Reprinted from JOURNAL OF FORESTRY, January 1957, Vol. 55, No. 1

Progress of Heart Rot Following Fire in Bottomland Red Oaks

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THE MOST IMPORTANT cause of cull in southern hardwood forests is heart rot that develops from wounds made by fire. This study derived means by which the forester working with bottomland red oaks can determine the amount of decay behind old fire scars and estimate the rot that can be expected from new wounds.

The spread of heart rot in fire-scarred trees is influenced by many factors.[3] Some that are very difficult to measure, such as site, climate, and resistance of individual trees, were not considered in this study. Of the factors that were evaluated, age and size of scar, and height of butt bulge and hollow, were judged the most practical to use.

A number of studies have correlated age and size of fire scar with amount of rot, but only two have dealt with bottomland hardwoods. Kaufert[4] pointed out the general importance of rot following fire and indicated some factors that influence the rate at which the rot progresses. Hepting[5] related the rate of decay to age and size of trees, age and dimensions of scar, and species of fungus. However, his work was limited to trees smaller than 11 inches d.b.h. This study extends the range of tree diameters and offers additional information on the rate of decay induced by various species of fungi.

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[3]Wagener, W. W., and R. W. Davidson. Heart rots in living trees. Botanical Review 20:61-134. 1954.

[4]Kaufert, F. H. Fire and decay injury in the southern bottomland hardwoods. Jour. Forestry 31:64-67. 1933.

[5]Hepting, G. H. Decay following fire in young Mississippi Delta hardwoods. U.S. Dept. Agric. Tech. Bul. 494, 32 pp., illus. 1935.

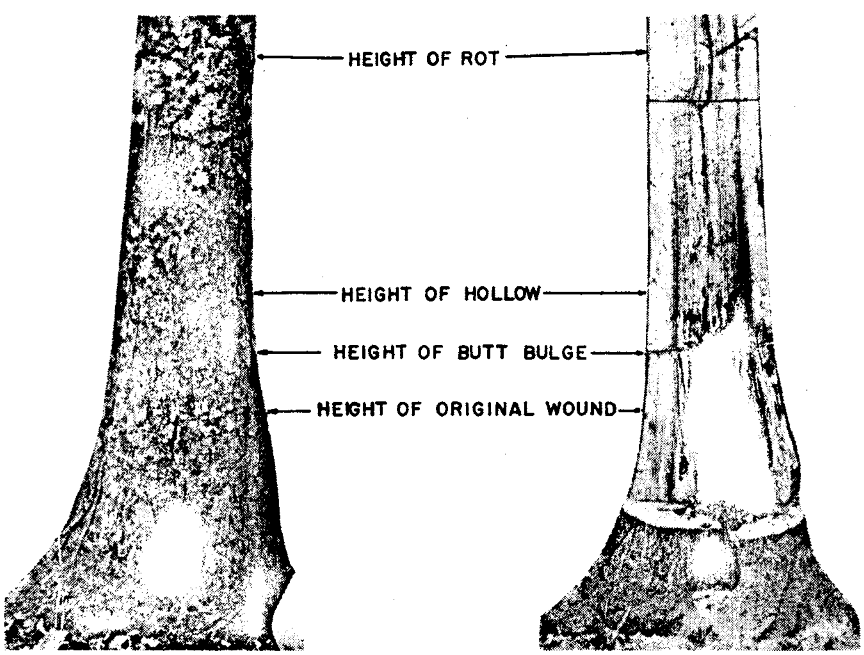

FIG. 1.—A fire-scarred Nuttall oak, wounded 16 years ago, before and after cutting. The heights of original wound, butt bulge, hollow, and rot are indicated.

Method of Study

The working areas were within the flood plain of the Missisipi River but protected from river rises by the levee system. The terrain is flat, and changes in elevation of only a few feet make wide variations in hardwood timber types. The soils range from heavy clays on the lower sites to silt loam and sandy loam on the higher elevations.

