 6 inch class consistently gave the highest temperatures, while the temperature of the smallest class, 0 to 2 inches, followed that of the surrounding air closest.

Studies of the temperatures that limit the action and growth of some of the wood-rotting fungi have been made under various conditions. The following studies are of interest here because the fungi used are wood destroyers of rather general distribution and occurrence in the Northeast, and some of them have been encountered in this study of slash decay.

Falck (*7*) tested cultures of *Merulius lacrymans* Wulfen, *Lenzites sepiaria*, and others. He found that mycelium of the former was killed at 34° C. and of the latter at about 44°. Falck (*8*) later tested extensively quite a number of fungi, including those mentioned above. His maximum temperatures for the two mentioned above vary. His results from subjecting growing mycelium in cultures to different temperatures are given in Table 3.

TABLE 3.—*Maximum temperatures for some wood-rotting fungi growing in pure cultures*

[Adapted from Falck (*9, p. 340*)]

Fungus	Temperature		Duration of exposure	Fungus	Temperature		Duration of exposure
	° *C.*	° *F.*	*Hours*		° *C.*	° *F.*	*Hours*
Fomes applanatus Fries	50	122	2½	Polyporus betulinus Fries	50	122	2
Fomes fulvus Fries	50	122	3½	Polyporus squamosus Fries	50	122	2
Lenzites betulinus Fries	[1] 60	140	1	Polyporus vegetus Fries	50	122	1
Lenzites sepiaria	[1] 60	140	3	Poria vaporaria Fries	50	122	1½
Lenzites squamosus Schaeffer	60	140	1				

[1] Maximum temperature not reached.

Snell (*28*) tested *Lenzites sepiaria*, *L. trabea* (Pers.) Fries, *Trametes serialis* Fries, *T. carnea* Nees, and *Lentinus lepidus* Fries in cultures. He found that the mycelium of *T. serialis* was killed at 34° C., that of *Lenzites sepiaria* at 44°, and that of the others at about 40°.

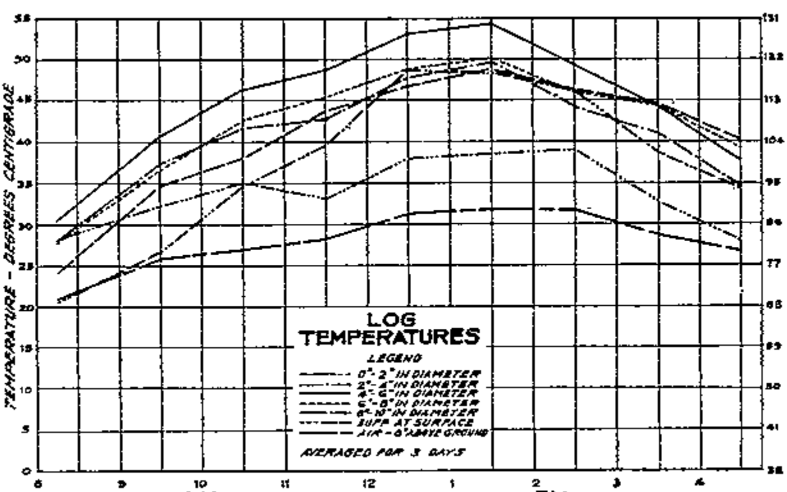


FIGURE 3.—Diagram showing average subcortical temperatures attained by various-sized slash of white pine for three consecutive days from 8.15 a. m. to 4.30 p. m. (After Gottlieb)

Still more recently Humphrey and Siggers[10] made a rather intensive study of the temperature relations of a considerable number of the common wood-rotting fungi. These were grown in pure cultures and the cultures subjected continuously to definite temperatures. The maximum temperatures, which were considered to be those at which no growth occurred in the cultures, are given in Table 4.

[10] HUMPHREY, C. J., and SIGGERS, P. V. Op. cit.

