NONINFECTIOUS DISEASES OF OAKS

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ABSTRACT. Noninfectious diseases arise primarily from the harmful effects of wound agents, chemical, and adverse environmental factors. Wounds directly result in damage to trees, but they are important primarily as infection courts for pathogenic organisms. Adverse environmental factors affect trees both directly and indirectly. Trees weakened by environmental stresses become susceptible to insects and fungi that normally are unable to attack. These "declines" of oak have occurred frequently in the Northeast and Southeast and will probably increase as concern for environmental quality restricts the use of pesticides.

NONINFECTIOUS DISEASES include all deleterious alterations in form or function that occur in the absence of pathogenic organisms. Wounds resulting from mechanical injuries and fire; damage caused by chemicals, including herbicides and air pollutants; and the effects of irradiation, mineral deficiencies, and adverse environmental factors, including insect defoliation, are the primary types of noninfectious diseases.

Most mechanical injuries are significant mainly as infection courts for organisms that incite discoloration, decay, cankers, or vascular wilts. For this reason, the subject of wounds is treated lightly in this paper except to note difference in susceptibility of major species to wound agents or ecological factors related to wound development.

Adverse environmental factors—particularly drought and frost—are probably the most important causes of noninfectious diseases. Oak declines, which are usually complexes of adverse environmental factors and organisms of secondary action, are treated in this paper even though infectious organisms are involved. The great importance of oak declines warrants discussion of these complexes at this symposium if for no other reason than to point out the need for further research.

Fire is a major source of injury to oaks in the Southern Appalachian and Southern States. Much attention has been paid to the discoloration and decay following wounding by fires, and several comprehensive accounts of the damage that can result have been published *(Hepting 1935, and 1941)*. The processes that result in discoloration and decay are treated in another paper in this symposium. Therefore my primary aim is to point to factors relating to severity of injury.

In general, the white oak group suffers less damage by fire than the red oaks (table 1). This is partly because the bark of the white oaks is usually thicker, more fibrous, and lighter in color. The ability of bur oak to survive in its Midwestern habitat where fires were common is attributed to its insulating bark, which can reach thicknesses up to 4 inches in old trees.

Chestnut oak occupies sites unsuitable for other species—a factor that contributes directly to the great damage it receives from fire. On steep dry slopes and ridges much litter accumulates—and severe scarring of the upper sides of the trees results from fire. Of the red oaks, scarlet oak suffers the greatest damage from fire. It has thin hard bark, and it often grows on dry sites. By contrast, willow oaks—with probably the most fire-susceptible bark—suffer little from fire because they grow mainly in river valleys and other moist situations that are low in fire hazard.

Chemicals, including air pollutants, are agents that can cause injury to oaks. Iron chlorosis is a common problem on pin oak, from New Jersey to Michigan to Texas, and is especially prevalent on the calcareous soils of the Midwest. This problem of iron deficiency has been corrected by acidifying the soil with H_2SO_4 or by adding iron chelate to the soil, and by spraying foliage with ferric phosphate or $FeSO_4$ *(Pirone 1941, Hacskaylo and Struthers 1959, Carpenter 1951)*. By contrast, bur oak does well on the calcareous ridges of the midwest.

White oak is resistant to salt spray and to brief salt water flooding, and live oak, which occupies primarily a coastal strip from North Carolina to Texas, is remarkably resistant to sea salt salinity and salt spray. Such information could be of value in selecting species to plant along roadways in areas where salt is used to reduce winter road hazard or in areas exposed to coastal storms.

Most damage from chemicals derives from the activities of man, and much is the result of air pollution. Until recently, information about air-pollution effects on trees was limited to field situations—and primarily on attempts to relate visible injury to proximity and direction from recognized industrial sources. The papers by Hedgcock *(1914)* and Scheffer and Hedgcock *(1955)* are good examples of this approach.

Recognition of the magnitude and complexity of today's pollution problems, and of the possible indirect and chronic effects of pollution has spurred research efforts to clarify the effects of different pollutants, singly and in combination. From such research, a better understanding of pollution effects on oaks has begun to emerge.

Oaks vary markedly in their responses to different pollutants. For example, pin, scar-

Table 1.—*Summary of relative susceptibility of representative oak species to noninfectious disease agents*[1]

Species	Fire[2]	Drought	Ice	Frost	Flooding	Decline	Mineral Deficiency
White oak	3	2	3	2	2	2	—
Overcup oak	—	—	—	—	5	—	—
Bur oak	5	4	—	4	—	—	—
Swamp chestnut oak	—	2	—	2	3	—	—
Chestnut oak	2	4	—	4	—	—	—
Post oak	—	4	—	—	—	—	—
Scarlet oak	1	4	—	4	—	—	—
Southern red oak	2	2	—	—	—	—	—
Nuttall oak	1	—	—	—	—	—	—
Pin oak	1	—	—	—	4	2	2
Northern red oak	—	—	2	—	—	2	—
Black oak	2	3	—	—	—	—	—
Live oak	—	—	—	2	—	—	—

