TB 494 (1935) USDA TECHNICAL BULLETINS UPDATA
DECAY FOLLOWING FIRE IN YOUNG MISSISSIPPI DELTA HARDWOODS
HEPTING, G. H. 1 OF 1

START

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

Technical Bulletin No. 494 December, 1935

UNITED STATES DEPARTMENT OF AGRICULTURE

WASHINGTON, D. C.

DECAY FOLLOWING FIRE IN YOUNG MISSISSIPPI DELTA HARDWOODS[1]

By George H. Hepting[2]

Assistant pathologist, Division of Forest Pathology, Bureau of Plant Industry

CONTENTS

	Page
Introduction	1
Description of working areas	3
Field methods	4
Frequency of fires	6
Formation of fire scars	6
Rate of healing of fire scars	7
Infection of scarred trees by fungi	8
Upward spread of decay in the bole	10
Relation between scar age and height of decay	14
Relation between age of tree and rate of decay	19
Relation between percentage of tree circumference scarred and rate of decay	19
Relation between tree diameter at time of scarring and rate of decay	20
Upward spread of decay in the bole—Contd.	
Relation between present diameter and rate of decay	20
Relation between rate of diameter growth and rate of decay	21
Effects of certain unmeasurable factors on decay rate	21
Importance of fire scars in causing breaking-over	22
Effect of repeated scarring on decay in red gum	24
The fungi	25
Insect damage	28
Insects collected behind fire scars	29
Summary	31
Literature cited	31

INTRODUCTION

The Delta area of the lower Mississippi River extends from the vicinity of Cape Girardeau, Mo., to the Gulf of Mexico, comprising the present and former flood plains of the river and portions of the bottom lands of a number of the important tributaries. It occupies a north and south belt approximately 600 miles long, and from 30 to 115 miles wide. Its total area is variously estimated as between 24,000,000 and 29,000,000 acres, according to the quantity

[1] The subject matter of this bulletin was submitted to the Graduate School of Cornell University in partial fulfillment of the requirements for the degree of doctor of philosophy.

[2] The writer wishes to express his thanks to Carl Hartley, of the Division of Forest Pathology, U. S. Department of Agriculture, under whose direction this study was carried on, for his interest, suggestions, and cooperation; to F. H. Kaufert, formerly of the same Division, for his suggestions and assistance; to F. X. Schumacher, of the Forest Service, U. S. Department of Agriculture, for his direction in the statistical analysis of the data; and to the Thistlethwaite Lumber Co., the Poinsette Lumber Co., and the other agencies that permitted trees to be cut on their lands; to R. W. Davidson, of the Division of Forest Pathology, U. S. Department of Agriculture, and F. H. Kaufert, who assisted materially in the determination of the fungi; and to R. A. St. George, T. E. Snyder, and A. G. Boving, of the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture, and to William Mann, of the U. S. Zoological Park, Washington, D. C., for the identification of most of the insects.

9407°—35——1

of bottom lands of the tributaries that are included.[3] This is one of the important hardwood-producing areas in the United States (*11*).[4] There are, roughly, 40 species of commercial importance within the area, oak, red gum, cypress, ash, and cottonwood being of greatest value. In spite of the importance of this region, there had been practically no professional forestry investigations in the Delta prior to 1928 and no forest pathological work until 1931 when Kaufert (*7*), working with L. O. Overholts, made a preliminary pathological reconnaissance.

Until recent years fire was considered of little importance in the Delta, partly because the area was thought to be too moist for frequent fires, and partly because it was thought by timberland owners that fire did little damage to hardwood timber. Both of these reasons have subsequently been shown to be false. As will be shown later, practically every year some part of the Delta burns; and in dry years in the past, large portions of this area have burned over. The dry spring and fall months of the 1910–11, 1916–17, 1917–18, and the 1924–25 seasons are examples. Because it is not possible to tell by ring counts whether a tree was burned in the fall of a given year or in the spring of the following year, preceding the growth period, the terms "fire season" and "fire year" will include both of these periods. That is, the fire year 1924–25 includes the fall of 1924 and the spring of 1925. Lentz (*11*) estimates that 80 to 90 percent or more of the hardwood stands in the bottom lands were found to have burned over in 1916, in the 1924–25 fire season, or during both of these periods.

The predominant fuel is leaf litter. While this litter of leaves and small twigs rarely exists for more than a year, because of its rapid decomposition, 1 year's accumulation, together with the undergrowth, is sufficient to produce a hot fire, in dry weather, which severely wounds the bases of the trees.

The chief causes of fire in the bottom lands are hunters and trappers who start fires to drive out game or to make the cut-over lands more accessible; loggers; farmers who, clearing land for cotton, permit their fires to run into the woods; and local woodchoppers who leave their warming fires without extinguishing them.

Surface fires, no matter how light, have a devastating effect on young growth. Seedlings and small reproduction are killed outright; saplings and poles, because their relatively thin bark offers little resistance to fire, are wounded at the base and sometimes completely girdled; and merchantable trees are wounded or killed. The wounding of trees by fire is well discussed by Lachmund (*8*, *9*) and by Nelson, Sims, and Abell (*16*).

The effect of fire scars on hardwoods is threefold. There is a mechanical weakening because of the cessation of increment over the scarred area; there is an interruption in the normal physiological functions of translocation of food, nutrients, and water; and, most important of all, the tree is exposed to the entrance of wood-destroying fungi and insects. These fungi may either so weaken the tree at the

---

[3] WINTERS, R. K., and BULL, H. THE GEOLOGICAL AND ECONOMIC BACKGROUNDS OF FOREST CONDITIONS IN THE LOWER MISSISSIPPI DELTA. U. S. Dept. Agr., Forest Serv. South, Forest Expt. Sta. Mimeographed Pub. pp. 1–7. 1932.

[4] Italic numbers in parentheses refer to Literature Cited, p. 31.

base that it breaks over, or else, if the tree remains in the stand, the fungi work upward in the bole, causing a reduction or complete loss of the merchantable portion of the tree.

Hedgcock (*5*) states that investigations in hardwood forests indicate that more than 90 percent of all basal or butt rots enter through fire scars. In the Delta area this figure might be raised still higher and be allowed to include trunk rots as well as butt rots. As yet there is little evidence of serious trunk rots in this area, excepting those that gain entrance through fire scars. *Polyporus hispidus* Fr., however, is a fungus which causes a trunk rot in bottom-land hardwoods and which can gain entrance through wounds other than fire scars.

Since the principal problem in the Delta hardwoods at the present time is the future of the cut-over lands and the immature stands, the present study is concerned with the effects of fire in immature stands, throughout the Delta, by permitting infection by wood-destroying fungi and invasion by insects. The purposes of this study were to secure information on the following points: (1) The importance of fire in causing the breaking over of young trees from decay at the base, (2) the importance of fire in causing cull in the surviving trees at a future date, (3) the relative susceptibility of certain important species to decay, (4) the organisms responsible for the decays, (5) the rate of healing of fire scars, and (6) insect activity behind fire scars. The study was instigated chiefly to provide the Forest Survey, United States Forest Service (*13*), now working in the Delta hardwood area, with information on the role of fungi in causing depletion in fire-scarred immature stands. The field work was done during the late spring, summer, and fall of 1932.

DESCRIPTION OF WORKING AREAS

On the basis of relative elevation, the Mississippi Delta can be divided into two broad classes, the first bottoms and the terraces. The first bottoms embrace the present flood plain of the river, and the terraces comprise what remains of the former and higher flood plains. All of the working areas in the present study were within the first bottoms. These bottoms are practically flat, with occasional ridges ranging from 2 or 3 feet to about 15 feet in elevation above the flats. The soil is predominantly heavy clay ranging to silty clay and silt loam, with little or no humus covering. There is considerable fine sand along stream fronts and ridges. The flats, while normally dry from late spring until fall, are more or less under water for the remainder of the year. Slight changes in elevation, with accompanying changes in soil (for example, from clay in a flat to a silty loam in a ridge) produce marked changes in forest types. Red gum, often in almost pure stands, is an indicator of ridge soil. Overcup oak and water hickory indicate a poorly drained flat. Water oak, willow oak, and Nuttall oak commonly accompany red gum on the better sites, while ash is usually found on the heavier soils. There is naturally much overlapping of types.

In choosing the species of trees to be studied, those which were considered to have the greatest economic value were selected. The following species were studied, in order of preference: Red gum

(*Liquidambar styraciflua* L.), ash (*Fraxinus americana* L. and *F. pennsylvanica lanceolata* (Bork.) Sarg.), Nuttall oak (*Quercus nuttallii* Palm.), water oak (*Q. nigra* L.), overcup oak (*Q. lyrata* Walt.), cherrybark oak (*Q. rubra leucophylla* Ashe, and *Q. rubra pagodaefolia* (Elliot) Ashe), willow oak (*Q. phellos* L.), hackberry (*Celtis laevigata* Willd.), and persimmon (*Diospyros virginiana* L.). These names are as given by Putnam and Bull.[5] Cottonwood and willow, also of importance, are confined mainly to the batture lands lying between the levees and the river, and would more logically constitute a separate study. They were omitted in this investigation.

As the purpose of this study was to supply information relating to the Delta as a whole, working areas were chosen at widely scattered points over the Delta. Trees were sampled from 7 sections in East Carroll and Madison Parishes in northeastern Louisiana, from 4 in St. Landry and Pointe Coupee Parishes in southern Louisiana, from 5 in Sharkey and Issaquena Counties in western Mississippi, and from 4 sections in Panola County in northwestern Mississippi. Working areas that met the following qualifications were chosen: A large proportion of fire-scarred trees; a stand consisting mainly of the species with which the study was concerned, the trees being within the required diameter limits of 3 to 11 inches, breast high; and accessibility. Because much of the Delta has burned over at least once in the past 20 years, there was no problem in finding burned areas. However, as a large proportion of the scars were found to have been formed during the bad fire season of 1924–25, and many of the remainder were formed in the fire season of 1917–18, it was not possible to secure a good distribution of scar ages for the study.

Nine of the working areas were located in the forest type recognized as "red gum" by the Forest Survey[6], 9 were in the mixed hardwood type, and 2 were in the overcup oak-pecan type. All of the stands were second-growth, and some had been old fields.

A total of 602 fire-scarred trees were cut and dissected, consisting of 213 red gum, 101 ash, 76 Nuttall oak, 69 water oak, 35 overcup oak, 14 willow oak, 10 cherrybark oak, 66 hackberry, and 18 persimmon.

FIELD METHODS

Only trees with visible fire scars, open or healed, were chosen for analysis. Since completely healed fire scars on young trees are rare, the exclusion of those healed beyond identification will have little effect on the results obtained. The principal reason why so few completely healed scars are found is because, on the average, these young trees have such large scars. In the species studied, fire scars occupied, on the average, 49 percent of the circumferences of the trees, measured where the scar was widest.

Plots were not laid out because in many cases there were but few desirable trees over a large area, as, for example, on recently cut-

[5] PUTNAM, J. A., and BULL, H. THE TREES OF THE MISSISSIPPI RIVER DELTA REGION. U. S. Dept. Agr., Forest Serv. South. Forest Expt. Sta. Mimeographed Pub., 207 pp. 1932.