TABLE 4.—*Maximum temperatures for growth of some common coniferous wood-rotting fungi tested in pure cultures*

[All from American sources except where otherwise stated]

Fungus	Temperature (° C.)	Fungus	Temperature (° C.)
Fomes annosus Fries [1]	32	Fomes pinicola (Sw.) Cke.	38
Coniophora cerebella Pers.	34	Poria subacida Peck	38
Peniophora gigantea (Fries) Massee	34	Lentinus lepideus Fries	40
Polyporus schweinitzii Fries	34	Polystictus abietinus	40
Poria incrassata (B. and C.) Burt	34	Fomes annosus Fries	44
Trametes pini (Thore) Fries	34	Ganoderma lucidum (Leyss.)	48
Merulius himantioides (Schrad.) Fries	36		

[1] From Europe.

The problem has been attacked in another way and considerable work has been done in attempting to kill wood-destroying fungi already established within wood. Hoxie (*1*) in a single experiment very largely killed mycelium of *Merulius lacrymans* in timbers of a mill by heating the interior of the mill to 115° F. from Saturday noon until Monday morning at four different times. Examination showed the fungus alive in but 4 out of 40 timbers after such treatment. This fungus, however, has a low maximum temperature and reacts to heat treatment more readily than many of the wood-rotting fungi. Snell (*27*), experimenting with spruce blocks three-fourths of an inch in cross section, found that moist heat was much more effective than dry heat in killing the fungi. He worked with the above-mentioned five fungi (see p. 10). None survived a 12-hour exposure to moist heat of 131°.

Hubert (*19*) made kiln tests at 100 per cent relative humidity with blocks of wood attacked by various fungi. He tested thus *Fomes fomentarius* Fries, *F. igniarius* (Linn.) Gill., *F. laricis* (Jacq.) Murr., *F. pinicola* Schwartz, *Ganoderma tsugae* Murrill, *Pholiota adiposa* Fries, *Polyporus schweinitzii* Fries, *Polystictus hirsutus* Fries, *P. versicolor* Fries, *Torula ligniperda* (Willk.) Saccardo, and *Trametes pini* (Thore). Cultures were made from each piece of wood before and after the heat treatment. Exposure to a temperature of 120° F. for six hours killed the mycelium of *Fomes fomentarius*, *F. igniarius*, *F. pinicola*, *Ganoderma tsugae*, *Pholiota adiposa*, and *Torula ligniperda* in blocks of 1 to 2 inches in thickness. *Fomes laricis* and *Trametes pini* were killed in 1 to 4 inch pieces by a temperature of 130° in six hours. *Polyporus schweinitzii* was killed in blocks 1 to 8 inches thick by exposure to 130° for nine hours. At 140° *Trametes pini* was dead after three hours' exposure in 1 to 4 inch pieces. At 145° for three hours *Polyporus schweinitzii*, *Polystictus hirsutus* and *P. versicolor* were killed in 1 to 4 inch blocks. Hubert's experiments were too scattered as to length of exposure and temperatures tested to do more than to indicate roughly the killing temperatures for the fungi tested.

Summarizing the foregoing we find that temperature probably has as potent an influence over wood-rotting fungi as it has over higher plants. Under favorable conditions the soil surface becomes heated by the sun's rays to an astonishing degree, occasionally even to the point of injury to growing plants. Temperatures of the soil surface with a sandy soil in southern New Hampshire frequently reach 120° to 150° F. Bark adhering to wood is not such an efficient insulator against heat of the sun's rays as has been rather generally supposed. Temperatures of 30° C. and over are known to be attained beneath the bark of living trees. Temperatures of 48° to 60° C. were found to exist in northern Minnesota under the bark of white-pine logs. At Petersham, Mass., the subcortical temperatures in white-pine slash reached 130° F. and were continuously 120° F. or over for periods of two or more hours a day for the three days on which tests were run. Killing temperatures for some of the wood-rotting fungi growing in cultures have been found to be 34° to about 44° C. Mycelium in wood rotted by the fungi was killed by exposure to moist heat at 131° F. for 12 hours. Tests with numerous species of fungi showed that a temperature of 130° F. was deadly to a considerable number of the more common wood-rotting fungi. It is found that the temperatures under the bark of white-pine slash approach and even surpass those that common wood-rotting fungi can endure.

