SOME PERSPECTIVES ON OAK DECLINE IN THE 80'S[1]

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Abstract.--A review of the past 80 years of oak decline revealed major episodes of oak decline in the 1920's and 1930's, and in the 1950's and 1960's. Most oak decline research of the past was observational in nature. Suggestions for future research include (1) the use of long-term permanent study plots, (2) controlled stress factor experiments, (3) comparative studies among oak species, (4) better quantification of stress factors for use in modeling and predicting declines, and (5) site modification and management studies to ameliorate decline.

INTRODUCTION

The purpose of this paper is to review the historical record of oak decline episodes in the past 80 years and then suggest areas where additional research is needed and where possible new experimental approaches might be appropriate. In this analysis, oaks of the Midland Hardwood Forest and the Appalachian Forest (Barrett 1980) are emphasized. Decline diseases of oak have periodically been noted in the eastern deciduous forest--particularly affecting members of the red oak group, subgenus Erythrobalanus (e.g., black, scarlet, pin, and red oak). The extensive literature on these past declines indicates that oak decline has been a recurring phenomenon during the 20th century in the eastern United States.

OAK DECLINE DEFINED

Oak declines are complex plant diseases that develop when trees altered (predisposed) by abiotic and/or biotic stresses are invaded and sometimes killed by opportunistic organisms of secondary action. Predisposing and secondary stress agents that may be involved in oak decline are:

Predisposing Stresses

Abiotic	Biotic
Drought	Defoliation
Soil flooding	-insects (e.g. gypsy moth)
Winter injury	-diseases (e.g. oak anthracnose)
Late spring frosts	
Highway deicing salt	
Air pollutants	

Secondary Stresses

Ultimate Mortality-causing Agents

Bark borers (Two-lined chestnut borer)
Root borers (Prionus species)
Root pathogens (Armillaria)
Bark pathogens (Hypoxylon)

Some characteristics of declining trees may be:

1. Reduced growth.
   a. Shoot growth elongation.
   b. Diameter growth.
   c. Smaller leaf size.
2. Dieback.
   a. Twigs and branches.
   b. Roots.
3. Sprouts arising from latent or adventitious buds.
4. Chlorotic foliage.
5. Premature fall coloration.
6. Reduced stored food reserves.
7. Reduced resistance to attacks by opportunistic pathogens and insects.
8. Degeneration of mycorrhizae.

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PAST INVESTIGATIONS OF DECLINE

Earliest Reports

Jensen (1901) described what appears to be a typical pattern of oak decline that occurred in southeastern Wisconsin around the turn of the century. Scarlet, red, and white oaks were affected, bur oak was not. The decline was thought to have been initiated by a period of unusually severe drought in 1893-1895. The climax of the decline followed the severe winter of 1898-1899--a winter with abnormally low temperatures and no snowfall. As a consequence of the lack of snow cover, the ground froze to great depths and did not thaw until the end of April. Greatest oak mortality occurred on "hard pan" soils.

A few years later Chapman (1915) reported mortality of scarlet, red, white, and bur oaks in southeastern Minnesota. In Minnesota trees weakened by factors such as drought and soil compaction from excessive pasturage were attacked by the Armillaria root rot fungus, Armillaria mellea, and the two-lined chestnut borer, Agrilus bilineatus. Death of trees was attributed to the attack of the root rot fungus and/or the stem invading beetle larvae.

About the same time in New York State, mortality of white oak and chestnut in an area where the chestnut blight organism was not present was attributed to A. mellea attack (Long 1914). Old stumps were thought to serve as a "breeding ground" for the mycelium of the fungus before invasion of living trees.

According to Baker (1941) the gypsy moth (Porthetria dispar), accidentally introduced into the Northeastern States in 1869, had become a serious pest of oaks in that region by 1890. Oak mortality associated with repeated defoliations by the insect peaked in 1912-1915 after a period of severe drought. At the same time, an outbreak of the two-lined chestnut borer hastened the death of oak trees weakened by defoliation and drought. Armillaria mellea was also noted as a ubiquitous root rot fungus that attacked and hastened the death of low vigor trees. Baker further established that single, complete defoliations by the gypsy moth rarely killed trees, but did greatly reduce diameter growth the same year of the defoliation.