[6] LENTZ, G. H. FIELD MANUAL FOR THE FOREST SURVEY IN THE BOTTOMLAND HARDWOODS OF THE MISSISSIPPI DELTA. U. S. Dept. Agr., Forest Serv. South. Forest Expt. Sta. Mimeographed Pub., pp. 12–14. 1932.

over land. Instead of laying out plots, the crew, composed of two men, walked back and forth over the area, cutting all fire-scarred trees of the desired species and size as they came to them. Trees were omitted only if they had wounds other than fire scars, which would make it impossible to determine definitely the entrance point of decay, or if the trees were so badly scarred that it was impossible to tell the age and extent of the scars. Rarely did a tree have to be discarded for either of these reasons. The trees were cut at the height at which the scar occupied the largest proportion of the circumference of the tree.

An impression was taken from the top of the stump of each tree, showing the former and present outlines of the scar, and the outlines of the decay. This impression was made by marking all desired outlines on the stump with a soft indelible pencil. Sheets of paper were then moistened and placed on the stump. By pressing the paper over the outlines a satisfactory print was secured. In this way it was possible to secure impressions of the decayed portion of the cross-sections, which were later planimetered to determine the area of decay. Measurements of the original and present width of scars were also made from these impressions.

All measurements, excepting diameter, were taken in feet and tenths of feet. Decay was measured as linear extent rather than as volume, as there is logically no cull in trees below merchantable size. After felling, the trees were sawed into sections and split, if decayed, to show the extent of decay. The ages of the fire scars were determined by ring counts on the callus folds. In most cases these ages could be ascertained accurately, but in red gum, particularly, the production of false rings often made exact counts impossible. In such cases the fire history of the neighboring trees was an aid. Tree ages were determined on the stump wherever possible, and where not possible were adjusted to age-on-stump on a basis of 2 feet of height growth per year. This rate was chosen arbitrarily, as no studies on rate of seedling growth have yet been made in the Mississippi bottom lands.

Whenever possible, cultures were made from the decayed trees, to determine the fungus causing the decay. In many cases there were merely hollows with firm walls, and no decay beyond. Several attempts were made to culture from the wood just above the hollow, in such trees, but no pure cultures of wood-destroying fungi were secured from them. In every case of typical decay, one culture was made from the typical rot and one from the incipient rot at the top of the decay column. Blocks of the decayed wood from which cultures were to be made were cut out of the trees in the field and placed in paper bags. The same night the blocks were split open and small pieces cut out with a sterile scalpel and placed in test tubes on 1½ percent malt agar at a pH of about 5. This was a very favorable medium for these fungi. At the high temperatures prevailing in the summer months, the fungi grew out from the slivers onto the agar within 1 to 3 days. A large amount of culturing was essential for the identification of the causal fungi of the decays because fruiting bodies on the fire scars are very rare in this area, and because sufficient facts are not yet known concerning these Delta hardwood decays to distinguish one rot from another, macroscopically, with any degree of assurance.

In addition to culturing from the dissected trees, cultures were made from a large number of sporophores collected in the field. The object of this was to build up a collection of known cultures with which the unknown decay cultures could later be compared for identification. These sporophore cultures supplemented similar cultures made by Overholts and Kaufert from the same area.

Wherever insects were found in association with fire scars, specimens were collected. These were forwarded to the Bureau of Entomology and Plant Quarantine for identification.

FREQUENCY OF FIRES

In the introduction, it was stated that fires were of frequent occurrence in the Delta, and that they were particularly prevalent in certain dry years. Table 1 is based on the results of an analysis of the fire scars on the 602 trees cut from the 20 areas sampled, and shows the number of trees scarred each year. This analysis shows that, with few exceptions, in each of the past 30 years, at least one of these areas has burned over.

TABLE 1.—*Fire years as determined by scarred trees*

Year	Trees scarred	Year	Trees scarred	Year	Trees scarred	Year	Trees scarred
	Number		*Number*		*Number*		*Number*
1930–31	49	1921–22	0	1912–13	2	1902–03	3
1929–30	8	1920–21	8	1911–12	6	1901–02	1
1928–29	50	1919–20	8	1910–11	10	1899–1900	10
1927–28	10	1918–19	1	1909–10	4	1897–98	1
1926–27	35	1917–18	135	1908–09	1	1894–95	4
1925–26	2	1916–17	4	1906–07	1	1890–91	1
1924–25	309	1915–16	11	1905–06	3	1867–68	1
1922–23	5	1914–15	15	1903–04	1		

Certain years stand out as exceptionally bad fire years. Over the areas studied, the fire year 1924–25 stands out as the worst. This is consistent with the findings of Lentz (*11*, *12*) and Kaufert (*7*). Prior to 1924 the worst fire years appear to be 1917–18, 1914–15, 1910–11, and 1899–1900. While the last four seasons are somewhat at variance with the seasons given by Kaufert as being particularly bad prior to 1924, this discrepancy may be due to the samples having been taken from different localities. Table 1 shows that fires occurred at least as far back as 1867, and that they are still of frequent occurrence in the Delta.

FORMATION OF FIRE SCARS

As there is almost always some accumulation of twigs and larger material at the bases of the trees, intense heat is generated there during slow-burning surface fires, with the result that large areas, if not all, of the living bark and cambium tissues near the base are killed. The bark adheres for a year or two and then drops off, exposing the sapwood of the scarred areas. A single fire rarely ever burns through the bark into the wood, although subsequent fires may hollow out a previously scarred tree. Plate 1 shows two groups of trees that are typical of fire-scarred young Delta hardwoods.

A, A group of young hackberry trees with 7-year-old fire scars, showing a tree broken over because of decay following scarring. (Photographed by F. H. Kaufert.) *B*, A group of young Nuttall oaks with 8-year-old fire scars, showing a tree broken over at the scar.

A, Overcup oak scarred 21 years and again 15 years before photographing. This tree never would have had merchantable value. *B*, A 68-year-old overcup oak with a 15-year-old fire scar. The typical decay extends above the level of the end of the ax handle. The decay was caused by an unidentified yellow hymenomycete. *C*, Young Nuttall oak with 7-year-old fire scar, showing heart rot running up from the scar.

In the field there was an apparent difference in the susceptibility of different species to scarring. In several stands composed mainly of hackberry and red gum, a large proportion of the thin-barked hackberry trees were found to be scarred, while but few of the relatively thick-barked red gum showed scars. However, as shown in table 2, if any of the species studied were scarred at all, the scars, on the average, were much the same size on all. All species taken together, the average fire scar occupied 49 percent of the tree circumference at the point where the scar was widest. None of the species studied varied essentially from this average. The length of scars ranged from about 6 inches to 10 feet, with an average of a little over 2 feet. Small scars on these young trees were uncommon, but it is to be noted that such very small scars as were formed may have completely healed and so remained unnoticed.

TABLE 2.—*Average percentage of tree circumference scarred,*[1] *by species*

Species	Number of scars measured	Average percentage of circumference occupied by scar[2]	Species	Number of scars measured	Average percentage of circumference occupied by scar[2]
Red gum	215	50	Willow oak	13	44
Ash	101	48	Cherrybark oak	10	52
Hackberry	68	48	Persimmon	20	42
Nuttall oak	78	49			
Water oak	71	50	All trees	610	49
Overcup oak	34	50			

[1] Those scars, the original limits of which were obliterated through decay, were omitted from this table.
[2] Measurements made at widest part of scar.

RATE OF HEALING OF FIRE SCARS

Completely healed scars, unless they had been very small to begin with, were rare. This is not because these Delta hardwoods do not heal wounds rapidly, but because the exposed scarred areas usually soon become hollowed out by fungi and insects (pl. 2), leaving no surface for the callus folds to heal over. It is for this reason that many trees that were scarred 30 and more years ago still have open scars.

In order to determine the relative rate of scar-healing of the various species studied, healing was measured only on those trees with a complete, firm, original surface for the callus folds to heal over, as shown in figure 1. Some of the trees chosen were decayed, but the decayed wood was firm enough to support the callus. Table 3 compares the various species as to their rates of healing. For example, a red gum tree with a scar 2.8 inches wide, healing at a rate of 0.56 inch per year, would be expected to be completely healed in 5 years, provided the exposed wood was not hollowed out by that time. Table 3 shows that the oaks and red gum heal most rapidly, followed by ash, hackberry, and persimmon. While the differences in rates between certain species are not significant, the table shows the relative rates for the different genera. Figure 1 shows a section from the base of a red gum tree which was scarred badly in 1910 and very badly in 1917. This tree had remained sound. Its first scar was completely healed, and its second, which had almost girdled the tree, was nearly healed.

TABLE 3.—*Rate of healing, by species* [1]

Species	Cases	Cases—			Average amount of scar covered per year	Standard error
		Over-topped	Inter-mediate	Codominant and dominant		
	Number	*Percent*	*Percent*	*Percent*	*Inches*	
Overcup oak	7	71	14	15	0.76	(²)
Nuttall oak	28	32	25	43	.67	±0.07
Red gum	111	23	48	29	.56	±.02
Willow oak	8	50	0	50	.55	(²)
Water oak	30	17	53	30	.54	±.04
Ash	34	26	41	33	.43	±.03
Hackberry	13	31	54	15	.39	±.05
Persimmon	9	44	33	23	.31	(²)

[1] Only trees with firm surface to heal over are included. Healing measured on cross section of scar as linear inches of callus formed over wound. Figures represent totals of both callus folds.
[2] Standard error of no value with so few cases.

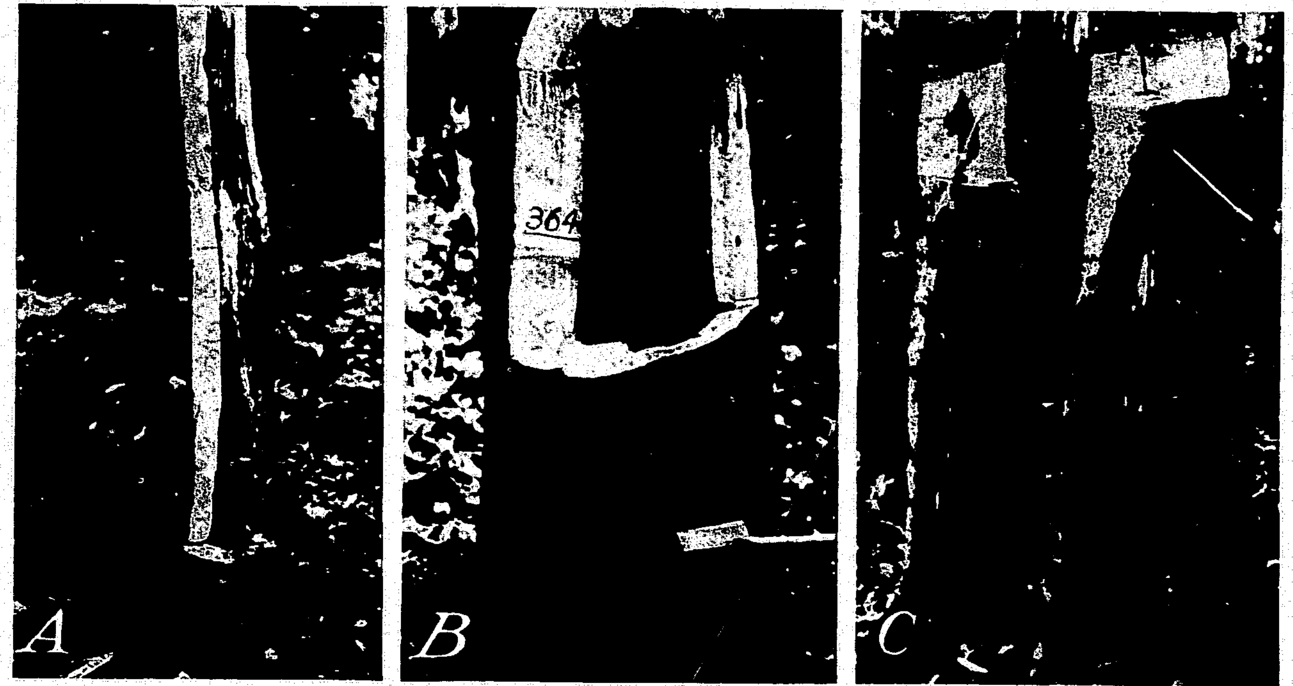
INFECTION OF SCARRED TREES BY FUNGI

The terms " decayed " and " sound " as applied to the condition of trees are used frequently throughout this bulletin and are defined, for the purpose of this study, as follows: A decayed tree is a tree in which the surface of the scar is decayed to a depth of one-half inch or more; a sound tree is a tree in which decay has progressed to a depth of less than one-half inch beneath the scar surface. Border-line cases were uncommon, however, so that trees designated as decay cases were usually definitely rotted, as shown in plates 2, 3, and 4.

