Successions of Microorganisms and Patterns of Discoloration and Decay after Wounding in Red Oak and White Oak

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ABSTRACT

Trunks and roots of 18 mature red oaks, *Quercus rubra*, and 5 white oaks, *Q. alba*, were dissected to determine the patterns of discolored and decayed wood associated with 22-year-old basal fire wounds and mechanical wounds inflicted during subsequent salvage operations. The columns of discolored and decayed wood had advanced farthest along the sapwood-heartwood boundary present at the time of wounding. The discolored and decayed tissues associated with the wounds were confined to the tissues present when the wounds occurred. The heartwood cylinder constricted abruptly below the root collar. Heartwood formation was retarded around wounds. Complex patterns of discolored and decayed wood occurred in the root-trunk transition zone. Isolations for microorganisms were made in a systematic way from columns of discolored and decayed wood in 19 trees. Bacteria and nonhymenomycetous fungi were isolated consistently from columns that contained only discolored wood, and from the discolored wood at the distal margins of columns that contained decay. Hymenomycetous fungi were isolated commonly from the tissues at the border of discolored and decayed wood. A large variety of microorganisms was isolated from the advanced decay. The results indicate that discoloration and decay are compartmentalized within the tissues present at the time of wounding, and that successions of microorganisms follow wounding in oaks.

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Additional key words: fire wounds on oaks.

Successions of microorganisms and patterns of discoloration and decay after wounding in deciduous trees have been studied mainly on species of *Acer*, *Betula*, and *Populus* (1, 2, 5, 6), which have wood that is diffuse or semidiffuse porous. Information on successions of microorganisms and patterns of discoloration and decay is needed from trees that have ring-porous wood. To obtain this information, studies were undertaken on mature *Quercus* species. Trees with wounds were dug out by the roots and pushed over, dissected, and studied in the field to determine the patterns of discoloration and decay. Isolations in the laboratory were made in a systematic way to determine whether successions of microorganisms followed wounding. Other investigators have made valuable contributions on the hymenomycetous fungi associated with decay, and on the rate of decay after wounding in oaks (3, 4, 8), different from the studies discussed here.

MATERIALS AND METHODS.—Trunks and roots of 18 red oak, *Quercus rubra* L., and 5 white oak, *Q. alba* L., trees were dissected with a chainsaw after they were dug out by the roots and pushed over on the Massabesic Experimental Forest, Alfred, Maine, during the summer of 1970. The trees ranged from 25 to 70 cm diam at 1.4 m aboveground. All trees had 22-year-old basal fire wounds. Also, some trees had mechanical wounds on the trunk inflicted during salvage operations conducted for several years after the fire of October 1947. Some root and butt sections were taken to a field laboratory where they were washed thoroughly and dissected. All dissections were made so as to expose the column of discolored and decayed wood associated with every wound and at least a meter of healthy wood distal to the vertical margin of the column. A photographic record of the dissections was made.

Columns of discolored and decayed wood and healthy wood beyond the columns were cut into billets ca. 15 X 10 X 5 cm from 14 red oak and 5 white oak trees, and taken the same day to a laboratory in Durham, N.H. The wood sections were then split with a sterile axe to yield two billets, each ca. 15 X 10 X 2.5 cm. From the freshly exposed surfaces, 2,826 wood chips ca. 10 X 3 X 3 mm were taken with a sterile gouge from the discolored and decayed tissues, from healthy tissues contiguous to them, and from healthy tissues beyond the vertical margin of the columns.

Six chips were taken in a line across the grain and placed carefully into an agar medium so that each chip touched the bottom of the petri dish. The medium consisted of 10 g malt extract, 2 g yeast extract, and 20 g agar/liter of distilled water, and had a pH of about 6. The cultures were incubated at 25 C and examined after 10 days. Additional examinations were made for 6 weeks for slow-growing microorganisms. The bottoms of the chips were examined for bacteria under a stereoscope at X 30. The position of each microorganism was fixed on diagrams of the columns of discolored and decayed wood that were drawn before the isolations were made.

RESULTS.—*Patterns of discoloration and decay*.—The columns of discolored and decayed wood associated with the wounds were confined to wood present at the time of wounding. The discolored and decayed columns associated with the 19- to 22-year-old trunk wounds inflicted during salvage operations had advanced farthest along the sapwood-heartwood boundary present at the time of wounding. Some dissections revealed two dark lines of discoloration; one at the sapwood-heartwood boundary present at the time of wounding, and one