In considering the conditions within the slash exposed to full sunlight in midsummer, experience in the field shows that the larger pieces of slash retain a high water content until the bark is shed. Determination has not been made, but the relative humidity of the air under the bark must be high. The condition in the first summer, then, must approximate that of the above-mentioned experiments conducted by Hubert in that a high relative humidity exists beneath the bark. On the three days when tests were run the subcortical temperature was 120° F. for periods of two or more hours each day. It is certain that this condition existed on numerous days of midsummer and on numerous consecutive days at times. The action of such heat on several consecutive days is exactly analogous to that of discontinuous sterilization of culture media in the laboratory, without steam pressure. By this method the material is heated for 15 or more minutes a day for three consecutive days. The action of the heating is as follows: The first heating kills the organisms that are growing in the materials of which the medium is made. The second heating kills germinating spores that may have begun to grow in the material. The third completes the killing of germinating spores that may have escaped the second heating. This results from the well-known fact that actively growing mycelium is most susceptible to the action of heat, just as active vegetation of the higher plants is most susceptible to heat and frost. In this way it is believed that the repeated heating of the inner bark and adjacent layers of wood on several consecutive days even at relatively low temperatures may prevent some or all of the wood-rotting fungi from growing there or may greatly retard their growth, in spite of their having earlier entered and established themselves to a limited extent. It should be stated that the slash of white pine, so far as known, furnishes extreme conditions of heat and therefore accentuates this effect to a maximum. It does not seem surprising that slash sometimes resists decay for excessive periods of time. The resistance of the smaller branches and twigs to decay appears not to be due to the heating so much as to their quicker drying and seasoning, probably because of the thinner bark.

The preceding discussion of the adverse effect of the heat of the sun is purposely extended because high temperatures are a feature of those localities where white-pine slash is usually situated. The white pine characteristically thrives naturally upon sandy soils. When the trees are felled and the full sunlight gains access, conditions are such that maximum temperatures occur, and their effect upon the decay of the rapidly drying slash is potent.

MOISTURE

Moisture is almost as potent as heat in its control of the decay of white-pine slash. Moisture in the slash absolutely determines the fungus that can attack it. *Lenzites sepiaria* can work only in slash that is exposed to the sun and consequently has a minimum of moisture. *Polystictus abietinus* is just as rigidly limited to slash that has a considerably higher water content but still is not water-logged.

About half way down in the piles of white-pine slash the fallen needles form a layer that is very effective in keeping out the sunlight and in keeping in the moisture. Under it the air is relatively moist and cool all the time. Slash often water-logs under this layer. The fungi attacking the slash below this mantle certainly require maximum water supplies. Recording hygro-thermographs have been run during an entire summer at Petersham, Mass., one in the top slash of a pile of white-pine slash and one beneath the leaf mantle in the lower part of the same pile. These records show definitely that the moisture is almost constantly higher and the temperature lower beneath the pile than in the top slash of that pile. The cool temperatures prevailing there also have much to do with the presence of some of the fungi, so that it is impossible to say which is really the decisive factor determining the fungi found there.

Again, water plays an important rôle in the soil upon which the slash lies. In this region swampy situations lead to water-logging and thus indefinitely delay decay. Soils of average water content are most favorable for rapid decay of slash. Leachy soils of coarse texture encourage too rapid drying out for the fungi to progress satisfactorily, and decay may be almost as greatly retarded on them as on swampy lands.

An interesting local variation in slash decay was found upon the low, dry area of thin sand around Winchendon, Mass. Here 21-year-old white-pine slash was rotted no more than 10 to 12 year old slash in other places. This sand would be classed as a poor site for white pine, although that species predominates in that area. There seem to be two possible factors that may determine the rapidity of the rotting of slash there, namely, acidity of the soil and heat from the sun.

The soil is acid, as is plainly indicated by the abundance of Vaccinium and other ericaceous plants. Acidity of the media is known to be detrimental to some of the fungi. But no definite tests of their reaction to acidity have been made with any of the fungi, except *Lenzites sepiaria*, found rotting white-pine slash. A number of different investigators have given data upon this fungus, all showing that its optimum condition is upon acid material (*11*, *23*, *25*, *26*, *38*, *41*, *42*). It apparently will not grow upon alkaline media. In the above-mentioned locality the only rot that was recognizable was that of *L. sepiaria*, but this was far from abundant. Judging merely by the growth of this fungus, the slash was slightly acid, but not any more so than in any other place where slash was investigated. The lower slash, which must be most influenced by soil moisture, was rotted the least. Apparently, then, acidity of the soil is not a powerful factor favoring *L. sepiaria*, or the lower slash would be rotted most. Acidity may or may not be effective in excluding other wood-rotting fungi.