FIGURE 1.—Section from young red gum tree scarred by fire 22 years and again 15 years before photographing. Section taken 1 foot from ground. Protective zone formed over scar prevented decay and permitted healing.

The different tree genera vary greatly in their liability to infection through fire scars. Referring, in figure 2, to the well-represented scar age class 7–12 years, it is found that while 100 percent of the hackberry trees were decayed, only 53 percent of the red gum were decayed. The oaks and hackberry, when scarred, usually develop sapwood rot over the scarred area within a year after scarring, and often before the dead bark has become loosened from the wood. There is apparently little protective effect of the living sapwood beneath the killed bark, in putting up any barrier against this infection in these two genera. In red gum and persimmon, however, the living sapwood beneath the killed bark is stimulated to the formation of wound gum, which exudes into

A, A 68-year-old ash scarred 18 years and again 10 years before photographing. The center and right-hand sections are longitudinal sections of the same piece. The piece on the left is the next section above. The decay extended about 6 feet from the ground and was caused by *Lentinus tigrinus*. *B*, Ash with 33-year-old fire scar. This tree was worthless and was taking up room that might have been occupied by thrifty trees.



A, Red gum, 28 years old, scarred by fire 8 years and again 4 years before photographing. This tree was so weakened by decay (caused by *Polyporus lucidus*) that it probably would have broken over within a few years. Note sporophore at base of scar. *B*, Red gum with 19-year-old fire scar almost healed. The tree, however, is a hollow cull. (Photographed by F. H. Kaufert.) *C*, A pair of young hackberry trees with 7-year-old fire scars. Note that while the exposed portions of the butts were badly decayed the decay spread but a short distance above the scar. (Photographed by F. H. Kaufert.)

several layers of the outer xylem elements, completely filling the vessels, fibers, rays, and parenchyma cells, so that a dense hard zone is formed over the face of the scar. As long as this layer is intact infection apparently cannot take place.

Figure 1 shows a red gum tree with the dark outer protective zone that has prevented infection and drying out of the sapwood for 15 years. Such protection, however, is usually not permanent. This is partly because checks commonly form over the scar face, admitting fungus spores which presumably germinate and infect before another protective zone is laid down beneath; and partly because, if the tree is reburned, the sapwood beneath the protective zone is killed, dries out, checks, and then infection can take place readily.

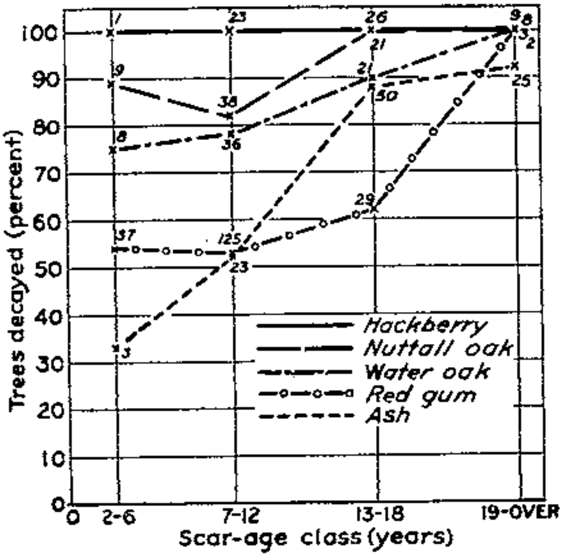


FIGURE 2.—Relation between percentage of trees decayed and years since scarring. The numbers beside the points indicate the number of trees studied in obtaining the data for the points.

Figure 2 shows that the greater the number of years since scarring, the greater is the proportion of decayed trees. Twenty years after scarring, practically all trees with open scars contained decay. The exception to this is persimmon, which is the most decay-resistant species noted. The small number of overcup oak, cherrybark oak, willow oak, and persimmon trees analyzed does not allow much weight to be given to these species, so they are not included in figure 2. In order of susceptibility to infection, the species are: Hackberry, Nuttall oak, water oak, ash, and red gum, as shown in figure 2.

The fact that only sapwood is exposed, following scarring, does not mean that serious decay will not result, or that heart rot will not develop. There are a number of facultative decay fungi in this area, which can readily attack dead sapwood, old living sapwood, or the heartwood of living trees. Two outstanding examples are *Polyporus lucidus* Fr. and *Lentinus tigrinus* (Bull.) ex Fr. As will be shown later, these two fungi attacked most of the principal tree species studied. In addition to the normally heart-rotting fungi and the facultative decay fungi, many of the more strictly saprophytic fungi, such as *Polyporus pargamenus* Fr. and *Stereum rameale* (S.) Redd., can work for some distance into the heartwood after decaying the exposed sapwood. Weir (*19*) lists 11 species of the normally saprophytic genus *Polystictus* alone, which have been found to cause rot in living trees. That no obligate heartwood-rotting fungus, such as *Polyporus dryophilus* Berk., was positively identified in connection with the decay in any of the trees analyzed may indicate that those fungi are not able to penetrate through the exposed sapwood, even if decayed. Referring to *P. dryophilus*, Hedgcock and Long (*6, p. 70*) state—"In no instance in Arkansas has the junior writer found this fungus entering a tree through fire scars, or other wounds on the butt of oaks, even where fire scars were common." Therefore those fungi which can rot both the dead and old sapwood and the heartwood of living trees with equal facility appear largely responsible for the extensive decay resulting from the scarring of young Delta hardwoods.

UPWARD SPREAD OF DECAY IN THE BOLE

Of all the various mechanical, physiological, and pathological effects of the fire-scarring of young Delta hardwoods, the most important effect, as far as the production of timber is concerned, is the reduction of the future merchantable portion of the trees through the action of wood-destroying fungi. That this infection through fire scars, with subsequent rapid spread of decay in the bole, is not confined to hardwoods is brought out by Meinecke (*15*), who states that in only 11 out of 59 fire-scarred white firs was no decay traced to the scars; and by Boyce (*1*), working in incense cedar, who states that the most serious wounds, both numerically and in regard to type of injury, result from fire. He states that as the charred face of the scar weathers away, an excellent place is offered for the entrance of wood-destroying fungi.

The upward spread of decay in trees is affected by a large number of factors. It depends upon the species of tree, the species of fungus causing the decay, the age of the tree, the diameter of the tree, the size of the fire scar, and a large number of unmeasurable factors such as climatic and site influences, extractive content of the wood and other types of tree resistance, and possibly the presence of insects and secondary fungi. It was decided, in this study, to determine the average annual upward spread of decay from fire scars, regardless of causal organism, for each well-represented tree species or species group; and then, for the black oak group and for ash, to determine the net effects of the following measurable factors on this rate: Age of tree, age of fire scar, length of fire scar, proportion of the tree circumference which had been scarred, present diameter at breast height (d. b. h.), and diameter at the time of scarring (measured on the stump). In a later section devoted to the fungi involved, differences in the rate of decay for the different fungi will be brought out.

The black oak group (which here includes Nuttall, water, willow, and cherrybark oaks) and ash were chosen for the intensive study of the effects of the six factors mentioned above, partly because these species were numerically well represented (142 black oaks and 78 ash), and partly because the rate of decay was relatively fast in those species, thereby bringing out more strongly the effects of those factors affecting the rate of decay. Only decayed trees were included in this analysis.

The rate of decay was determined by the relation between the number of years since the trees were burned and the height of decay in the trees. The number of years since burning was determined by the number of rings on the callus folds. In red gum, overcup oak, and hackberry only the gross relation between age of fire scar and height of decay was determined, the other factors being allowed to vary as they would. In the black oak group, and in ash, however, a multiple correlation was run to determine the net relation between the age of fire scar and height of decay; and also the net effects of the five other factors already mentioned, on the rate of decay. By means of multiple correlation analysis one can determine the net effect of any one factor (for example, age of fire scar) on the factor being studied (height of decay), independent of the effects of the other related factors such as age of tree, diameter at breast height, etc. This is accomplished by holding all factors not being considered, at their mean values, while the factor under consideration (age of fire scar) is allowed to vary with the dependent factor (height of decay). The method of multiple correlation is used in the analysis of the data presented in this bulletin in part to get the most information possible from these data, and in part to test the applicability of the method as a device for studying the independent effects of each of several factors on decay.

The methods used in this correlation analysis are essentially those given by Ezekiel (*3, pp. 158–186*). Regression equations were worked out to determine the effects of the factors mentioned on height of decay in black oaks and ash. The regression equations determined are as follows:

For black oaks—

$$X_1 = -2.642 + 0.188X_2 + 0.005X_3 + 0.014X_4 + 0.003X_5 + 0.119X_6 + 0.172X_7$$

For ash—

$$X_1 = -9.221 + 0.127X_2 + 0.065X_3 - 0.004X_4 + 0.039X_5 + 0.236X_6 + 0.318X_7$$

When X_1 = height of decay
X_2 = age of fire scar
X_3 = age of tree
X_4 = length of fire scar
X_5 = percentage of circumference scarred
X_6 = present diameter at breast height (i. e. at time of examination)
X_7 = stump diameter at time of scarring.