Species studied were Nuttall oak (*Quercus nuttallii* Palm.), willow oak (*Q. phellos L.*), water oak (*Q. nigra* L.), and cherrybark oak (*Q. falcata* var. *pagodaefolia* Ell.). One hundred and forty trees were sampled in the central Delta of Mississippi, and 34 in the northeast Delta of Louisiana.

A field crew went through some sample stands cutting all fire-scarred trees larger than 6 inches in diameter. In other stands, the sample trees were felled by commercial loggers. After the trees had been felled, the lower stems were sectioned into workable lengths and each section split open so that extent of hollow and rot[6] could be determined.

Ages of fire scars, which ranged from 4 to 61 years, were determined by counting annual rings in the callus formed at the edge of old wounds. Width and length of the scar, both at time of wounding and at time of sampling, were measured. Widths were taken at the widest point, usually near the ground. Also recorded was the height of butt bulge[7] (Fig. 1) above the ground.

[6]Height of rot was used in preference to cull volume because in practice the total cross-section of the stem is lost through jump-butting nearly to the upper limit of decay.

[7]Butt bulge is defined in this paper as an abnormal enlargement of the butt portion of the stem. It is nearly always accompanied by hollow butt and is different from normal butt swell.

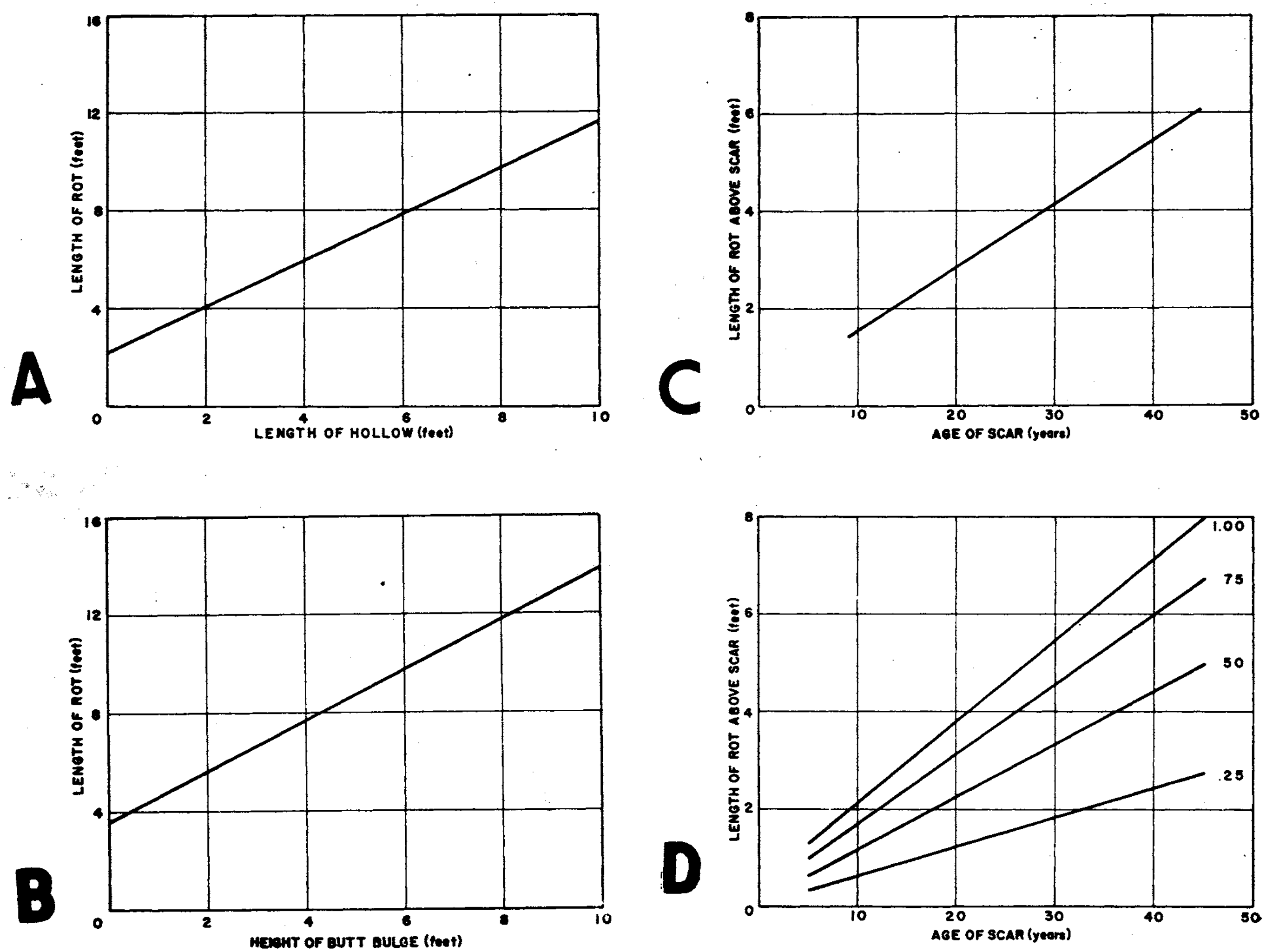

FIG. 2.—*A*. Length of heart rot in red oaks as related to length of hollow.
B. Length of heart rot in red oaks to height of butt bulge.
C. Length of heart rot above original fire scar in red oaks as related to age of scar.
D. Length of heart rot above original scar height in red oaks as related to age of scar for different values of width of original scar minus 2 divided by stump diameter at time of wounding.

TABLE 1.—FINAL REGRESSIONS USED IN DEVELOPING PREDICTIONS OF BUTT ROT IN FIRE-SCARRED RED OAKS IN THE SOUTHERN BOTTOMLAND[1]

Form[2]	Mean squared residual	Degrees of freedom for error	Coefficient of multiple correlation
(A) $Y = b_0 + b_1 X_1$	2.351	89	.858**
(B) $Y = b_0 + b_1 X_2$	6.318	86	.710**
(C) $Y - Z = b_0 + b_1 X_3$	8.659	172	.739**