[1] Information obtained from many sources, most of which are cited in Hepting, G.H. 1970.
[2] 1. Very sensitive. 2. Sensitive. 3. Moderately resistant. 4. Resistant. 5. Very resistant.

let, gambel (*Quercus gambelli Nuth.*), and white oaks were found to be sensitive to ozone, while red and shingle (*Quercus imbaiuria Michy*) oaks were resistant; pin oak was sensitive to chlorine while red oak *Quercus rubra L.*, was resistant; and black oak *Quercus velutina Lam.*, was sensitive to 2,4-D while pin and red oaks were intermediate in sensitivity *(Jacobson and Hill 1970, Means and Lacasse 1969, Wood and Davis 1969).*

The above rankings were based on foliar symptoms. Little is known about effects that are less obvious. Such effects may be important. For example, marked abnormal tyloses formation and aberrant cambial and parenchyma production occurred in blackjack oak that survived 2,4-D poisoning. Even roots showed tyloses formation *(Marts 1947).* This latter response was utilized by Kuntz and Drake *(1960)* to control spread of the oak wilt fungus through root grafts of northern pin oak. Soil fumigants induced tyloses formation in injured roots and prevented movement of spores through vessels from disease to healthy trees.

Research with other tree species has revealed the fallacy of establishing "safe" concentrations for single pollutants. Ozone at levels below those causing symptoms on white pine has been shown to interact with SO_2 at relatively low levels to cause injury. Studies are needed to determine if pollutant mixtures are injurious to oak, and further to determine the environment-pollutant relationship.

Hepting *(1964)* has suggested that we must consider the effects of climate as it influences air-pollution phenomena in explaining the decline of northeastern hardwoods, including oaks. It is probable that indirect effects of chronic exposures to air pollutants will become more and more important. Scheffer and Hedgcock *(1955)* reported that *Armillaria mellea* (Fr.) Quel. was much more prevalent within areas damaged by SO_2 in the Columbia River Valley south of Trail, B. C., than in adjacent areas where trees were unaffected by the toxicant. This suggests that there may be an increase in the predisposition of trees to *Armillaria* in areas where pollution is increasing.

Irradiation has been studied as a source of injury to plants. Oaks apparently are severely damaged when subjected to continuous gamma-ray irradiation *(Sparrow et al. 1961).* Effects include abnormal and restricted development of vegetative parts and floral primordia, pollen abortion, and reduced seed production and seedling development *(Mericle et al. 1962, Stairs 1964a and b, Mergen and Stairs 1962).* In forests surrounding gamma fields, there was a continued decrease in species diversity, and severe ecological disturbances apparently would occur following accidental contamination of vegetation *(Woodwell and Rebuck 1967).*

Adverse climatic factors, both directly and indirectly, are important causes of noninfectious diseases of oak. Frost cracks have received attention for many years—indeed good accounts of the development of frost cracks were given by Hartig in 1894. Most research on frost cracks since then has come from Europe. In Hungary, damage to *Quercus cerris L.* was most severe on the largest stems and on trees with spiral grain, large crowns, and coarse branches *(Kondor 1966).* In Switzerland, most damage to *Q. robur L.* occurred on steep slopes where codominants were more susceptible than dominants *(Lamprecht 1950)*, while the worst sites for *Q. cerris* in Hungary were valleys and level lowlands *(Igmandi 1956).* In Belgium red oak was most susceptible when grown as isolated individuals or on edges of stands, especially on southeastern, southern, and southwestern aspects *(Malaisse 1957).*

In a Pennsylvania woodlot, Fergus *(1956)* found that frost cracks occurred on 17.5 percent and 22.3 percent of the white and scarlet oaks, respectively, and were most common on the larger dominants and codominants. Most frost cracks, like fire scars, occur on the lower 6 to 8 feet of trunk and can serve as infection courts for discoloration and decay fungi.

Late spring frosts are important in many areas, often causing severe damage over large regions. Tryon and True *(1964)* discussed the nature of frosts and the relative susceptibility of Appalachian hardwoods. Oaks were considered moderately susceptible and white, scarlet, chestnut, and red oaks were ranked in that order (high to low). These authors recommended favoring resistant reproduction when regenerating stands and leaving at least a partial canopy if possible. Single-tree selection, small group-selection cuttings, and shelterwood cuttings were recommended.

In late May 1925 a severe frost injured tremendous numbers of white oak trees in the valleys and hollows of North Carolina *(Beal 1926)*. Over 3,000,000 feet of white oak died by the summer of 1926. White oak was more seriously affected than the red oaks because its leaves were less fully developed at this date. Beal indicated also that a widespread drought occurred in the summer of 1925.