An early attribution of tree injury to the effects of acid deposition was presented by Galloway and Woods in 1896. They stated that "In the vicinity of manufacturing establishments and often in cities and villages where large quantities of bituminous coal are used, vegetation, especially trees and other woody plants are frequently injured by the fumes which are thrown off into the atmosphere." They further concluded that the chief injury was due to sulphurous and hydrochloric acids. Symptoms of pollution damage they described included reddish brown spots and marginal necrosis of leaves and cumulative dieback of tree crowns year after year.

Oak Decline in the 1920's and 1930's

Drought was a primary factor in several episodes of oak decline during the 1920's and 1930's. In the southern Appalachians a drought around 1925 caused extensive mortality of black oak (Hursh and Haasis 1931). Red and scarlet oak were also affected but to a lesser degree. Chestnut oak was least affected by the drought. Armillaria root rot and the chestnut borer were thought to be secondary factors that contributed to the impact of the drought.

Balch (1927) noted that the 1920's oak mortality in the southern Appalachians appeared to peak around 1927 and attributed it largely to drought in 1925 and late frosts at the end of April 1927. Most of the dying oaks were mature dominant trees that had been growing poorly for the previous decade. Dying trees often had extensive trunk rot and carpenter worm infestations. Their roots frequently harbored Armillaria mycelial fans and Prionid root borer larvae. All affected trees showed varying degrees of infestation by Agrilus bilineatus larvae.

In Pennsylvania an extended drought round 1930 caused extensive losses of scarlet and black oak (McIntyre and Schnur 1931). Chestnut and white oaks were little affected. The drought produced changes in species composition of all oak types on severely affected areas except for the chestnut oak type.

Parr (1937, 1940) described a dieback-decline of chestnut oak in Connecticut during 1933-1937 caused by heavy infestations of the pit-making oak scale, Astrolecanium variolosum. Chestnut oak is the preferred host for this scale insect. Trees on poor sites were more seriously affected by scale infestation than those on better sites. White oak was occasionally infested when closely associated with chestnut oak. Black and scarlet oak were not attacked by this scale even when growing near chestnut oak.

Knull (1931) was one of the first investigators to observe that oak defoliations caused by complexes of several species of defoliators could lead to tree decline and mortality. In Pennsylvania he described a synergistic complex where defoliation by the elm spanworm, Ennomos subsignarius, and the fruit tree leaf roller, Archips argyrospila, weakened trees' defenses to attack by the two-lined chestnut borer.

Oak Decline in the 1950's and 1960's

In the 1950's many red oaks, particularly scarlet oaks, died in Pennsylvania (Fergus and Ibberson 1956, Hadley 1956), West Virginia (Gillespie 1956, Tryon and True 1958), and Virginia (Skelly 1974, Staley 1965). Fergus and Ibberson (1956) suggested that, although drought may have been involved in some areas, oak mortality was occurring on all types of sites and environmental conditions. In West Virginia Gillespie (1956) found that many dead

oaks had declining growth for 6-8 years before dying. Before a tree died, leaves in the upper crown often suddenly turned brown and wilted during late July-early August. In subsequent years, a gradual dying back of branches occurred in the bottom two-thirds of the crown of such trees. Tryon and True (1958) observed that the root systems of declining trees were the last parts of the trees to die.

Staley (1962, 1965) provides the best and most extensive coverage of the oak decline of this period. He found that the principal factors involved in the decline were leaf roller defoliation, root rot, Agrilus borer attack, late spring frost, drought, and unfavorable soils. Drought, frost, and root rot were considered contributors to the decline but not the primary initiating agents. He also concluded that initial symptoms of decline indicated diminished availability of carbohydrates for growth and that final symptoms leading to mortality reflected extreme moisture stress.

In Canada ice damage to red oak during the winter of 1959-1960 reduced tree vigor and predisposed trees to Armillaria root rot infections. In addition the twig colonizing fungi, Pseudovalsa longipes and Diatrypella quercina, were associated with crown dieback in the reduced vigor trees (Dance and Lynn 1963).