(D)[3] $Y\text{-}Z = b_1 X_5 + b_2 X_4 X_5 + b_3 X_4 X_5^2$	6.827	171	.823**

Coefficients for above regressions

Coefficients[4]	A	B	C	D
b_0	2.172	3.582	0.279	-------
b_1	0.946	1.021	0.128	1.108
b_2	-------	-------	-------	0.262
b_3	-------	-------	-------	—0.095
C_{00}	.06005	.07399	.03310	-------
C_{01}	— .00789	— .01489	— .00118	-------
C_{11}	.00127	.00354	.00005	.03829
C_{12}	-------	-------	-------	— .00103
C_{13}	-------	-------	-------	— .00063
C_{22}	-------	-------	-------	.00017
C_{23}	-------	-------	-------	— .00011
C_{33}	-------	-------	-------	.00015

[1]Regression analysis indicated no significant difference attributable to locality in any of these regressions.

[2]Definition of variable terms:
Y = present length of butt rot (in feet),
Z = original length of wound (in feet),
$Y\text{-}Z$ = present length of butt rot minus original length of wound (in feet),
X_1 = length of hollow (in feet),
X_2 = length of butt bulge (in feet),
X_3 = age of wound (in years),
X_4 = age of wound minus 4 years (in years),
X_5 = original width of wound minus 2 inches, all divided by stump diameter at time of wounding (in inches).

[3]Regression through mean not significantly better than regression through origin. Higher degree polynomial terms in series failed to improve fit significantly.

[4]Subscripts denote order of single or joint term appearance in regression, not variable subscripts in term.

**Significant at the 1-percent level.

Incidental information was secured on the identification of fungi causing rot in the wood. In the southern bottomlands fruiting bodies or conks of fungi are rarely found in connection with decay behind fire scars. Therefore, the only means of identifying the fungi causing decay was by comparing cultures from decayed wood with known stock cultures. Cultures were prepared from 85 of the study trees. Sixty-six of these yielded pure cultures of decay fungi. With the help of the Forest Disease Laboratory, Beltsville, Maryland, 55 of the cultures were identified. The other 11 were not present in the Beltsville collection of named fungi. Although 23 different species of fungi were found, it is evident that these do not represent all that are associated with heart rot in bottomland red oaks.