These regression equations were then plotted. The resulting regression lines, as shown in figures 3 and 4, show how the dependent variable (height of decay) varies as each of the independent variables vary. As these regression lines were determined mathematically, the group-average deviations of the actual values from these calculated lines were also plotted, and are shown as dots about the regression lines in figures 3 and 4. In addition to the lines shown, regression lines were worked out for the relation between length of fire scar and height of decay above scar, but in both the black oaks and ash these lines were practically horizontal, indicating that no relation exists between these two factors, within the range studied,

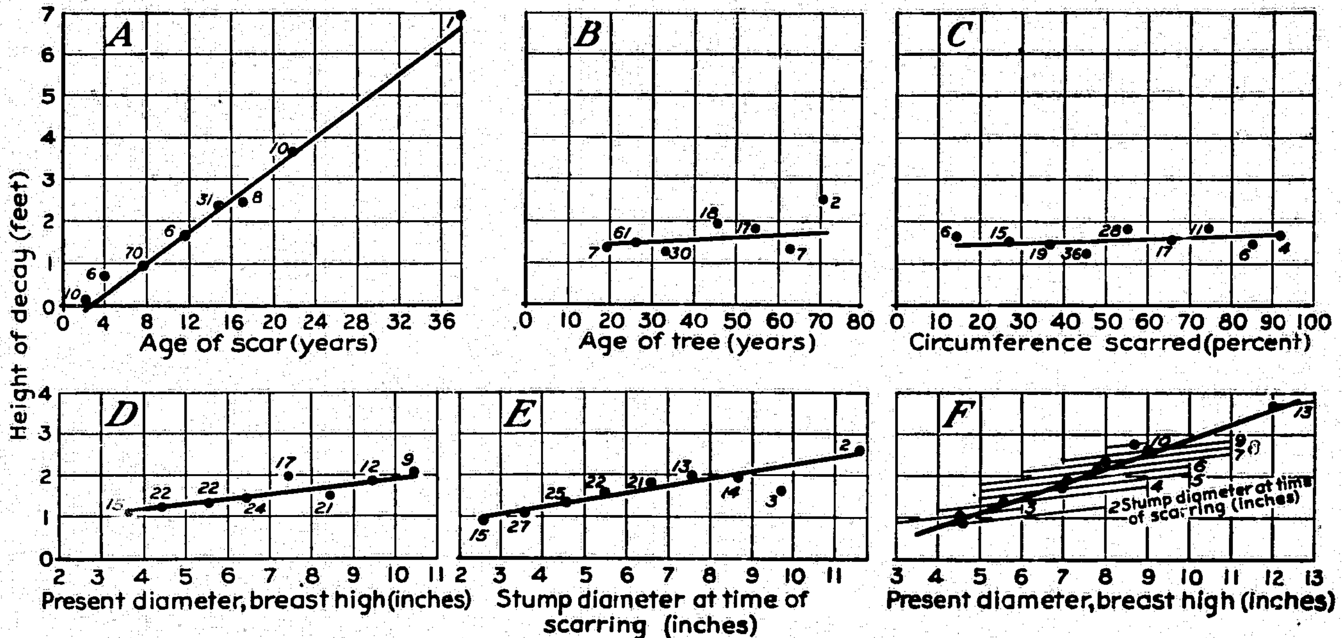


FIGURE 3.—Regression lines showing net effects of each of five factors on height of decay above fire scars in black oaks. The numbers beside the plotted points indicate the number of trees upon which each point is based. Graph F is a combination of graphs D and E. The fine lines in graph F show the decay heights with increasing present diameter at breast height, each line being for trees with the stump diameter at time of scarring that is indicated by the small figures at the right end of the line. The heavy line in graph F is the important one, showing how decay varies with present diameter at breast height when diameter at time of scarring is not held constant.

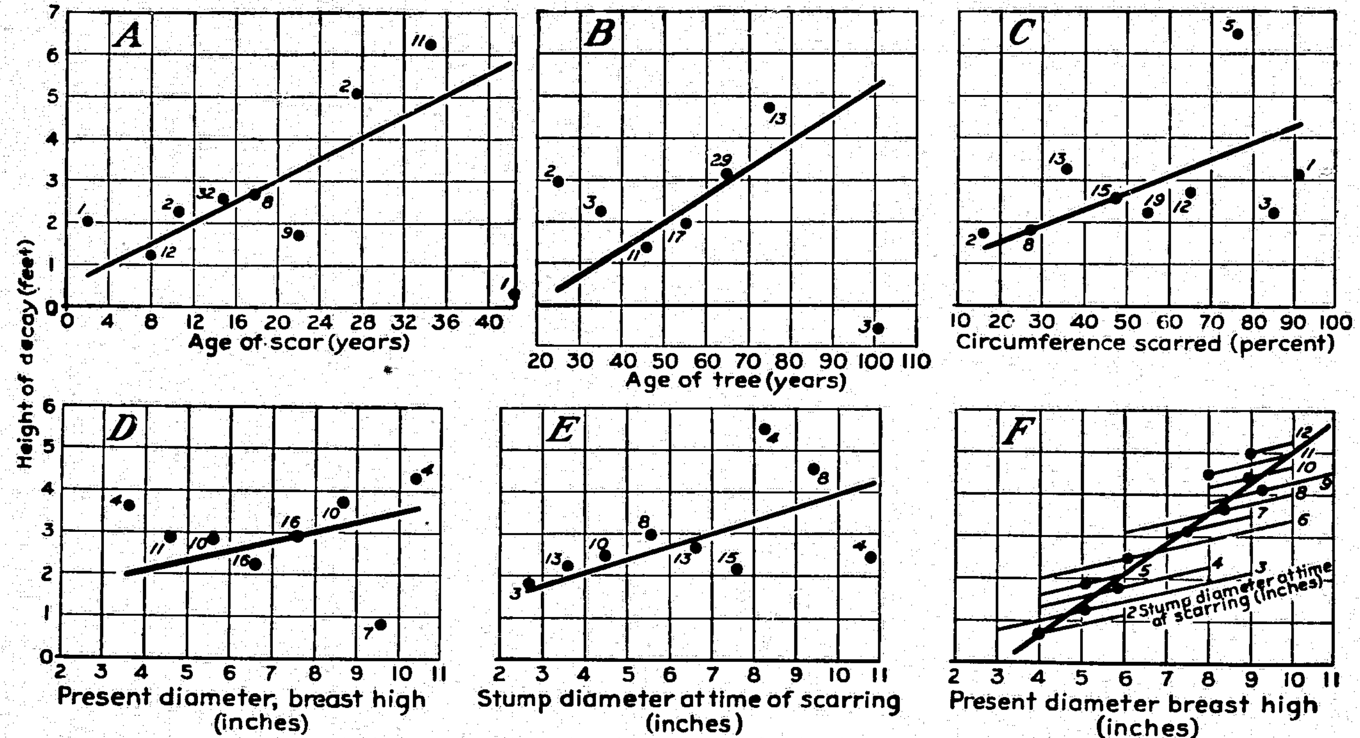


Figure 4.—Regression lines showing net effects of each of five factors on height of decay above fire scars in ash. The numbers beside the plotted points indicate the number of trees upon which each point is based. Graph F is a combination of graphs D and E. The fine lines in graph F show the decay heights with increasing present diameter at breast height, each line being for trees with the stump diameter at time of scarring that is indicated by the small figures at the end of the line. The heavy line in graph F is the important one, showing how decay varies with present diameter at breast height when diameter at time of scarring is not held constant.

if we assume that a straight line properly expresses any relation that might exist.

In none of the analyses of factors is there sufficient basis for assuming a curvilinear relation to exist. That is, as the age of scar, age of tree, etc., increase, the height of decay appears to increase at a constant rate. While in ash, particularly, the deviations of the actual values from the estimated are widely scattered about the regression lines, there is still no basis for assuming curvilinearity as there is an insufficient number of cases to fix the trend definitely. All are therefore assumed to be straight-line relationships. The oak regression lines, based on almost twice the number of cases as the ash, show a much closer conformity of the averaged actual values to the estimated, than do the ash.

In analyzing the graphs shown in figures 3 and 4 it must be borne in mind that in each graph, excepting graphs F, the effect of only one factor on height of decay is studied and that all the other factors are held at their average values. This statistical treatment often leads to absurdities when extremities of the regression lines are examined. For example, with the diameter at time of scarring at its mean value of 5.5 inches we can find a value for present diameter (fig. 3, graph D) of 4 inches. This is an absurdity. This condition arises out of the fact that each regression line represents only the relationship between the two factors studied, holding all others at their averages, so that each line can be interpreted literally only at that point on the line at which the other factors in the regression equation that are not represented in the given graph are at their averages. This in no way affects the value of the regression lines as indicators of relationship.

The coefficient of determination for the black oak group is 0.39, which means that 39 percent of the variance in the height of decay is ascribable to the six factors studied, namely: Age of fire scar, age of tree, length of fire scar, percentage of circumference scarred, present diameter at breast height, and stump diameter at the time of scarring. The remaining 61 percent of the variance is due to other factors not considered in this correlation, such as type of fungus causing the rot, resistance of trees, etc. The coefficient of determination for ash is 0.31. Both coefficients of determination were found to be highly significant (odds greater than 100 to 1).

RELATION BETWEEN SCAR AGE AND HEIGHT OF DECAY

There is a distinct relation between the number of years since a stand of trees was scarred and the height of decay in the trees of that stand.

DECAY IN BLACK OAKS

Figure 3, graph A, shows that in young black oaks decay spreads upward in the bole from the fire scar at an average rate of 2.3 inches per year, beginning 2 or 3 years after scarring. This figure is applicable to trees within the size range covered in this study. It means, for example, in a young stand composed of the black oaks studied, in the Delta area, 20 years after a fire the best prediction on the basis of the present data is that practically all of the trees with visible scars will contain decay (fig. 2), and the decay will have reached an average of 3.3 feet above the scars (fig. 3, *A*). As the average height of scars for this group is 2.8 feet (table 4), there will be an average of 6.1 feet of decay in the visibly scarred trees. The decay rate of 2.3 inches per year is the average rate for all trees from 3 to 11 inches diameter at breast height, but the individual rates of decay of different trees vary as the size, age, etc., of these trees vary.

TABLE 4.—*Average values of factors considered to influence rate of decay*[1]

Tree species	Trees	Average height of decay above scar	Average scar age	Average tree age	Average scar height	Average percentage of circumference scarred	Stump diameter at time of scarring	Present diameter, breast high
	Number	*Feet*	*Years*	*Years*	*Feet*		*Inches*	*Inches*
Black oaks	142	1.5	10.8	30	2.8	50.6	5.5	6.7
Overcup oak	32	2.5	14.2	55	1.8	50.4	6.3	6.9
Red gum	104	.9	9.1	31	1.8	53.2	6.0	6.8
Ash	78	2.7	18.2	62	2.2	51.2	6.3	7.0
Hackberry	56	1.1	14.8	62	2.2	48.3	6.3	6.8

[1] Sound trees excluded.

While the figure for rate of decay has value when applied to a stand, it has little value when applied to an individual tree. For example, while the average height of decay in black oaks with 15-year-old fire scars is 2.4 feet, two-thirds of the cases lie between 0.3 foot and 4.2 feet, while one-sixth lie below and one-sixth above these limits.

In the application of the results secured in such a study as this, great care should be taken not to attempt making use of the trends beyond the limits of the data upon which the trends were established. To use the regression equations determined in this study or the graphs based on them for trees larger than 11 inches diameter at breast height would be an example of such extrapolation.

In some cases active decay apparently ceased following the rotting away of the exposed wood on the scar, and in others it ceased after working up in the bole for 2 or 3 feet. In such cases the decayed wood is usually removed by insects and secondary fungi, leaving hollows with firm walls of sound wood (pl. 2, *A*). In still other cases decay was found to have progressed several feet in the bole, with the fungus still in an active condition. Plate 2, *C*, shows an actively decaying Nuttall oak scarred in 1924. Little can be expected in the future from a young stand composed of such trees as these.

Young oaks are particularly susceptible to decay because that genus forms heartwood at an early age. The oaks of this area usually begin heartwood formation after the trees are about 15 years old, in contrast to red gum in which heartwood is usually not formed until the trees are at least 40 years old. No significant difference was noted, either in the field or in the mathematical analysis of the data, between the rates of decay in the four species of black oaks included in this study.