Nichols (1968) maintained case histories of 70 stands experiencing oak mortality in Pennsylvania. Mortality in all the 70 oak areas was always preceded by either heavy insect defoliation or severe frost damage. Generally two consecutive years of 60 to 100 percent spring defoliation were required to kill the trees. Nearly all dying and recently killed trees were infested by the two-lined chestnut borer.

Drought was not judged to be a major cause of mortality as evidenced by data from the 70 areas collected during the severe drought years 1962-1966. The effect of drought was judged to be roughly equal to that of a moderate defoliation. Yearly growth losses in terms of annual ring growth following dry years never exceeded 30 percent of normal growth.

Oak Decline in the 1970's and 1980's

Dunbar and Stephens (1975) studied mortality patterns of oaks severely defoliated by the gypsy moth and elm spanworm in Connecticut. Mortality ranging from 18 to 79 percent was attributed mainly to stem and branch girdling of the weakened trees by the two-lined chestnut borer. All dying and recently dead trees contained borer larvae. In contrast, mycelial fans of the Armillaria root rot fungus were found under the bark of only 31 percent of the recently dead trees and under none of the dying trees.

Wargo (1977) attributed a more important role to Armillaria root rot in killing oaks severely defoliated by the gypsy moth. By using a tractor-mounted front-end loader, Wargo excavated root systems to examine the extent of root rotting. The roots of most recently dead or dying trees were found to be extensively colonized by the Armillaria root rot fungus, even though in many instances the fungus was not visible at the root collar. The results suggested that both Armillaria root rot and girdling by Agrilus larvae were involved in tree mortality and that trees died because water and food relations were drastically disrupted in the stem by the borer and in the roots by the fungus.

A decline of red oak in western North Carolina on upper slopes in 1979 was thought to be initiated by lower than normal February temperatures in 1963 and then aggravated by dry summers starting in 1968 and worsening in 1973-1978 (Tainter et al. 1984). After 1979 those trees surviving experienced little subsequent decline.

In the Missouri Ozarks, scarlet oak and black oak experienced serious mortality that began around 1978 and extended into the early 1980's (Law and Gott 1987). Scarlet oak stands more then 60 years old were most affected. Weather factors that may have played a role in the mortality were (1) prolonged high temperatures during the summer of 1980, (2) two severe winters of 1976-1977 and 1978-1979, and (3) below normal rainfall during 1976, 1978, and 1980. Secondary organisms contributing to the decline appeared to be the two-lined chestnut borer and the stem and branch colonizing fungus, Hypoxylon atropunctatum.

Oak mortality-decline was also a problem in Kentucky and surrounding States in the 1980's (Stringer et al. 1987). Chief oaks affected were black, scarlet, and red oak. Principal factors responsible for the decline appeared to be drought, intra-stand competition, and Agrilus stem girdling. Dissection of root systems of declining and dying oaks revealed no indication of Armillaria root rot infection.

Although oak mortality and decline have occurred in both North American and European regions where air pollutant concentrations, including acid deposition, are high, field evidence of adverse effects on growth of oaks remains inconclusive (Smith 1987). McClenahan and Dochinger (1985) studied whether air pollutants had an effect on stem growth of white oak in a highly industrialized portion of the Ohio River Valley in southern Ohio. Their results suggested that nonclimatic factors, presumably pollutants, had caused annual growth reductions in the industrialized portion of the Ohio River Valley, particularly after 1930. Detrimental effects of ambient ozone concentrations on net photosynthetic rates (output growth reductions) have been demonstrated for red oak (Reich et al. 1986) and black oak (Carlson 1979). Reich et al. (1986) found that red oak seedlings were relatively insensitive to acidic rain over a single growing season, although acidic rain did cause decreases in percent and numbers of short roots infected by mycorrhizal fungi (Reich et al. 1985).

Phipps and Whiton (1988) studied long-term growth trends in 60 white oak stands located throughout the white oak range. A permanent, non-reversed growth decline apparently as a consequence of a growth rate change in the mid 1950's was noted in the white oaks in two-thirds of the stands. The event in the 1950's that initiated the growth decline did not appear to be related to either climate or pollution.