Considering the heat of the sun as a possible factor, the conditions in this area are favorable for the exerting of its maximum effect. The soil is thin, consisting of rather coarse sand and some fine gravel. It is porous, leading to extreme dryness in the top layers in hot weather. A soil of this type is well known to be liable to become overheated (*37*). While no records of the temperatures attained in summer upon this soil are available, there is no doubt that they are very high, especially just at the surface where the rotting of the slash is least. The reflected heat is surely ample at certain times to inhibit the action of most if not all of the ordinary wood-rotting fungi. This action is certainly intensified by the additional effect of dryness due to and accompanying the high temperature.

AIR OR OXYGEN

Wood subjected to ordinary conditions tends to lose water and becomes seasoned, as the lumberman says. Under such conditions there is always sufficient air for the luxuriant growth of any of the slash-rotting fungi, but there is not enough water for them to thrive. Authentic cases are known in Europe where original roof timbers are still in place in sound condition in buildings that are a thousand years old. This is simply because water has been successfully excluded. But when the conditions lead to the imbibition of water from the soil or surrounding air, wood tends to become overloaded with water and is said to be water-logged. Then the amount of air present within the wood may be much reduced, even to such a degree that some of the wood-rotting fungi can not grow. For instance, water-logged slash persists for very long periods of time. Water-logged timbers are well known to have remained practically sound for hundreds of years. This was simply due to the fact that wood-destroying fungi could not endure the entire absence of air and oxygen. Really but little is yet known of the oxygen requirements of the various wood-rotting fungi, but air as a factor in their growth is undoubtedly fundamental. When it is said that a certain fungus grows in the bottom slash of the piles because of the lower temperature or the greater water supply, only the most obvious fact is being mentioned, and the air relation, which actually may be even more important, is apt to be ignored entirely.

INSECTS

Almost nothing is known of the influence that insects may exert upon the decay of white-pine slash. Observation shows that intensive attacks of the usual bark-inhabiting insects hasten the loosening and shedding of the bark. Smaller sized slash, which is decorticated early, resists decay because of the prompt drying out of the bare wood before fungi have become established within it. Insects by hastening decortication may retard decay. What their influence may be as a result of their tunnel making within the wood is unknown. Experiments that, it is hoped, will give some light on this question are under way.

PRACTICAL CONSIDERATIONS

On soils that are moist the year round slash lying directly on the ground becomes water-logged, so that fungi can not attack it. Scattered or lopped slash remains unrotted for an excessively long time and to an abnormal degree. Under such conditions a maximum amount of slash will rot if high piles are made, if slash is not lopped, or if piles are placed on old logs, rocks, or anything that will hold the bottom layers off the ground. In other words, a minimum amount of the slash should be left lying in direct contact with the ground. This is especially true where there is a rank, dense ground cover on a moist soil.

On dry, well-drained soils the optimum condition for the rotting of slash is under partial shade resulting from partial cutting. There slash rots most quickly if it is lopped and scattered or loosely piled; i. e., with a maximum amount resting directly on the ground.

In open sunlight on dry soils unlopped, loosely piled, or scattered slash soon becomes decorticated, dries excessively, and rots very slowly because of the excessively dry conditions. Here slash piled closely or lopped and piled so as to lie compactly together, with a minimum surface presented to the sun, rots with maximum speed. Even then high temperatures may limit the action of even *Lenzites sepiaria*, which has the highest optimum temperature, so far as known, of all of the fungi that attack white-pine wood.

Under favorable conditions, white-pine slash will disintegrate but not entirely disappear in about 15 years. About 5 to 10 years more are required for the rotten wood to disappear, and even then a layer of flattened, fibrous, wood mold is hidden by the recent débris of the forest. Conditions adverse to decay may delay distintegration of white-pine slash for 10 years or longer, as compared with decay under optimum conditions.