DECAY IN ASH

Figure 4, graph A, shows that in ash, decay spreads upward from the scar at an average rate of 1.5 inches per year. The figures on rates of decay are based upon trees with average values as given in table 4. From figure 4, graph A, we can expect that in an ash stand in the Delta area, 20 years after scarring, the average height of decay will be 3 feet above the scars. As the scars average 2.2 feet in height there should be an average of 5.2 feet of decay in those trees. Again, while applicable to a stand, these figures cannot be applied to an individual tree. This is evident if it is noted that while the average height of decay for ash trees with 15-year-old fire scars was 2.5 feet, two-thirds of the cases fell between 0.6 foot and 4.7 feet, while a sixth were above and a sixth below these limits. There is the same wide variability in height of decay in red gum trees scarred the same length of time, while the rate of decay in hackberry and persimmon trees is much less variable. For all species the variation is much less if the tree population consists of trees of similar age and diameter.

Heartwood may form in ash any time after a tree is about 30 years old. However, the fungi which were most active in causing decay in the young trees studied (for example, *Lentinus tigrinus*) do not need heartwood to feed on, but can work up the bole equally well in a tree containing only sapwood. This is an unusual case of a parasitic sap-rot fungus. In some cases a zone of pathologic heartwood is formed in advance of the decay column. Plate 3, *A*, shows a young ash in which typical heart rot has progressed about 6 feet up from the base. This tree was scarred in 1914 and again in 1922. Notice, however, that the scar is small, and that there is no external evidence of the active decay within. Plate 3, *B*, shows the remains of an ash scarred in 1899. Such a tree is locally called a "stovepipe."

One of the working areas chosen for this study, a pure ash stand near Tallulah, La., was badly scarred in 1917. Many of the larger trees have broken over at the base, and the remaining stand is practically worthless as a result of decay following scarring.

DECAY IN OVERCUP OAK

In overcup oak, red gum, and hackberry only the gross relation between height of decay and age of fire scar is shown. Substituting the values of the independent variables for overcup oak (table 4) in the regression equation for the black oaks, it is found that if black oak had these values its height of decay would be almost the same as that found in overcup oak, indicating that the rate of decay is the same for both; that is, that decay travels upward at a rate of roughly 2.3 inches per year in all oaks studied. A graph showing the gross relation between height of decay and age of scar is given in figure 5, *A*.

Overcup oak is a notoriously defective tree in that part of the Delta south of Arkansas. It not only decays rapidly when wounded, but it is commonly riddled with large insect galleries of *Parandra brunnea* Fabr., and the wood is "shaky." Plate 2, *B*, shows a young overcup oak scarred in 1917, with active heart rot running up several feet, and with a gallery of the *Parandra*.

DECAY IN RED GUM

Substituting the values of the independent variables for red gum, in the black oak regression equation, it is found that if black oak had these values its height of decay would be 1.3 feet, whereas the actual height of decay in red gum was 0.9 foot. This indicates that red gum decays less rapidly than oak. The gross relation between height of decay and age of fire scar, for red gum, is shown in figure

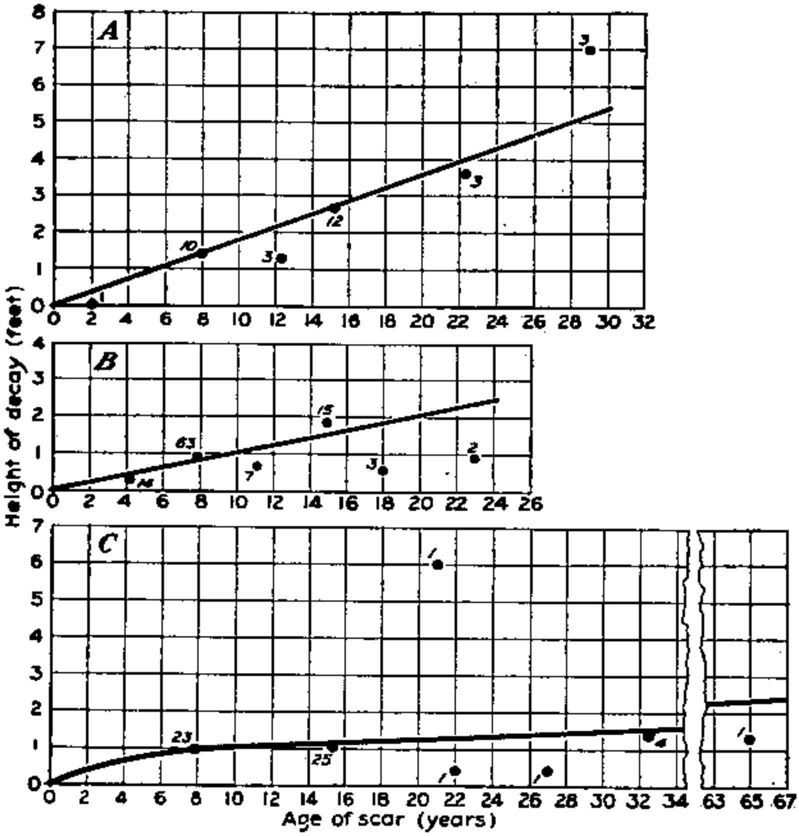


FIGURE 5.—Gross relation between age of fire scar and height of decay in overcup oak (*A*), red gum (*B*), and hackberry (*C*).

5, *B*. This graph shows that young fire-scarred red gum decays at a rate of about 1.2 inches per year.

A very small percentage of the red gum trees studied contained any normal heartwood. However, as in the case of ash, a cone of pathologic heartwood is commonly formed above the active decay, thus paving the way for the fungus if it be a heart-rotting fungus. Again, however, as in the case of ash, the important fungi can work upward in the bole, rotting only sapwood. Plate 4, *A*, shows a small red gum tree scarred in 1924 and again in 1928, in which decay caused by *Polyporus lucidus* has worked up several feet, without any heartwood having been present. Plate 4, *B*, shows a "stovepipe" caused by decay following fire-scarring.

An example of the effects of fire-scarring on merchantable red gum is given by Lentz (*10*). A gum stand in Pointe Coupee Parish, La., was burned in 1916 and again in 1924. The stand was cut in 1928, and there was a loss of 15 percent of the merchantable volume of the stand due to decay following those two fires.

A characteristic of decay in young Delta hardwoods that is particularly striking in red gum is that decay which sets in subsequent to fire-scarring practically confines itself to the cylinder of wood extant at the time of scarring. For example, if a gum tree is 5 inches in diameter at the time it is scarred, and composed entirely of sapwood, the decay which follows will remain confined to that 5-inch cylinder, not spreading appreciably into the sapwood layers laid down after scarring. There is, therefore, some marked difference between the sapwood extant at the time of scarring and the sapwood laid down later as to their susceptibility to decay. This difference may possibly be due to differences in the water content of the newer and older sapwood. This explanation is strengthened by the fact that the condition just described is most striking in red gum, which has a high water content when green; and least striking in ash, which when green has a lower water content than any other of the bottom-land species. In ash the decay will work out farther into the newer sapwood than in any of the other species studied. The resistance of trees to the radial spread of decay is of importance in the prevention of weakening at the butt and subsequent breaking over.

DECAY IN HACKBERRY

While hackberry is readily susceptible to infection, as shown in figure 2, the decay spreads but a very short distance upward in the bole. None of the hackberry trees studied contained any heartwood. Substituting the values of the hackberry independent variables, as given in table 4, in the black oak regression equation, it is found that if black oak had these values its height of decay would be 2.5 feet, while the average actual height of decay in hackberry was only 1.1 feet above the scar. This indicates that decay progresses much more slowly up the bole in hackberry than in the oaks. Figure 5, *C*, shows the gross relation between height of decay above scar and age of scar. It also shows a relatively rapid early rate of decay, so that the average height of decay is 1 foot at the end of 8 years. Then the rate falls off rapidly so that at the end of 32 years the decay has only spread about 6 inches farther. The small number of trees with scars older than 15 years precludes the possibility of very well establishing the curve beyond that point.

Plate 4, *C*, shows two hackberry trees with scars 7 years old. Note the badly decayed exposed sapwood and the short distance which the decay has spread into the bole.

While decay in young hackberry is of importance in weakening the bases of the trees, it appears from this study to be of little importance in causing cull in the portion of the tree above the scar, at least before heartwood formation begins.

DECAY IN PERSIMMON

Persimmon is the soundest species studied. An examination of 18 trees with fire scars ranging in age from 2 to 27 years showed that only 50 percent were decayed. One tree was omitted because of decay having entered through a branch stub above the scar. Of the remaining 8 decayed trees, with an average scar age of 11 years, the average height of decay above the fire scar was only 0.2 foot.

RELATION BETWEEN AGE OF TREE AND RATE OF DECAY

Practically all investigators who have studied the relation between ages of trees and rate of decay, or volume of rot, have found decay to travel at a faster rate in older than in younger trees. Boyce (*1*) presents two tables showing increase in number of infections and increase in cull percentage with increase in tree age in incense cedar. While most investigators attempting to establish this relationship have worked with great ranges in tree ages (Boyce's trees ranged from less than 40 to over 440 years old), the present study on young Delta hardwoods is concerned with a very small age range, thus making any relationship between tree age and decay less striking.

Figure 3, graph B, for black oaks, shows that there is a slight increase in height of decay for increase in tree age. For the range studied there is an increase in height of decay of 3 inches for each 50-year increase in tree age. This relationship, as expressed by the regression line in graph B, for the black oaks, shows the net effect of tree age on decay height, holding all other factors considered constant at their means (table 4). Similarly, if we consider figure 4, graph B, for ash, we find an increase in the height of decay accompanying increase in tree age. While this regression line is not as well defined as the line for black oaks, it shows the same trend. The line for ash shows an increase of 3.3 feet of decay for each increase of 50 years in tree age, holding all other factors constant.

This increase in decay with increase in tree age is probably correlated with increase in heartwood formation. Yet, as will be shown later, increase in tree diameter is also accompanied by increase in decay, holding tree age constant.

RELATION BETWEEN PERCENTAGE OF TREE CIRCUMFERENCE SCARRED AND RATE OF DECAY

Instead of the degree of scarring being expressed as area of the tree scarred it is expressed here in two ways—as percentage of circumference scarred and as length of fire scar. Regression lines were plotted for the latter, as previously mentioned, but no relation was found to exist between height of decay and scar length. Figure 3, graph C, shows that for black oaks practically no relation exists between the proportion of circumference scarred and height to which the decay will run. While it is possible that a rather sharp relation might be found to exist for percentages of circumference between 1 and 10, such small scars are uncommon. This regression line indicates that once infection has taken place the size of the scar has no effect on the subsequent rate of decay. However, the situation in ash appears to be somewhat different. Figure 4, graph C, shows that in ash there is an increase of 4.8 inches of decay for each increase of 10 percent of the circumference scarred, holding all other factors constant. While, again, the scatter of the deviations about the ash regression line is considerable, nevertheless a definite trend of relationship is established. This slightly more rapid decay in the case of the larger scars in ash may be attributed to a number of factors, such as the larger amount of initial inoculum, the better chance for aeration for the fungus involved, and others.

RELATION BETWEEN TREE DIAMETER AT TIME OF SCARRING AND RATE OF DECAY

Holding the other five factors constant, a definite relationship is found between the diameter of the tree, at the time it was scarred, as measured on the stump and the rate of decay. Figures 3 and 4, graph E, show that for black oak there is an increase of 6 inches and for ash an increase of 1 foot in the height of decay for each increase of 3 inches in diameter at the time of scarring. It must be kept in mind that this is independent of any increase in tree age. This increase in decay rate, with tree size at the time of scarring, is closely correlated with the fact brought out in the discussion on decay in red gum, that the decay column is usually confined to that portion of the bole extant at the time of scarring.