Mueller-Dombois et al. (1983) compared oak decline with other North American decline diseases. The other declines were maple decline, birch dieback, pole blight of western white pine, and little leaf disease of southern pines. In all these declines, trees typically died in groups rather than singly. This spatial pattern of mortality was thought to be due to a stand dieback mechanism that involved (1) cohort senescence as a predisposing cause, (2) a sudden adverse perturbation of the stand as a secondary cause but serving as a synchronizing cause, and (3) biotic agents as tertiary causes but contributing to dieback and mortality. Cohort senescence was defined as uniform loss of vigor of a canopy cohort due to aging and gradually increasing environmental stress. Cohort senescence was viewed as a normal phenomenon of population dynamics rather than as a disease.

RESEARCH NEEDED AND SOME POSSIBLE EXPERIMENTAL APPROACHES

1. Long-term permanent study plots. Most oak decline studies of the past have involved studies within single States. Regionwide studies to monitor and ascertain the decline status of north central oak forests are needed, particularly to establish if decline is primarily a local problem or a regionwide one. Permanent study plots regularly remeasured and observed can be used to establish the relative importance and interaction of various decline causal agents.

2. Controlled stress factor experiments. Experiments where several levels of suspected stress factors are applied to oak decline candidate trees are rare. Gradwell (1974) hand defoliated oaks to simulate insect defoliations occurring at different times of the year. Air pollutant treatments at several concentrations have been applied to young oaks under greenhouse and growth chamber conditions (Carlson 1979, Reich et al. 1985, 1986).

Critical experiments where concentrations of root and stem borer infestations are varied or intensity of Armillaria root infection is controlled are desirable to establish the importance of such secondary stress agents in the decline syndrome. Application of moisture stress regimes to large oaks in the field could be patterned after studies by Copeland (1955) on drought effects on shortleaf pine and by Skilling (1964) on sugar maple blight.

3. Comparative studies among oak species. Most cases of oak decline have involved selected oak species. Often only members of the red oak group are chiefly involved. White oaks and hickories occupying the same sites are generally affected to a much lesser degree. Comparative studies of several species occupying the same decline sites could involve analyzing their site requirements for major and minor nutrients and moisture throughout their phenological development. Survival adaptations that involved drought and cold tolerance, crown type, rooting pattern, root-shoot ratio, growth rate and time of growth could be usefully compared. Finally, much needs to be learned about allelopathic relationships among the trees, shrubs, and herbaceous vegetation of oak stands.

4. Quantification of stress factors, modeling, and predicting decline. While most of the abiotic stress factors--moisture stress, cold injury, pollutant concentrations, heat stress, etc.--can be quantified providing resources are available for instrumentation and data gathering, the biotic factors, particularly the diseases, are harder to quantify. Few experiments have been conducted with forest tree declines where disease levels have been regulated or actually increased by artificial manipulation. To develop good oak decline models, all the suspected stress agents must be quantified particularly to study how different levels of several stress agents interact. The possible interaction of relatively low levels of several stress agents that singly would have little effect on tree growth would be an early candidate for modeling. The historical recurrence of oak decline plus the added effect of possible changes in global warming suggests that new waves of oak decline will occur in the future. Predictive models that anticipate oak decline are needed by forest managers and planners. Finally, generalized models are needed that can take conclusions from local areas that have been intensively studied and apply them to large forest units.

5. Site modification and management. Detailed knowledge of the requirements to initiate a decline may provide information as to how sites could be manipulated or better managed to avoid decline. Some items for experimentation are species composition, understory changes, and fertilization including liming some acid soils.

Many of the sites where oak decline is most severe are former chestnut sites. Perhaps the oaks that have colonized the chestnut niche are not particularly suited to these sites. The time may be approaching (or is here) where the technology is available to transfer a chestnut blight resistant gene from resistant Asiatic chestnut or possibly one of the oaks to American chestnut. A national commitment to return the American chestnut to its former preeminence would probably have strong appeal to a diverse segment of the American population.

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