Statistical Analysis

Inspection of the data indicated straight-line relationships between length of hollow and length of heart rot, and between height of butt bulge and length of heart rot. Of the 174 trees, 91 had hollows and 88 of these showed butt bulge. The data for these trees were fitted to equations A and B in Table 1. They are graphically illustrated in Figures 2A and 2B.

The data on size and age of scar for the 174 trees were fitted to 19 different regression equations. The final regressions are listed in lines C and D of Table 1 and graphically illustrated in Figures 2C and 2D. The rejected equations are listed in Table 2. No heart rot was found associated with wounds 4 years or less in age, or with fire scars 2 inches or less in width.

Analysis of variance showed no significant difference attributable to locality in these four regressions. The coefficients of multiple correlation for each were significant at the 1 percent level (Table 1).

Table 3 shows that rate of decay also depends upon the fungus causing the decay. For example, *Hydnum erinaceous* had an average annual rate of decay above the scar of 2.2±0.8 inches, while for *Pleurotus ostreatus* this figure was 1.5 ±0.5 inches. The difference between these fungi was significant at the 10 percent level. The upward spread of rot in this study was .6 inch per year behind small wounds (with widths up to ¼ of the basal circumference) and 2.0 inches behind large wounds (with widths over ½ the basal circumference). Hepting[8] gives an average upward spread of 2.3 inches per year for his black oak group, which included only trees less than 11 inches d.b.h. of the three species studied here. Hepting's figures for average annual rate of decay for the different fungus species are likewise within the same general range reported here. This study has extended the size class range and added several useful variables not used by Hepting.

Practical Application

This study has led to some information that foresters can conveniently use when marking or cruising hardwood timber that has been damaged by fires.

Estimating rot behind old scars.—The extent of rot behind an old fire scar can be estimated from the length of the hollow (as determined by probing with a stick) or from the height of the butt bulge. On the average, rot extends about 2 feet above the top of the hollow and 3½ feet above the butt bulge. If more precise relationships are desired, they can be read directly from Figures 2A or 2B.

A rule of thumb for deducting the volume lost through butt rot is to reduce the merchantable length of stem by the length of rot as indicated by hollow or butt bulge, and then reduce the d.b.h. measurement 1 inch for each 6 feet of rot. When necessary, the d.b.h. should also be corrected for butt swell. This rule is accurate enough for practical use with the whole range

[8]Op. cit.

TABLE 2.—LIST OF REJECTED REGRESSIONS (EITHER INFERIOR TO OR NO SIGNIFICANT IMPROVEMENT OVER FINAL REGRESSIONS)[1]