RELATION BETWEEN PRESENT DIAMETER AND RATE OF DECAY

The relation between the present diameter (breast high) and the rate of decay is not so striking as the relation between the diameter at the time of scarring and the rate of decay. This again emphasizes the greater significance, as to decay, of the wood laid down prior to scarring over the wood laid down after scarring. Figure 3, graph D, shows that in black oaks there is an increase of 6 inches of decay for each increase of 4 inches diameter at breast height, holding all the other five factors constant. Figure 4, graph D, shows that for ash there is an increase of 1 foot of decay for each increase of 4 inches in diameter at breast height. It is now seen that both the diameter of the tree at the time it was scarred and the present diameter, each independent of the other and both independent of tree age, affect the rate of upward spread of decay in black oaks and in ash.

In figures 3 and 4, graph F, original diameter, at time of scarring is allowed to vary with present diameter, as it normally does. The heavy line on each graph expresses the total effect of diameter variation upon decay rate, holding the other four factors constant. These lines show that for black oak there is an increase of 1 foot of decay for each increase of 3 inches in diameter, while for ash there is an increase of 1 foot of decay for each increase of 1.4 inches of diameter for trees of equal age and scar age.

In the past it has been common to attribute the relation between diameter and decay to the relation of diameter to tree age and amount of heartwood present. The above figures show, however, a decided relation between diameter and rate of decay, even when age is held constant, and that this relationship holds in a species such as ash, the great majority of the trees of which contained no heartwood.

RELATION BETWEEN RATE OF DIAMETER GROWTH AND RATE OF DECAY

In studying the relationships of age of tree to height of decay holding diameter at a constant value, and diameter of tree to height of decay holding tree age constant, the growth rate must of necessity vary. It may therefore be logical to suppose that the apparent net relationship of age or diameter to height of decay as shown in the regression graphs is in reality a relationship of rate of growth to decay. However, if rate of growth is considered the more important factor determining decay rate, it is found that graphs B and F in each of figures 3 and 4 contradict each other. In graph B, showing the relation between tree age and decay, the less vigorous trees would be found to decay more rapidly, while in graph F, showing the relation between diameter and decay, the more vigorous would be found to decay more rapidly. Since such a conclusion is impossible, it seems likely that vigor, as measured by rate of diameter growth, was not an important factor. If rate of diameter growth were closely correlated with decay, graphs B and F would tend to balance each other and the regression lines would be more nearly horizontal.

The direct effect of rate of diameter growth on decay rate was studied for black oaks with 8-year-old scars and for those with 15-year-old scars. Graphs were prepared with height of decay as the ordinate and rate of diameter growth, expressed as the ratio of diameter to age, as the abscissa. The actual decay-height values were plotted. The line of best fit for the 8-year-old scars sloped slightly upward and the line for the 15-year-old scars sloped slightly downward. No definite relation between decay and rate of diameter growth could be established. It thus appears that rate of growth is not significantly correlated with decay and that the relationships determined between tree age and decay and between diameter and decay are dependent not on rate of growth but on some other conditions in the wood. For example, the decay fungi may be favored by access to a large core of wood of high age, or to wood remote from the active cambial zone.

EFFECTS OF CERTAIN UNMEASURABLE FACTORS ON DECAY RATE

The regression analyses involved the study of several measurable factors suspected of affecting the rate of decay. There are a number of other possibly influential variables that are not quantitatively measurable. For example, is decay more rapid in trees on which the scars reach the ground? Is the decay rate appreciably different in the four parts of the Delta where the work was done? Having once developed the regression equation these unmeasurable factors can be studied as shown in the following example.

The effect on decay rate of the scar reaching the ground was studied for black oaks and for ash. By substituting the values for the independent variables in the regression equations or by using alinement charts, it is possible to arrive at a figure for height of decay in each tree. These may be called the estimated values. The actual heights of decay in the trees are also determined. The difference between the two values for a given tree is called the error of estimate. The next step is to separate the trees into two groups, depending on whether or not the scars reach the ground. The average deviation of the actual from the estimated for each group is next determined. If those trees with scars reaching the ground decayed faster than the other group then their actual values for decay height would fall significantly above the estimated, and the actual values for those with scars not reaching the ground would fall below the estimated. This allows a fair comparison of the two lots of trees even though they may differ significantly in some of the measurable factors, such as scar age, which affect height of decay. In ash, the average of the actual values for height of decay in the trees with scars reaching the ground was 0.31 foot below the estimated values. The average of the actual values for those with scars not reaching ground was 0.59 foot above the estimated. This is a difference of 0.9 foot. The standard error is 0.72 foot. In black oaks, the average of the actual values for height of decay in trees with scars reaching ground was 0.14 foot above the estimated. The average of the actual values for those with scars not reaching ground was 0.16 foot below the estimated. Thus ash and oak are contradictory as to the relationship they indicate between the decay height and the scar reaching ground. In both ash and oak, however, the difference in decay height between the trees with scars reaching and not reaching ground is not mathematically significant.

In a manner similar to that just described, the relation between decay rate and the different parts of the Delta sampled was studied for black oaks and ash. The plus and minus deviations of the actual values from the estimated were computed. Little difference appeared between the rates of decay at Lake Providence, La., Opelousas, La., Rolling Fork, Miss., and Batesville, Miss., or between the percentage of scarred trees decayed at these places. This does not mean, however, that there is necessarily no actual difference in decay rates in different parts of the Delta because the number of trees used as a basis, in each locality, was small. There was some indication that decay progressed somewhat more slowly at the northernmost study area (Batesville, Miss.) than at the other localities. (See table 7.)

The fungi causing the decays represent an unmeasurable factor affecting decay rate. Their effect is analyzed later in this bulletin.

IMPORTANCE OF FIRE SCARS IN CAUSING BREAKING-OVER

A large proportion of the young second-growth hardwood stands in the Mississippi Delta are considerably understocked. In seeking the reason for this understocking, it was apparent early that fire was largely responsible. The effect of fire in causing this understocking can be divided into three principal headings: (1) The complete consumption of seedlings and small saplings, (2) the girdling of saplings and poles, and (3) the weakening of the bases of young trees through decay entering through fire scars. This study deals only with the last of these headings and the process is here referred to as "rotting down." Plate 1 illustrates this process.

In order to determine the significance of the rotting down of young fire-scarred trees, all trees that had fallen from this cause within the last 2 or 3 years were sought wherever they could be found. The object was (1) to determine how common in occurrence the process is, and (2) to determine what set of conditions cause the trees to fall. Only recently fallen trees and trees that were still alive were counted and analyzed. These qualifications were essential because fallen material decays so rapidly in this area that if attempts were made to analyze trees down longer than 2 or 3 years, or dead trees, it would be impossible to separate the decay that set in after falling from the decay that began in the trees while they were still standing. Hence it would not be possible to ascertain the conditions within that caused the tree to fall. The exclusion of the dead trees has but little effect on the data, however, as the great majority of fallen trees were still alive several years after falling. They remain alive because of the continued functioning of the unscarred portion of the phloem tissues in the transfer of food and nutrients, and because a portion of the sapwood usually remains unbroken, even after the trees are prostrate.

In the 20 areas on which this study was conducted, only 28 trees were found, within the diameter at breast height limits of 3 and 11 inches and still alive, which had fallen within the past 3 years because of decay following fire-scarring. Sixty-one percent of these trees were red gum, 25 percent were hackberry, and 14 percent were various oaks. No ash or persimmon within these diameter limits was found to have fallen from this cause. With but few exceptions, the trees that had broken over were either suppressed trees or trees that had crowns in poor condition. Of the fallen trees, 64 percent had been overtopped, 32 percent had been intermediates, and 4 percent had been codominants; while of the standing trees of these species that were analyzed only 34 percent were overtopped, 32 percent were intermediates, and 34 percent were codominants and dominants. The former crown classes of the fallen trees were determined by comparing the lengths of the down trees with the heights of the trees with which they had been in association. The fallen trees were analyzed in the same manner as were the standing trees.

The fallen trees had an average scar age of 8 years, an average stump diameter of 6 inches when scarred, and an average of 70 percent of original circumference scarred (table 5). The average percentage of circumference scarred of standing trees was 49. Twenty-five standing trees were found, from the data sheets, to be comparable to the 28 fallen trees, as described in table 5. These two groups were then compared to determine the reason why the fallen trees broke over. Table 5 shows that a somewhat larger proportion of the basal area (area extant at time of scarring) was decayed in the case of the fallen trees than in the standing trees; but the most significant difference lies in the quantities of wood laid down after scarring, in the two groups. This table shows that while the standing trees had added an average of 120 percent to their basal areas in the 8 years following scarring, the fallen trees had added only 41 percent in the same length of time. This shows that, all other things being equal, the fallen trees broke over primarily because their rate of diameter growth was not rapid enough to offset the rate of decay in the butts. This is consistent with the fact that 64 percent of these trees were overtopped. The low average scar age of the fallen trees is in part caused by the severe and extensive fires of

1924–25; but it also indicates that trees that do not rot down within 10 years after scarring are not likely to go down subsequently.

TABLE 5.—*Comparison of fallen with comparable standing trees, showing cause of falling*[1]

Description	Cases	Average percent original basal area decayed[2]	Average percent increase over original basal area[2]	Red gum	Hackberry	Oaks
	Number			*Percent*	*Percent*	*Percent*
Standing	25	68	120	56	12	32
Fallen	28	83	41	61	25	14

[1] Both fallen and standing trees have an average scar age of 8 years, had stump diameters of 6 inches when scarred, and an average of 70 percent of original circumference scarred.
[2] At time of scarring.

That this breaking over in these young stands is not a prevalent process, and tends to remove chiefly the overtopped trees and trees in poor condition of vigor, makes the process of doubtful harm, and possibly it may be a benefit by removing undesirable individuals. Ordinarily, regardless of how badly a young tree is scarred, in this region of rapid growth it will put on wood rapidly enough to remain in the stand, in spite of decay. Badly scarred trees thus remaining in the stand, which will have little or no merchantable value in the future, simply take up space that might be occupied by young healthy timber. The conclusions drawn here on the significance of the rotting down of young scarred trees is in close agreement with those drawn by Kaufert (*7*) for the same region. Kaufert (*7, p. 67*) states:

> This process takes place to some extent in many of the immature stands of the Delta. However, the understocking on many areas appears to be due primarily to direct killing of reproduction rather than to the falling over of immature trees that have been weakened by fire and decay.

It must be borne in mind that the results of this study are applicable only to timber in the diameter range studied. Field observations in fire-scarred timber of merchantable size indicated that breaking at or near the ground level was of more common occurrence than in young timber.

EFFECT OF REPEATED SCARRING ON DECAY IN RED GUM

In order to determine the effect of repeated burning on decay, the species best represented numerically, red gum, was selected. The trees were separated into two groups: Those scarred but once, in 1924, and those scarred in 1924 and one or more times since that year. These two groups were then compared as to the percentage of trees decayed and the percentage that were sound. Table 6 shows the results of this comparison. Forty-two percent of the once-scarred trees were decayed when cut in 1932, while 79 percent, or nearly double the percentage, of repeatedly scarred trees were decayed by that year. Basing the significance of this difference on the number of trees analyzed, the odds are greater than 1,000 to 1 (χ^2 test) that repeatedly scarred trees are more susceptible to decay than are once-scarred trees.