PRODUCTS OF DECOMPOSITION OF WOOD

Each fungus that attacks and destroys wood has its own peculiar method of attack. In general, it may be said that there are two methods by which wood is destroyed by the fungi. One results in the formation of a brown, charcoallike mass, which is crisscrossed by many irregular cracks and crevices. The rot caused by *Lenzites sepiaria* is a good example of this (fig. 1). The fungi that produce this type of rot decompose the cellulose and part of the other constituents of the wood-cell walls. The fibrous nature of the wood is entirely lost, and the rotted wood crumbles easily between the fingers. The second type of rot results from the work of fungi that attack more especially the lignin of the wood-cell walls and leave the cellulose, resulting in a stringy or fibrous type of rot. In extreme cases of this rot the cellulose also may finally disappear locally, in which case hollow pockets are formed in the wood. This type of rot is well represented by the decay caused by *Polystictus abietinus*. (Fig. 2.)

Analyses show that approximately one-half of wood is cellulose (*6*); this also is shown by the paper maker, whose wood pulp is nearly pure cellulose (*18*). The remainder of healthy wood is composed of a number of substances of complex chemical composition, which serve to strengthen the fibers of cellulose and to cement the cells together (*18, 30*). When these various cell-wall components are attacked by fungi their chemical composition is changed, and secondary products are formed, which in turn may be broken down and finally disappear. This undoubtedly happens to cellulose just as to the other cell-wall constituents. While comparatively little is really known about these matters, there is much to be learned about the identity of these decomposition products and their influence upon the growth of a new forest.

It is a common observation that young trees do not appear on the sites of large slash piles until after a prolonged period of years. This action has been generally attributed to the mechanical influence of the layer of rotted wood mold. The growth of some tree species is undoubtedly thus affected, but so far as the writer knows, no one has thoroughly investigated the matter. Certain investigations of the soil in cultivated lands show that the decay of cellulose exerts a detrimental influence upon the development of herbaceous plants (*4, 29, 36*). Upon tender tree seedlings may there not be a similar unfavorable effect of the decaying cellulose from slash left in the forest? Here seems to be a promising field for experimentation, which may shed much light upon some puzzling kinks in silviculture.

RELATION OF SLASH-ROTTING FUNGI TO THE NEW FOREST

None of the fungi found rotting white-pine slash is known to attack living, normal trees of this species. *Lenzites sepiaria* and *Polystictus abietinus* will grow in dead patches of bark and wood on living trees, such as are caused by fire or bruising, but these trees can not be called normally healthy. *Stereum sanguinolentum*, which was found a few times on white-pine slash, is known to be a serious enemy of living balsam fir, *Abies balsamea* (Linnaeus) Miller, in Canada and Maine (*10*), where this species has been attacked by the spruce bud worm. Whether it will be found to attack trees that have not been weakened by such insect attacks is unknown. It may prove to be more important than is now known. If this should be the case, this fungus may be dangerous to forests near decaying lots of slash. A noticeable thing was the absence of *Fomes pinicola* and *Trametes pini* in the white-pine slash examined. This must be accidental, as both are certainly present within the forests of the area covered. Experience shows that the latter is to be feared as a cull-producing agent in new forests.

It will be noted that this discussion is limited to the decay of slash left to rot and disappear by the action of natural factors. The burning of the slash is a question that must be decided largely from the economic and silvicultural standpoint and is therefore not touched upon in this investigation. There can be no doubt that controlled burning of slash is the most effective sanitary measure that can be readily undertaken. It removes a large amount of material that serves to feed a host of wood-destroying fungi, some of which may ultimately prove to be dangerous to living trees of the succeeding forest. Even where considerable amounts of charred material are left unconsumed on the ground it appears that a minimum crop of fungus sporophores is produced in such material. An investigation of this matter in the western white pine (*Pinus monitcola* Douglas) region of Idaho showed that comparatively few fruits of the fungi, known to be present in that vicinity, were formed after fire had charred the cull logs (*40*). Examination of such charred white-pine débris shows that fungi are scarce in it and decay is much retarded. Just what effect the decomposition products of large quantities of slash may have upon a succeeding generation of young tree seedlings appears to be practically unknown. The writer has called attention earlier to a possible, immediate, deleterious action. But what may be the beneficial effects as contrasted with the burning of all of this material?