Drought in 1925 was an important factor in the mortality of several oak species in North Carolina *(Hursh and Haasis 1931)*. During July and August only 11.6 percent of the normal average rainfall fell. Trees were seriously affected on ridges and upper slopes. In 1927 and 1929 no sign of damage occurred on trees that were symptomless in 1925. Half the trees that had drought symptoms in 1925 recovered but the rest had dead branches or had died. Chestnut oak suffered no permanent damage, but black, scarlet, and red oaks with severe leaf injury in 1925 were dead by 1929. Recovered trees showed little effect while those that died during the 4 years showed definite reductions in diameter increment during the period they were alive after the drought. True and Tryon *(1956)* and Tryon and True *(1958)* also correlated increment of dying scarlet oaks with precipitation deficits of the previous July-August period.

Hursh and Haasis *(1931)*, in their 4-year study of the 1925 drought, mentioned that severe late frosts occurred in April 1927. (At this time foliage of the red oak group probably would be susceptible.) They concluded that the combination of adverse environmental factors reduced the vigor of trees and predisposed them to attack by *Armillaria*, *Agrilus bilineatus* web., and long-horned beetles.

A relationship between drought and frost was shown by Bolycevcev *(1967)* in Russia. Injury to sapwood by frosts—ring rot—was greatest when the two preceding years had been droughty, and particularly when severe frosts were preceded by drought in the second half of the growing season.

True and Tryon *(1956)* associated the initiation of stem cankers on red, black, and scarlet oaks to the drought of 1953. A facultative fungus, *Fusarium* sp., grew from 18 percent of the isolation chips. *Fusarium* species have been associated with annual-type cankers of many tree species, and their incidence is often correlated with a stress factor.

The preceding examples indicate that serious problems may result from the cumulative effects of several adverse environmental factors and organisms of secondary action. Drought and frost are often associated with widespread declines of oak; and serious declines and mortality have resulted when these or other factors, singly or together, have occurred in association with severe insect defoliation. Thus, oak forests in the Save Valley of Switzerland declined when spring floods and silting were followed by defoliation by gypsy moth, *Porthetria dispar L.*, and attack by the fungus *Oidium quercinum* Thüm *(Barbey 1937)*. In Russia, a decline of oak was correlated with droughts of 1921, 1948, and 1956; followed by defoliation in 1927-1928, 1953, and 1959 by brown-tailed moths, *Nygmia phaeorrhoea* (Donov.), gypsy moths, and leaf rollers *(Minkevich 1962)*. The weakened trees were predisposed to vascular pathogenic fungi.

In the United States, oak frequently has exhibited decline on a massive scale. In general these occurrences have involved adverse environmental factors, particularly drought, defoliation by insects or hail, and finally attacks of weakened trees by root fungi and bark borers. Decline of oak over extensive areas of the Southeast occurred in the early 1960's. This area had suffered a series of dry years in the middle 1950's and probably from attacks of the elm spanworm (*Ennomos subsignarius* [Hbn.]), and cankerworms *(Hepting 1970)*.

A decline of red and scarlet oaks occurred from Pennsylvania to North Carolina. An intensive study of this problem by Staley *(1956)* revealed that decline resulted from leaf roller defoliation aggravated by drought and late spring frost and by attacks of *Agrilus* and *Armillaria*. Essentially the same conclusions were reached by Nichols *(1968)*. Periodic declines of white oak in the Northeast have also followed similar combinations of adverse factors.

In Canada, severe deterioration of red oak was attributed to ice damage that reduced tree vigor and predisposed them to infection by *Armillaria (Dance and Lynn 1963)*. *Pseudovalso longipes* (Tul.) Socc. and *Diatrypella quercina* (Pers. ex. Fr.) Nits., two twig-blighting fungi, were associated with dieback of the crowns. Similar relationships of weakened trees attacked by twig cankering fungi were noted by Marshall *(1939)*.

THE LOOK AHEAD

The current emphasis on environmental quality will have an influence on factors that contribute to noninfectious disease of oak, especially to the declines. For example, restrictions on pesticides probably will increase the significance of defoliation as a stress factor, while increased controls of air pollution will probably lessen the importance of this agent as a possible stress factor.

Urbanization and resultant fragmentation of forest lands will increase the scope and magnitude of noninfectious disease problems. Research is needed to determine the roles of an ever-increasing array of stress factors. As the value of trees increases, foresters, pathologists, and others will be forced to understand more clearly the direct and indirect impacts of noninfectious agents.

The increasing frequency and the magnitude of the oak decline problem indicate that additional research effort ought to be focused here. The complexity of the causal relationships suggests that interdisciplinary efforts should be mounted to effect solutions of these problems. Knowledge is needed about the impact upon trees of defoliation, drought, frost, and air pollution, singly and in concert; and about the relation of this impact to susceptibility to organisms of secondary action. Such knowledge can be acquired only through a multidisciplinary approach.

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