The reason for this greater susceptibility of reburned red gum trees to decay is probably due to the killing of the sapwood exposed by the first fire, with its subsequent drying out and checking. As stated earlier, for this species, as long as the outer exposed sapwood remains alive, a protective barrier of gum-filled cells is put up against infection. If this sapwood is killed, however, as in repeated burning, it decays readily. This increase in susceptibility to decay of reburned trees is of prime importance probably only in those trees that form a protective layer, such as red gum and persimmon. In such species as the oaks and hackberry, decay of the sapwood usually begins soon after a single fire. In some cases portions of the previously exposed sapwood are burned away by subsequent fires, although this is not common in young timber in the Delta.

TABLE 6.—*Comparison of once-scarred with repeatedly scarred red gum as to susceptibility to decay*

Description [1]	Decayed in 1932		Sound in 1932	
	Number	*Percent*	*Number*	*Percent*
Once-scarred trees	36	42	49	58
Repeatedly scarred trees [2]	23	79	6	21

[1] Once-scarred trees were scarred only in 1924. Repeatedly scarred trees were scarred in 1924 and one or more times since.

[2] Odds are greater than 1,000 to 1 that repeatedly scarred trees are more susceptible to decay than once-scarred trees. Odds determined by χ^2 test.

THE FUNGI

Because sporophores of fungi were so rarely found in connection with decay behind fire scars, and because the decays of hardwoods in the Delta area are so imperfectly known, it was apparent at the start of this study that the only means of determining definitely the fungi causing the decays would be by preparing cultures. However, so little progress has been made, up to the present time, in the determination of wood-destroying fungi on a basis of cultural characteristics that the method has distinct limitations. Fritz (*4*) studied several northern wood-destroying fungi in culture, and provides a key for their separation on a basis of cultural characteristics; and Long and Harsch (*14*) describe methods for the study of wood-destroying fungi in culture, with emphasis on methods of securing artificial sporophore production. Little information is available that would serve to distinguish wood-destroying fungi in pure culture other than the few kinds described in these two papers.

In the time allowed for this investigation, it was not possible to go into a detailed study of the microscopic and physiologic characters, in culture, of the large number of wood-decay fungi found in the Delta area. The determinations of fungi which were found to cause decay behind fire scars were made by comparing, on a basis of macroscopic characters, the unknown cultures made from isolations from the decayed wood, with known cultures made from sporophores collected in the area. In this way it was possible to determine definitely many of the important fungi, and to group many others which appeared to be similar.

Two cultures were made from every tree containing typical decay. The methods have already been described. The cultures were permitted to get a good start and were then sent to Washington, D. C., where transfers were made for study. Cultures were prepared from 251 of the 429 decayed trees. Of these 251 trees, 171 yielded apparently pure cultures of decay fungi, 52 yielded cultures which were obviously contaminated, and 28 yielded no organisms whatsoever. The principal contaminants from the wood were *Trichoderma* spp., *Torula* spp., *Penicillium* spp., and various bacteria.

In only 2 cases out of the 171 sets of successful cultures did the 2 cultures taken from the same tree yield 2 different hymenomycetous fungi. This brings out the fact that, in the trees analyzed, but one fungus is responsible for the major decay in any one tree.

In table 7 are listed the fungi determined in connection with the decays, the host trees, the average scar age of the trees in which they were found, and the average height of decay in those trees. The table clearly indicates the nature of part of the 61 percent of variance of decay in black oaks and of the 69 percent in ash, unaccounted for by the six factors studied in the correlation analysis of height of decay. Table 7 shows that the height to which decay will progress depends, to a considerable degree, upon the fungus causing the decay. For example, *Hydnum erinaceus* (Bull.) Fr. was found to have progressed an average of 6.7 feet above the fire scars, with an average scar age of 23 years. The unidentified yellow hymenomycete found only in overcup oak is also capable of active decay many years after scarring, and it progressed almost as fast as *H. erinaceus*. On the other hand, *Fomes geotropus* Cke., which was the fungus the writer most commonly isolated, was found to have progressed an average of only 2 feet above the fire scars, with an average scar age of 11 years. The fungi least capable of spreading beyond the exposed wood into the boles of the trees were species of *Stereum*, *Polyporus pargamenus* Fr., and *Coprinus radians* (Desm.) Fr.

The Stereums listed and *Polyporus pargamenus* Fr., which are essentially saprophytic decay fungi, practically confine their activity to the exposed wood of newly formed scars. When this sapwood has been decomposed, the activity of these fungi usually ceases. There may be no further decay activity, in which case little damage will result to the tree; or it is possible that certain more potent wood-destroying fungi can follow these sapwood rotters, causing active trunk rot.

Table 7 shows that a great variety of hymenomycetous fungi are involved in decay behind these fire scars, and that agarics play a major role. *Lentinus tigrinus*, one of the most important tree-decay fungi in the Delta area, has been isolated from decayed wood as far as 9 feet above a fire scar, and *Pleurotus ostreatus* has been isolated from as far as 5 feet above a fire scar.

TABLE 7.—*Fungi determined in connection with fire-scar decay*

[Composed of data taken in connection with the study described in this bulletin and data taken by F. H. Kaufert in connection with a similar study made in the Mississippi Delta in 1931]

Fungus species [1]	Where found [2]				Cases in—					Total	Average scar age	Average height decay above scar	Average annual rate of decay
	A	B	C	D	Red gum	Ash	Black oak group	Overcup oak	Hackberry				
					No.	*No.*	*No.*	*No.*	*No.*	*No.*	*Years*	*Feet*	*Inches*
Hydnum erinaceus (Bull.) Fr.	2	3	1	1	0	0	5	2	0	7	25	0.7	3.5
Yellow hymenomycete	3	0	4	0	0	0	0	7	0	7	14	3.6	3.1
Polyporus lucidus (Leyss.) Fr.	10	2	4	0	4	1	10	0	1	16	8	2.0	3.0
Polyporus fissilis Berk. and Curt.	3	1	0	0	1	0	2	1	0	4	13	3.0	2.8
Pleurotus ostreatus (Jacq.) Fr.	5	1	4	4	7	2	5	0	0	14	9	1.0	2.5
Lentinus tigrinus (Bull.) Fr.	26	3	14	0	5	28	3	7	0	43	15	3.0	2.4
White hymenomycete I	3	1	1	1	0	1	3	2	0	6	14	2.6	2.3
White hymenomycete II	0	1	2	1	3	0	1	0	0	4	11	2.0	2.2
Fomes geotropus Cke.	26	7	6	0	8	11	16	2	2	39	11	2.0	2.0
Polyporus zonalis Berk.	3	2	0	0	1	1	1	1	1	5	12	1.9	1.9

[1] Weakly or nonparasitic fungi found causing decay behind fire scars, but extending little or not at all above the scars: *Polyporus distortus* (Schw.) Fr., *P. pargamenus* Fr., *P. supinus* (Sw.) Fr., *Stereum rameale* Schw., *S. ochraceo-flavum* Schw., *Armillaria mellea, Coprinus radians*. Sixty isolations in the present study could not be determined.

[2] A, Northeastern Louisiana; B, vicinity of Opelousas, La.; C, vicinity of Rolling Fork, Miss.; D, vicinity of Batesville, Miss.

No attempt will be made here to describe in detail the cultural characteristics of the fungi listed in table 7. However, the principal criteria in the determination of the more important fungi follow: *Hydnum erinaceus* has a white mycelium which produces numerous corallike protrusions. *Lentinus tigrinus* has a white mycelium with the surface and aerial hyphae turning dark brown or black with age, and always forms small but perfect sporophores if left in the light (fig. 6). *Polyporus fissilis* has a white, coarse mycelium which grows slowly, often forming a thick tuft around the inoculum before reaching the edge of the agar. *P. lucidus* has a white mycelium which produces no aerial hyphae but forms a flat mat with a distinctly chalky surface which may be white or yellowish in color. *Pleurotus ostreatus* produces a white, light cottony mycelium with an abundance of aerial hyphae and sometimes small abortive sporophores. *Fomes geotropus* has a white mycelium which adheres closely to the agar, somewhat similar to *Polyporus lucidus*, and which produces small lamellate fruiting bodies where the agar comes in contact with the test tube. *P. zonalis* has a white mycelium which sends characteristic white hyphal strands (not rhizomorphs) straight down into the agar from the surface. *P. supinus* has a white mycelium with no definite macroscopic characteristics for its differentiation, and was identified by the presence of sporophores on the tree. *P. distortus* has a pinkish-white mycelium which produces small, typical, pink, somewhat daedaloid sporophores where the agar comes in contact with the tube. *Armillaria mellea* has a pale-brown mycelium with a very scant surface growth, no aerial hyphae, and thick brown rhizomorphs which branch and penetrate deeply into the agar. *Stereum rameale* and *S. ochraceo-flavum* have light-brown mycelium with a dense cottony hyphal growth over the surface of the agar, and were identified and separated by the presence of sporophores on the wood. *Polyporus pargamenus* has a white mycelium with scant and patchy surface growth and no aerial hyphae. *Coprinus radians* has a brown mycelium, and the one culture obtained produced a tall perfect fruiting body which deliquesced soon after forming, leaving an abundance of spores over the hyphal mat and along the sides of the tube.

FIGURE 6.—Two cultures of *Lentinus tigrinus* showing dark-colored surface mycelium and sporophores.

INSECT DAMAGE

Fire-scarring, in addition to exposing trees to fungus infection, also leaves them open to insect attack. In an attempt to determine the importance of insect invasion through fire scars in young Delta hardwoods, all insects and insect damage, and the region of activity of the insects (whether in decayed or sound wood) were noted. Wherever insect activity was found, it was associated with decay. Out of 173 sound fire-scarred trees none showed any insect activity in the wood behind the scars. However, referring to table 8, 335, or 78 percent, of the decayed trees were or had been infested with insects. Insect activity was determined by the presence of the insects, by galleries of various sorts, or by the etched walls of hollows in the trees. Table 8 shows that the decayed wood of all species of trees studied is highly susceptible to insect attack, the most readily infested species being hackberry.

TABLE 8.—*Insect infestation of fire-scarred trees of different species*[1]

Species	Decayed trees	Decayed trees infested		Species	Decayed trees	Decayed trees infested	
	Number	*Number*	*Percent*		*Number*	*Number*	*Percent*
Hackberry	59	55	93	Red gum	106	81	76
Cherrybark oak	9	8	89	Nuttall oak	68	51	75
Willow oak	9	8	89	Water oak	56	38	68
Persimmon	9	7	78				
Ash	80	62	77	Total	429	335	78
Overcup oak	33	25	76				

[1] Trees classed as "infested" include those in which insects were found to be working in the wood and those in which evidence of their activity only remained. No sound tree was found to be infested.

INSECTS COLLECTED BEHIND FIRE SCARS

As might be expected, a large variety of insects were found to inhabit the decayed and adjacent sound wood in fire-scarred trees. Table 9 lists the insects collected, with their host trees. It is apparent from this table that the insects most commonly found were ants and termites, followed in frequency of occurrence by certain tenebrionid beetles and their larvae, a passalid beetle, and a cerambycid beetle. An assortment of other coleopterous insects were found, which are, for the most part, general invaders of any partially decomposed wood, and of little economic importance.