SUMMARY

The course of the usual program of the rotting of white-pine slash is outlined as follows: Fruiting bodies of wood-rotting fungi begin to form in the second year. *Lenzites sepiaria* and *Polystictus abietinus* are commonly the first to appear. In the fourth year decay is well advanced. From the seventh to the ninth years the piles of slash flatten down. By the fifteenth year most of the slash is well rotted, but practically sound pieces of the smaller branches persist. By the twentieth year the material has formed a mat of fibrous mold under the recently fallen leaves of the new forest. Unfavorably wet or dry situations may retard decay 10 years.

About 23 different fungi were found rotting white-pine slash. Of these *Lenzites sepiaria* rots more than any other species. *Polystictus abietinus* rots the next largest quantity, while the rest are scavengers, working rather indiscriminately on what is left. The former attacks smaller slash, well exposed to the sunlight in the top of the piles or on the sides. The latter species works lower down in the piles in the sapwood of the larger pieces. *L. sepiaria* continues its work in the heartwood, after the sapwood is rotted, until the slash is completely disintegrated.

Considering the factors controlling decay, it is found that the type of the slash itself is important; forestry sites and soils, so far as the studies went, were not significant; decay is retarded upon western and northern slopes and accelerated upon southern and eastern ones: the heat of the sun may be decisive, depending upon local conditions; soil moisture is important. Swampy conditions lead to water-logging of slash and indefinitely postpone its decay. Coarse, leachy soils encourage excessive dryness and thus delay decay by reducing moisture below the minimum requirements of most of the wood-rotting fungi.

Local conditions will dictate the best method of disposing white-pine slash for most rapid decay. On wet situations slash should be left as little as possible in direct contact with the soil. On very dry land the slash should be piled compactly; lopping will help to get the material close together. On medium situations the slash can be left more or less as felled, but with as much in contact with the soil as possible. Here, again, lopping will help.

None of the fungi found rotting white-pine slash, with the possible exception of *Stereum sanguinolentum*, appears to be threatening to the new forest following the one producing the slash.

LITERATURE CITED

(1) ASSOCIATED FACTORY MUTUAL FIRE INSURANCE COMPANIES, INSPECTION DEPARTMENT
[1915]. DRY ROT IN FACTORY TIMBERS, 1915. Ed. 2, 107 p., illus. Boston, Mass. ([Pub.] 32.)

(2) BATES, C. G., and ROESER, J., JR.
1924. RELATIVE RESISTANCE OF TREE SEEDLINGS TO EXCESSIVE HEAT. U. S. Dept. Agr. Bul. 1263, 16 p., illus.

(3) BOYCE, J. S.
1923. THE DETERIORATION OF FELLED WESTERN YELLOW PINE ON INSECT-CONTROL PROJECTS. U. S. Dept. Agr. Bul. 1140, 8 p., illus.

(4) COLLISON, R. C., and CONN, H. J.
1925. THE EFFECT OF STRAW ON PLANT GROWTH. N. Y. State Agr. Expt. Sta. Tech. Bul. 114, 35 p., illus.

(5) CRAIGHEAD, F. C.
1920. DIRECT SUNLIGHT AS A FACTOR IN FOREST INSECT CONTROL. Ent. Soc. Wash. Proc. 22: 106–108.

(6) CZAPEK, F.
1913. BIOCHEMIE DER PFLANZEN. Aufl. 2, Bd. 1, illus. Jena.

(7) FALCK, R.
1907. WACHSTUMSGESETZE, WACHSTUMSFAKTOREN UND TEMPERATURWERTE HOLZZERSTÖRENDER MYCELIEN. *In* Möller, A., Hausschwammforschungen in amtlichem Auftrage, Heft 1, p. [53]–154, illus. Jena.

(8) ———
1909. DIE LENZITES-FÄULE DES CONIFERENHOLZES. *In* Möller, A., Hausschwammforschungen in amtlichem Auftrage, Heft 3, 234 p., illus. Jena.