$Y = f\ (X_3X_7,\ X_3^2X_7,\ X_3X_7^2,\ X_3^2X_7^2)^2$
$Y = f\ (K,\ X_3,\ X_3^2,\ X_3X_8,\ X_3^2X_8,\ X_3X_8^2,\ X_3^2X_8^2)$
$Y = f\ (K,\ X_3,\ X_3^2,\ X_3X_7,\ X_3^2X_7,\ X_3X_7^2,\ X_3^2X_7^2)$
$Y = f(K,\ X_3,\ X_3^2,\ X_3X_7X_8,\ X_3^2X_7X_8,\ X_3X_7^2X_8,\ X_3^2X_7^2X_8,\ X_3X_7^2X_8^2,\ X_3^2X_7^2X_8^2)$
$Y = f\ (K,\ X_3X_{11},\ X_3^2X_{11},\ X_3X_{11}^2,\ X_3^2X_{11}^2)$
$Y = f\ (K,\ X_3X_{10},\ X_3^2X_{10},\ X_3X_{10}^2,\ X_3^2X_{10}^2)$
$Y = f\ (K,\ X_3X_{10}X_{11},\ X_3^2X_{10}X_{11},\ X_3X_{10}^2X_{11},\ X_3^2X_{10}^2X_{11},\ X_3X_{10}^2X_{11}^2,\ X_3^2X_{10}^2X_{11}^2)$
$Y = f\ (X_4X_6,\ X_4^2X_6,\ X_4X_6^2,\ X_4^2X_6^2)^{2,3}$
$Y = f\ (X_4X_{10},\ X_4^2X_{10},\ X_4X_{10}^2,\ X_4^2X_{10}^2)^2$
$Y = f\ (X_4X_6X_{10},\ X_4^2X_6X_{10},\ X_4X_6^2X_{10},\ X_4^2X_6^2X_{10},\ X_4X_6^2X_{10}^2,\ X_4^2X_6^2X_{10}^2)^2$
$Y = f\ (X_4X_5,\ X_4^2X_5^2)^{2,4}$
$Y = f\ (X_4X_{10},\ X_4^2X_{10}^2)^2$
$Y = f\ (X_4X_5X_{10},\ X_4^2X_5X_{10}^2)^2$
$Y = f\ (K,\ X_9)$
$Y\text{-}Z = f\ (K,\ X_5,\ X_4X_5,\ X_4X_5^2,\ X_4^2X_5^2)$
$Y\text{-}Z = f\ (K,\ X_{10},\ X_4X_{10},\ X_4X_{10}^2,\ X_4^2X_{10}^2)$
$Y\text{-}Z = f\ (X_{10},\ X_4X_{10},\ X_4X_{10}^2)^2$
$Y\text{-}Z = f\ (K,\ X_3,\ X_3^2)^5$

[1]Definition of terms:
Y = present length of butt rot (in ft.).
Z = original length of wound (in ft.).
$Y\text{-}Z$ = present length of butt rot minus original length of wound (in ft.).
X_1 = length of hollow (in ft.).
X_2 = length of butt bulge (in ft.).
X_3 = age of wound (in years).
X_4 = age of wound minus 4 years (in years).
X_5 = original width of wound minus 2 inches, all divided by stump diameter (in inches).
X_6 = original width of wound minus 2 inches.
X_7 = present length of fire scar (in inches).
X_8 = present width of fire scar (in inches).
X_9 = present diameter of rot (in inches) at stump height (1 to 2 feet).
X_{10} = original length of wound (in inches).
X_{11} = original width of wound (in inches).
K = a constant appropriate to a given regression.

[2]Regressions through means not significantly better than regressions through origin. Higher degree polynomial terms did not significantly improve fit.

[3]Differences between crown classes significant.

[4]Differences between localities significant.

[5]No significant curvilinearity.

TABLE 3.—FUNGI IDENTIFIED IN CONNECTION WITH FIRE-SCAR DECAY IN BOTTOMLAND RED OAKS

Fungi isolated[1]	Cases	Average annual rate of decay above scar[2]
	No.	*Inches*[3]
Pleurotus ostreatus	10	1.5 ± 0.5
Hydnum erinaceus	8	2.2 ± 0.8
Polyporus lucidus	6	3.0 ± 1.4
Polyporus fissilis	5	2.5 ± 1.4
Polyporus zonalis	3	2.9
Odontia spp.	3	1.9
Lentinus tigrinus	2	1.6
Ustulina vulgaris	2	1.9
Polyporus versicolor	2	0.7
Corticium lividum	1	2.6
Stereum frustulosum	1	7.8
Stereum gausapatum	1	3.9
Polyporus sulphureus	1	3.7
Merulius tremellosus	1	3.3
Poria andersonii	1	4.4
Poria laevigatus	1	1.5
Fomes ignarius	1	3.6
Stereum subpileatum	1	1.3
Polyporus obtusus	1	1.3
Fomes geotropus	1	1.6
Stereum rameale	1	2.4
Fomes robustus	1	1.6
Fomes lobatus	1	2.1

[1]Eleven of the 66 fungi isolated in the present study have not been identified.