TABLE 9.—*Distribution of insects behind fire scars, by tree genera*

[All insects are adults unless otherwise noted]

Insect	Trees infested					
	Red gum	Oaks	Ash	Hackberry	Persimmon	Total
Hymenoptera:						
Formicidae—	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Crematogaster sp.	21	14	6	11	2	54
C. victima F. Smith	0	0	1	0	0	1
Monomorium pharaonis L.	0	0	0	2	0	2
M. minutum minimum Buck	2	2	0	0	0	4
Pheidole sp.	3	3	1	1	0	8
Aphaenogaster fulva Roger	0	4	0	0	0	4
A. tennesseensis Mayr	0	1	0	0	0	1
Camponotus herculeanus pennsylvanicus DeG.	0	3	2	0	0	5
C. caryae Fitch	1	0	0	0	0	1
Camponotus sp.	1	0	0	0	0	1
Ponera coarctata pennsylvanicus Buck	0	0	1	0	0	1
Pseudomyrma sp.	0	0	1	0	0	1
Isoptera:						
Rhinotermitidae—						
Reticulitermes flavipes Kol	4	2	0	0	0	6
R. virginicus Bks.	0	1	0	0	2	3
Reticulitermes sp.	12	8	2	6	1	29
Kalotermitidae—						
Kalotermes approximatus Say	0	0	0	1	0	1
Coleoptera.						
Passalidae—						
Passalus cornutus Fab.	2	2	4	0	0	8
Tenebrionidae—						
Alobates pennsylvanicus DeG.	4	[1] 12	1	1	0	18
Strongylium tenuicolle Say	3	1	1	2	0	[1] 7
S. terminatum Say (near)	2	1	0	4	0	7
Xylopinus sp.	0	3	1	0	0	[2] 4
Carabidae—						
Chlaenius erythropus Dej.	5	1	0	0	0	6
Galerita bicolor Drury	0	1	0	0	0	1
Lophoglossus haldemani Lec.	1	0	0	0	0	1
Brachynus sp.	1	0	0	0	0	1
Cerambycidae—						
Parandra brunnea Fabr.	4	3	1	0	0	[2] 8
Malludon dasystomus Say	1	0	1	0	0	[2] 2
Elateridae—						
Melanotus fissilis Say	1	0	0	0	0	1
M. sp.	0	0	0	1	0	1
Orthostethus infuscatus Germ.	1	0	0	0	0	1
Melanactes puncticollis Lec.	1	0	0	0	0	1
Scarabeidae—						
Valgus sp.	0	0	1	0	0	[2] 1
Ligyrus or *Eutheola*	0	1	0	0	0	[2] 1
Cleridae—						
Priocera castanea Newm.	0	0	0	1	0	[2] 1
Curculionidae—						
Pseudopentarthrum robustum Csy	0	0	0	1	0	1
Erotylidae—						
Megalodachne fasciata Fabr.	0	1	0	0	0	1
Diptera:						
Phoridae—						
Megaselia sp.	1	0	0	0	0	1
Lepidoptera:						
Noctuidae—						
Epizeuxis lubricalis Gey. (?)	0	1	0	0	0	1

[1] 1 larva.

[2] All larvae.

A member of the genus *Crematogaster* was the most commonly found ant. This insect was found to feed both in the decayed wood and in the sound wood immediately beyond the decay column. Its galleries were never found to extend more than a few centimeters into the sound wood. This insect, along with the termites, is responsible for much of the hollowing out of the decayed trees, but practically confines its activity to decayed material. In most species of trees the nests are diffused through the decayed wood, but in hackberry, in which the decayed wood is removed as it is formed, the nest is at the top of the hollow, the ants feeding on the wood as it decays. Another member of this genus, *C. lineolata*, is mentioned by Comstock (*3, p. 943*) as commonly inhabiting decayed logs and stumps in northeastern United States and Canada.

Termites occurred almost as frequently as ants and are often found working behind the same scar. Species of the subterranean genus *Reticulitermes* were by far the most commonly observed, although a species of the nonsubterranean genus *Kalotermes* was also collected. The habits of these termites are well described by Snyder (*18, pp. 1–5*). He states, "Subterranean termites live in forests, building their nests in the wood of standing timber, logs, or stumps, any wood in contact with the ground. . . ." While Snyder states that these subterranean forms will attack wood directly, usually eating out the spring wood, following the grain, they were found, in this study, to practically confine their feeding to decayed wood, never extending their galleries more than a few centimeters beyond the decayed portion. The feeding habits of the worker class of the *Reticulitermes* were similar to those of the *Crematogaster* mentioned above. Termite galleries could usually be readily distinguished from ant galleries by the presence of earthen linings. As neither the ants nor the termites appeared to extend their feeding very far into sound wood, they are regarded as having done little damage to the trees in which they occurred. Within a few years after active decay ceased, the trees were found to be forsaken by the ants and termites. It was unusual to find ants or termites in trees with fire scars older than about 10 years, while in trees with younger scars active colonies were present in most cases.

The adult beetles of *Passalus cornutus* and *Alobates pennsylvanicus* were found boring large tortuous galleries through the decayed wood. They were not observed in sound wood. The larvae of *Strongylium tenuicolle* and *S. terminatum* were also found only in decayed wood. Of all the insects observed and collected, the only species which penetrated more than a few centimeters into apparently sound wood was the cerambycid *Parandra brunnea*, already mentioned in connection with decay in overcup oak. In all cases in which larvae of this insect were found, they had formed galleries running several inches into the sound wood above the decayed portion. This insect is of considerable importance in causing defects in standing hardwood timber in this area, particularly in overcup oak and red gum. Snyder (*17, p. 21*) shows photographs of grub holes formed by this insect in overcup oak.

While fire-scarred hardwoods are constantly subject to the attack of insects, in the young fire-scarred Delta hardwoods included in the present study, insects were secondary in importance to fungi, and were playing a minor role in the cull that was developing in the butts as a result of the scarring.

SUMMARY

During the summer and fall of 1932, 602 fire-scarred trees of 9 species of Delta hardwoods were dissected and analyzed for decay and insect activity. The trees were between 3 and 11 inches in diameter, and were taken from 4 parishes in Louisiana and 3 counties in Mississippi.

Forest fires have been of frequent occurrence in the Mississippi Delta area at least for the past 30 years, with the fire seasons 1917–18 and 1924–25 outstanding in severity of damage done during those seasons.

Fire scars healed most rapidly in the oaks and red gum, followed by ash, hackberry, and persimmon.

The greater the number of years since scarring, the greater the proportion of scarred trees decayed. Of the species studied, hackberry was found to be the most susceptible to initial infection, followed by the oaks, ash, red gum, and persimmon.

Following scarring, in red gum and persimmon, wound gum is produced just under the scarred surface, which protects the trees against infection. Much of this protective effect is lost, if subsequent fires kill the exposed sapwood.

Decay spread upward from the fire scar most rapidly in the oaks (2.3 inches per year), followed in order by ash, red gum, hackberry, and persimmon.

A definite relation was found between the rate of decay and each of the following factors: Age of tree, percentage of tree circumference scarred, diameter at the time of scarring, present diameter, and fungus causing the decay.

The breaking-over of young trees at the base, because of decay following fire-scarring, was found to be of infrequent occurrence and chiefly confined to overtopped trees and trees otherwise in poor vigor.

A large number of fungi, from several families of the Hymenomycetes, were found to cause decay behind fire scars in the Delta area. Many of these fungi, including *Lentinus tigrinus* and *Polyporus lucidus*, can rot dead sapwood, old sapwood of living trees, and the heartwood of living trees. But one fungus in any one tree was responsible for the major decay.

A large variety of insects, chief among which are ants and termites, invade the decayed wood behind fire scars in this area. Only one insect, *Parandra brunnea*, was found to invade the sound wood beyond the decay column for any distance. Insects appeared to play a minor role in the ultimate damage.

LITERATURE CITED

(1) Boyce, J. S.
1920. THE DRY-ROT OF INCENSE CEDAR. U. S. Dept. Agr. Bull. 871, 58 pp., illus.

(2) Comstock, J. H.
1925. AN INTRODUCTION TO ENTOMOLOGY. 3d ed. of pt. 1, 1044 pp., illus. Ithaca, N. Y.

(3) EZEKIEL, M.
1930. METHODS OF CORRELATION ANALYSIS. 427 pp., illus. New York and London.
(4) FRITZ, C. W.
1923. CULTURAL CRITERIA FOR THE DISTINCTION OF WOOD-DESTROYING FUNGI. Roy. Soc. Canada Trans. (3) 17 (sec. 5): 191–288, illus.
(5) HEDGCOCK, G. G.
1927. FIRE-SCAR DAMAGE IN WOODLANDS HEAVY. U. S. Dept. Agr. Yearbook 1926: 363–364.
(6) ——— and LONG, W. H.
1914. HEART-ROT OF OAKS AND POPLARS CAUSED BY POLYPORUS DRYOPHILUS. Jour. Agr. Research 3: 65–78, illus.
(7) KAUFERT, F. H.
1933. FIRE AND DECAY INJURY IN THE SOUTHERN BOTTOMLAND HARDWOODS. Jour. Forestry 31: 64–67.
(8) LACHMUND, H. G.
1921. SOME PHASES IN THE FORMATION OF FIRE-SCARS. Jour. Forestry 19: 638–640.
(9) ———
1923. BOLE INJURY IN FOREST FIRES. Jour. Forestry 21: 723–731, illus.
(10) LENTZ, G. H.
1929. LOSS IN MERCHANTABLE RED GUM DUE TO TWO FIRES. South. Lumberman 135 (1756): 40, illus.
(11) ———
1929. SUMMARY OF FIRST YEAR'S HARDWOOD INVESTIGATIONS IN LOUISIANA. Jour. Forestry 27: 486–494.
(12) ———
1931. FOREST FIRES IN THE MISSISSIPPI BOTTOMLANDS. Jour. Forestry 29: 831–832.
(13) ———
1931. THE FOREST SURVEY IN THE BOTTOMLAND HARDWOODS OF THE MISSISSIPPI DELTA. Jour. Forestry 29: 1046–1055.
(14) LONG, W. H., and HARSCH, R. M.
1918. PURE CULTURES OF WOOD-ROTTING FUNGI ON ARTIFICIAL MEDIA. Jour. Agr. Research 12: 33–82.
(15) MEINECKE, E. P.
1915. FOREST PATHOLOGY IN FOREST REGULATION. U. S. Dept. Agr. Bull. 275, 63 pp.
(16) NELSON, R. M., SIMS, I. H., and ABELL, M. S.
1933. BASAL FIRE WOUNDS ON SOME SOUTHERN APPALACHIAN HARDWOODS. Jour. Forestry 31: 829–837, illus.
(17) SNYDER, T. E.
1927. DEFECTS IN TIMBER CAUSED BY INSECTS. U. S. Dept. Agr. Bull 1490, 47 pp., illus.
(18) ———
1926. PREVENTING DAMAGE BY TERMITES OR WHITE ANTS. U. S. Dept. Agr. Farmers' Bull. 1472, 22 pp., illus. (Revised, 1930.)
(19) WEIR, J. R.
1923. THE GENUS POLYSTICTUS AND DECAY OF LIVING TREES. Phytopathology 13: 184–186.

U. S. GOVERNMENT PRINTING OFFICE: 1935

END