(9) ———
1912. DIE MERULIUS-FÄULE DES BAUHOLZES. *In* Möller, A., Hausschwammforschungen in amtlichem Auftrage, Heft 6, 405 p., illus. Jena.

(10) FAULL, J. H.
1924. II. "SAPIN ROUGE" OR RED HEART ROT OF BALSAM, ITS CAUSE AND ITS RELATION TO SLASH DISPOSAL. Ontario Min. Lands and Forests Rpt. 1922/23: 198–200.

(11) FRITZ, C. W.
1923. CULTURAL CRITERIA FOR THE DISTINCTION OF WOOD-DESTROYING FUNGI. Roy. Soc. Canada Proc. and Trans. (3) 17 (sect. 5): 191–288, illus.

(12) GOTTLIEB, A. W.
1928. RELATION BETWEEN SUBCORTICAL TEMPERATURE AND SIZE OF WHITE PINE (PINUS STROBUS) SLASH. Ecology 9: 243–248, illus.

(13) GRAHAM, S. A.
1920. FACTORS INFLUENCING THE SUBCORTICAL TEMPERATURES OF LOGS. Minn. State Ent. Rpt. 18: 26–42, illus.

(14) ———
1924. TEMPERATURE AS A LIMITING FACTOR IN THE LIFE OF SUBCORTICAL INSECTS. Jour. Econ. Ent. 17: 377–383.

(15) HANN, J.
1906. LEHRBUCH DER METEOROLOGIE. Aufl. 2, neubearb., 642 p., illus. Leipzig.

(16) HARTIG, R.
[1894]. TEXT-BOOK OF THE DISEASES OF TREES. Translated by W. Somerville. Rev. and ed. by H. M. Ward. 331 p., illus. London.

(17) HARTLEY, C.
1918. STEM LESIONS CAUSED BY EXCESSIVE HEAT. Jour. Agr. Research 14: 595–604, illus.

(18) HAWLEY, L. F., and WISE, L. E.
1926. THE CHEMISTRY OF WOOD. 334 p., illus. New York.