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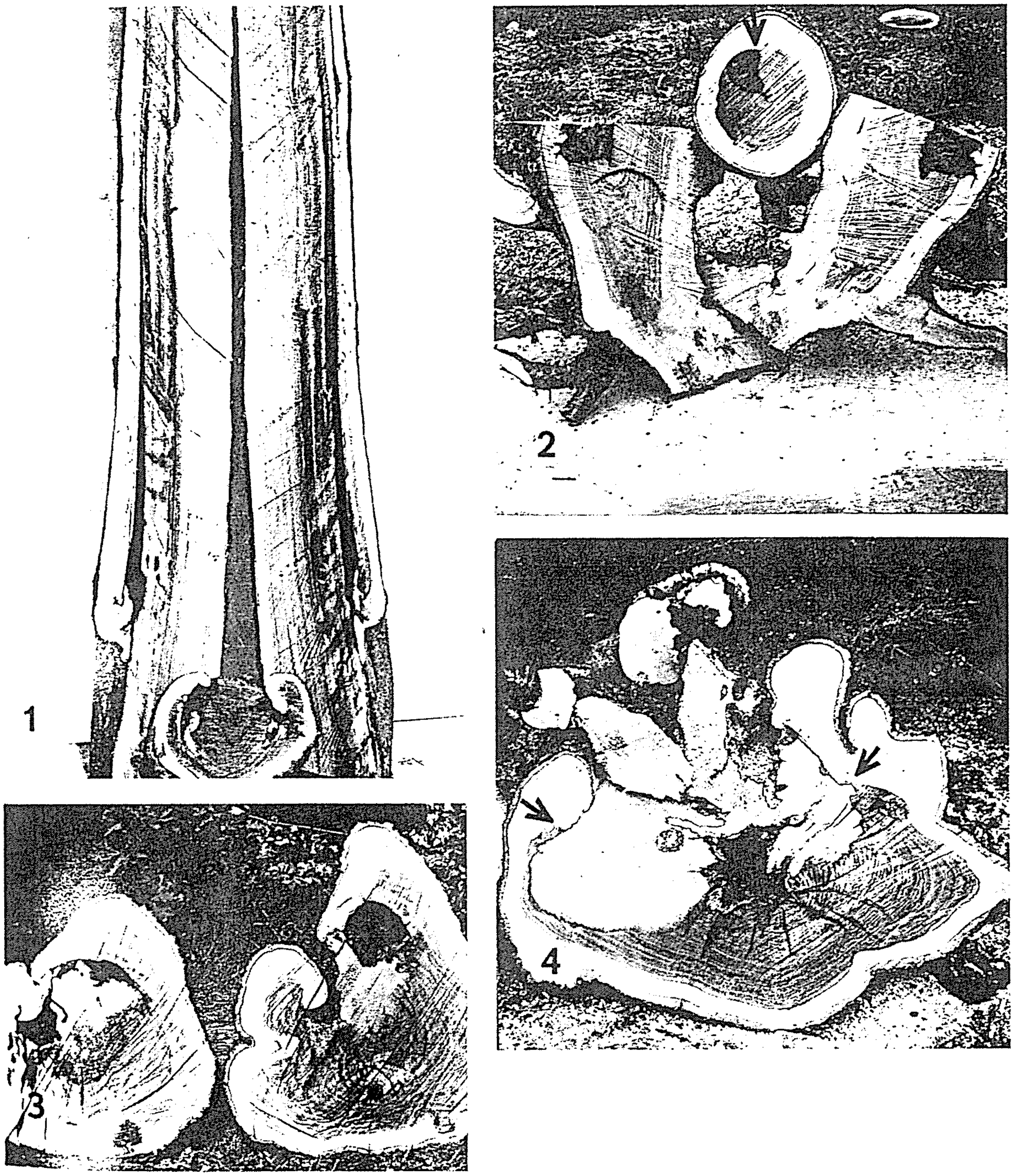

Fig. 1-4. 1) Dissection of a red oak with a 22-year-old fire wound. The column of discolored and decayed wood associated with the wounds advanced most rapidly in the heartwood-sapwood boundary present at the time of wounding. 2) Dissection of a taproot of a white oak, and a cross section of the lower stem. The heartwood constricted abruptly in the root. The column of decay constricted abruptly as it advanced into the root-trunk transition zone. Heartwood formation is retarded in the tissues around the wound as shown in the cross section (arrow). 3) Cross sections of red oak; (left) base of tree; (right) 15 cm below base. The decay fungi did not grow into the heartwood tissues that formed after the wounds were made. 4) Basal cross section of a red oak with decay supporting a sporophore of *Fomes applanatus*. The cracks along the rays were common in sections having decayed or completely decomposed centers. Heartwood formation was retarded in tissues around the wound (arrows).

along the youngest ring of sapwood present at the time of wounding. Wood-boring insects that invaded the wood through the wounds created new wounds that disrupted the pattern of discoloration and decay.

Decay was associated with every fire wound. The columns of discoloration and decay advanced most rapidly in the youngest ring of sapwood present at the time of wounding, and not toward the center of the trunk (Fig. 1). The columns and the heartwood cylinders constricted abruptly into the roots, as did columns advancing upward from the roots (Fig. 2). The white wood in the roots that was present at the time of the fire wounds was often discolored slightly around the entire root.

Decay associated with large dead basal stems was confined to pockets in the butts and roots. The decay did not spread throughout the heartwood, nor into tissues that formed after the stem died (Fig. 3).