[2]Analysis by the "t" test indicated that *Hydnum erinaceus* differs in rate of decay above scar from *Pleurotis ostreatus* at the 10 percent level of significance. These two fungi differ from *P. lucidus* and *P. fissilis* in annual rate of decay above scar at the 10 percent level of significance.

[3]Mean ± standard error.

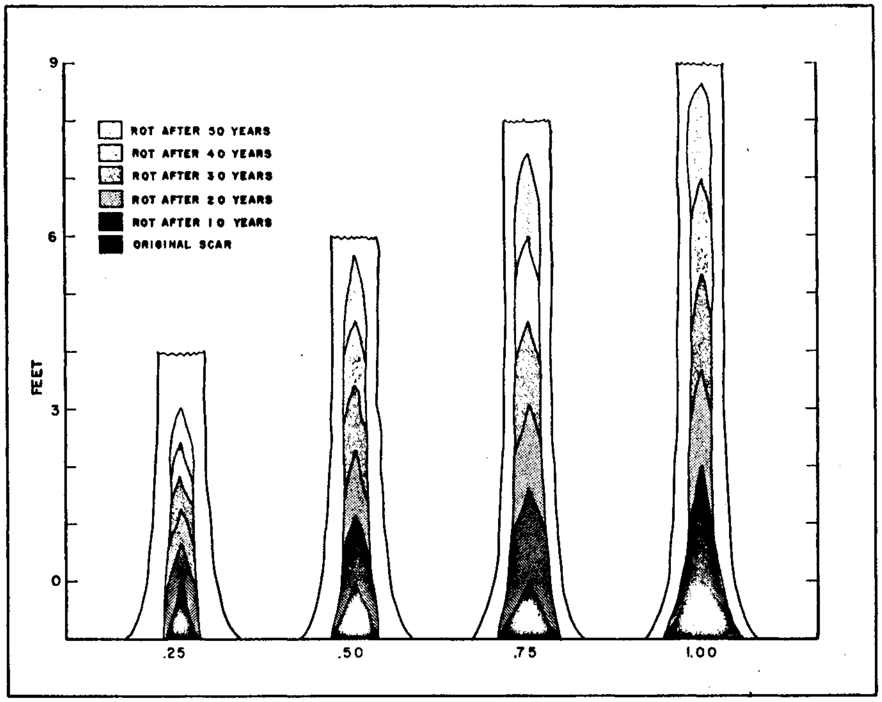

FIG. 3.—Increase of heart rot above original scar height for various values of the ratio $\frac{\text{original wound width minus 2}}{\text{stump diameter at time of wounding}}$

of bottomland red oaks. In principle, however, a smaller reduction in d.b.h. is in order for a form class higher than 75, and vice versa.

This information should be applied with caution when scars are more than 50 years old. It is known that with increase in age, many rot fungi will change their rate of spread.

Rot expected from recent scars.—In evaluating fire damage for claims, and in marking for salvage cuttings, it is important to be able to predict soon after a fire the rot to be expected in the future. Such a prediction can be obtained by using age of wound alone (Fig. 2C). More accurate predictions may be made by employing, as an additional variable, the ratio of wound width to diameter at stump height, both taken at time of wounding (Fig. 2D). This method of prediction is presented graphically in Figure 3.

If a cruise is made, before callus formation has begun, the dimensions of the wound may be predicted from the amount of charred bark. Studies made after recent fires have shown that the width of scar is approximately equal to the width of charred bark. However, the height of the scar may exceed the height of charred bark by several feet.[9]

The average rate of spread of established rot as determined by the study was 1¼ feet per decade. This information can be used in routine timber marking as a guide in deciding whether to cut or leave a tree with rot already established. However, in judging the future value of a tree, factors other than the extent of rot and its effect on net volume must be considered. Some of these are: (1) The best or most valuable part of the tree is being destroyed by rot; (2) breakage may remove the tree from the stand, (3) degrade from stain and insect attack is often associated with rot.

[9]Toole, E. R., and J. S. McKnight. Fire and the hapless hardwood. Southern Lumberman 191 (2393):181-182, illus. 1955.