(19) HUBERT, E. E.
1924. EFFECT OF KILN DRYING, STEAMING, AND AIR SEASONING ON CERTAIN FUNGI IN WOOD. U. S. Dept. Agr. Bul. 1262, 20 p., illus.
(20) LIVINGSTON, B. E., and LIVINGSTON, G. J.
1913. TEMPERATURE COEFFICIENTS IN PLANT GEOGRAPHY AND CLIMATOLOGY. Bot. Gaz. 56: 349–375, illus.
(21) LONG, W. H.
1915. A NEW ASPECT OF BRUSH DISPOSAL IN ARIZONA AND NEW MEXICO. Soc. Amer. Foresters Proc. 10: 383–398.
(22) ———
1917. INVESTIGATIONS OF THE ROTTING OF SLASH IN ARKANSAS. U. S. Dept. Agr. Bul. 496, 15 p.
(23) MEACHEM, M. R.
1918. NOTE UPON THE HYDROGEN ION CONCENTRATION NECESSARY TO INHIBIT THE GROWTH OF FOUR WOOD-DESTROYING FUNGI. Science (n. s.) 48: 499–500.
(24) MERRIAM, C. H.
1894. LAWS OF TEMPERATURE CONTROL OF THE GEOGRAPHIC DISTRIBUTION OF TERRESTRIAL ANIMALS AND PLANTS. Natl. Geogr. Mag. 6: 229–238, illus.
(25) RUMBOLD, C.
1907. BEITRÄGE ZUR KENNTNIS DER BIOLOGIE HOLZZERSTÖRENDER PILZE. 60 p., illus. Ludwigsburg. (Inaug. Diss. München Univ.)
(26) ———
1911. ÜBER DIE EINWIRKUNG DES SÄURE- UND ALKALIGEHALTES DES NÄHRBODENS AUF DAS WACHTSUM DER HOLZZERSETZENDEN UND HOLZVERFÄRBENDEN PILZE; MIT EINER ERÖRTERUNG ÜBER DIE SYSTEMATISCHEN BEZIEHUNGEN ZWISCHEN CERATOSTOMELLA UND GRAPHIUM. Naturw. Ztschr. Forst u. Landw. 9: [429]–465, illus.
(27) SNELL, W. H.
1922. THE EFFECT OF HEAT UPON WOOD DESTROYING FUNGI IN MILLS. Amer. Wood Preservers' Assoc. Proc. 18: 25–29, illus.
(28) ———
1922. STUDIES OF CERTAIN FUNGI OF ECONOMIC IMPORTANCE IN THE DECAY OF BUILDING TIMBERS. U. S. Dept. Agr. Bul. 1053, 47 p., illus.
(29) SÖDERBAUM, H. G., and BARTHEL, C.
1924. [INFLUENCE OF SAWDUST ON CROP GROWTH IN SOILS.] Meddel. Centralanst. Försöksv. Jordbruksområdet [Sweden] 271, 22 p., illus. [In Swedish. Abstract in U. S. Dept. Agr. Expt. Sta. Rec. 53: 121. 1925.]
(30) SPAULDING, P.
1906. STUDIES ON THE LIGNIN AND CELLULOSE OF WOOD. Missouri Bot. Gard. Ann. Rpt. 17: 41–58, illus.
(31) ———
1911. THE TIMBER ROT CAUSED BY LENZITES SEPIARIA. U. S. Dept. Agr., Bur. Plant Indus. Bul. 214, 46 p., illus.
(32) STEVENS, N. E.
1917. THE INFLUENCE OF TEMPERATURE ON THE GROWTH OF ENDOTHIA PARASITICA. Amer. Jour. Bot. 4: 112–118, illus.
(33) ———
1922. ENVIRONMENTAL TEMPERATURES OF FUNGI IN NATURE. Amer. Jour. Bot. 9: 385–390, illus.
(34) TOUMEY, J. W., and NEETHLING, E. J.
1924. INSOLATION A FACTOR IN THE NATURAL REGENERATION OF CERTAIN CONIFERS. Yale Univ. School Forestry Bul. 11, 63 p., illus.
(35) TUBEUF, C. VON
1914. HITZETOT UND EINSCHNÜRUNGSKRANKHEITEN DER PFLANZEN. Naturw. Ztschr. Forst u. Landw. 12: 19–36. illus.
(36) VILJOEN, J. A., and FRED, E. B.
1924. THE EFFECT OF DIFFERENT KINDS OF WOOD AND OF WOOD PULP CELLULOSE ON PLANT GROWTH. Soil Sci. 17: 199–208, illus.
(37) WARMING, E., and VAHL, M.
1909. OECOLOGY OF PLANTS. Eng. ed. prepared by P. Groom, and I. B. Balfour. 422 p. Oxford.

(38) WEBB, R. W.
1919. STUDIES IN THE PHYSIOLOGY OF THE FUNGI. X. GERMINATION OF THE SPORES OF CERTAIN FUNGI IN RELATION TO HYDROGEN ION CONCENTRATION. Ann. Missouri Bot. Gard. 6: 201–222, illus.

(39) WEIR, J. R.
1915. OBSERVATIONS ON THE PATHOLOGY OF THE JACK PINE. U. S. Dept. Agr. Bul. 212, 10 p., illus.

(40) ———
1923. THE EFFECT OF BROADCAST BURNING OF SALE AREAS ON THE GROWTH OF CULL-PRODUCING FUNGI. Jour. Forestry 21: 183–184.

(41) ZELLER, S. M.
1916. STUDIES IN THE PHYSIOLOGY OF THE FUNGI. II. LENZITES SAEPIARIA FRIES, WITH SPECIAL REFERENCE TO ENZYME ACTIVITY. Ann. Missouri Bot. Gard. 3: 439–512, illus.

(42) ———
1917. STUDIES IN THE PHYSIOLOGY OF THE FUNGI. III. PHYSICAL PROPERTIES OF WOOD IN RELATION TO DECAY INDUCED BY LENZITES SAEPIARIA FRIES. Ann. Missouri Bot. Gard. 4: 93–164, illus.

(43) ZON, R.
1914. METEOROLOGICAL OBSERVATIONS IN CONNECTION WITH BOTANICAL GEOGRAPHY, AGRICULTURE AND FORESTRY. U. S. Mo. Weather Rev. 42: 217–223, illus.

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

END