Many wounds were found on the roots after they were dug. Dissections of the wounds showed patterns of discoloration and decay similar to those associated with trunk wounds on species of *Acer* and *Betula* (5, 6). The columns were confined to tissues present when the roots were wounded, and the columns advanced more rapidly in the center of the root. As these columns advanced upward toward the butt, they usually did not move into the heartwood.

Several trees had large sporophores of *Fomes applanatus* (Pers. ex Wallr.) Gill. associated with the wounds (Fig. 4). The decay yielded *F. applanatus* in culture. The columns associated with the sporophores were more advanced in the butts and roots than columns associated with other wounds, and they constricted abruptly above the wounds.

Dissections of butts and roots revealed that most of the trees had several stems when young. A central pocket of decay or a hole where the tissues were decayed completely was associated with the stems that had died and decayed early in the life of the tree (Fig. 4). Cracks along the rays were associated with these pockets of decay (Fig. 4). The origin of some of these was deep in the base, and they could only be seen after the roots were dissected. Heartwood formation was retarded in the tissues that formed around the wound (Fig. 2).

Successions of microorganisms.–Bacteria and nonhymenomycetous fungi were isolated from discolored wood associated with every wound. These microorganisms were isolated from the discolored tissues at the distal margins of all but one column of decay. Healthy tissues beyond the distal margins of columns of discolored tissue and healthy tissues contiguous to the columns of discoloration and decay usually did not yield microorganisms. Many bacteria grew only from the bottom of the chips.

The boundaries of the columns of discoloration in the heartwood were marked immediately after dissection. After the wood began to dry, it was difficult to see the distal margins of discolored wood in the dark heartwood of some trees.

In columns that contained advanced decay moving through large columns of discolored wood (Fig. 1), there were three zones of microorganisms. Wood at the distal margin of the discolored column and discolored wood throughout the column yielded bacteria and nonhymenomycetous fungi. The tissues where the decay was advancing into the discolored wood yielded principally hymenomycetous fungi. The advanced decay in back of the wound yielded a great variety of bacteria, Actinomycetes, nematodes, nonhymenomycetous fungi, and some hymenomycetous fungi, as well as Phycomycetes and slime molds.

The principal nonhymenomycetous fungus isolated from the discolored wood was *Paecilomyces varioti* Bainier. This fungus was often isolated from tissues that did not appear discolored after the wood dried. From the wood that remained discolored after the wood dried, species of fungi that had phialides were isolated most commonly. The fungi were tentatively identified as *Torula jeanselmei* Langeron and *Rhinocladiella* sp. Other fungi isolated were in the genera *Phialophora, Ascocoryne, Ceratocystis, Gliocladium, Cephalosporium*, and *Fusarium*. From the advanced decay, fungi in the genera *Trichoderma, Mucor*, and *Mortierella* were isolated commonly. Other than *Fomes applanatus*, the hymenomycetous fungi were not identified.

DISCUSSION.–There appears to be a succession of microorganisms involved in the processes initiated by wounding that results in discoloration and decay of wood in oaks, and the columns of discoloration and decay characteristically develop in the tissues present at the time of wounding. In general, this is similar to conditions occurring in species of *Acer* and other diffuse-porous trees after wounding (5, 6).

The species of microorganisms that invade the wood in species of *Acer* and *Quercus* differ, but species of fungi that have phialides are among the first to invade wounds in both groups of trees. The three zones of colonization of columns of discoloration and decay in both types of trees are similar. The advanced decayed zone contains a wide variety of microorganisms; the zone between the decayed wood and the discolored wood is the primary site of the hymenomycetous fungi; and the discolored wood in advance of the decayed wood is the zone that yields mostly bacteria and nonhymenomycetous fungi. The healthy tissues distal to the columns of discolored and decayed wood and the healthy tissues contiguous to the discolored and decayed wood seldom yielded microorganisms, indicating that there was no indigenous microflora associated with these tissues.

There is little doubt that successions occur, but it would be unwise to state that they occur always in the same manner as described here. It is possible that hymenomycetous fungi could act as pioneer invaders of wood, expecially in wounds that leave a large volume of dead tissues.

The role of bacteria in these processes needs to be recognized. These microorganisms could be overlooked if the bottoms of chips are not examined carefully, and if the media and methods used for isolations are not suitable for their growth. Anaerobic bacteria have been shown to exist in discolored tissues in oak (7). They may be more common than we realize.

In the oaks, columns advanced most rapidly in the heartwood-sapwood boundary that was present at the time of wounding, while in *Acer* species, the columns advanced most rapidly in the center of the trunks (5, 6). The columns of discoloration and decay associated with wounds in oak roots were similar to the columns in trunks of *Acer* species. There was no central column of dark heartwood in the oak roots.

The columns of discolored and decayed wood did not advance into tissues that formed after the trees were wounded. Even when heartwood formed, these tissues were not invaded by the microorganisms in the column. This indicates that the columns of discoloration and decay are compartmentalized within the tissues present at the time of wounding. These results support the early observations by Hepting on decay in fire-wounded oaks (3).

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