SITE FACTORS AND STAND CONDITIONS ASSOCIATED WITH OAK DECLINE IN SOUTHERN UPLAND HARDWOOD FORESTS[1/]

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Abstract -- Evaluations of oak stands from Virginia to north Georgia and west to Arkansas, Illinois and Missouri revealed that oak decline and mortality occurs over a wide geographic area, but that severity is highly variable. Site factors such as soil texture and depth, topographic position and site index were associated with high incidence and severity of oak decline and mortality. Plots with the highest incidence of mortality were characterized by shallow, rocky soils; were on ridge or upper slope topographic positions with west to north aspects; had average or lower site indices ($\leq$70); and a predominance of red oak species (especially black and scarlet oaks). A general classification of mortality risk was assembled by combining these attributes with other factors such as recent history of defoliation and growing season precipitation. This classification may be used for identifying or prioritizing stands for regeneration, preventive or remedial silvicultural treatments and may suggest modification of management objectives. Since the association of site factors varies with geographical area, it may be possible to tailor risk rating systems to specific areas.

1/ Paper presented at the Seventh Central Hardwoods Forest Conference, Carbondale, Illinois, March 5-8, 1989.

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INTRODUCTION

Oaks comprise the most important group of upland hardwood trees in the eastern United States. They are widely distributed, abundant on a variety of sites, have relatively high timber values and contribute substantially to wildlife habitat quality and recreational opportunities. Oak decline is the most widespread, common, and perhaps complex disease problem of this group. Dieback and mortality occur in varying degrees causing loss in timber volume, growth, wildlife and recreational values (Starkey and Brown 1986).

Episodes of oak decline in the eastern U.S. have been reported since the early 1900's (Balch 1927) up to the present time. Cases have been reported from Arkansas (Rhodes and Tainter 1980, Lewis 1981, Mistretta *et al*. 1981, Bassett *et al*. 1982, Yeiser and Burnett 1982), Connecticut

(Dunbar and Stephens 1975), Florida (Lewis 1981), Massachusetts (Feder et al. 1980), Minnesota (Chapman 1915, Walters and Munson 1980), Mississippi (Lewis 1981), New Jersey (Kegg 1971), New York (Long 1914), North Carolina (Beal 1926, Tainter et al. 1984), Pennsylvania (Fergus and Ibberson 1956, Staley 1965, Nichols 1968, Wargo 1977), Virginia (Beal 1926, Rauschenberger and Ciesla 1966, Skelly 1974), West Virginia (Gillespie 1956, Staley 1965) and Wisconsin (Haack and Benjamin 1982).

Oak decline is a complex disease resulting from the interaction of predisposing stress factors with disease or insect pests which are secondary in action (i.e. not normally highly aggressive or capable of individually causing severe damage or death). Predisposing stress agents for the initiation of decline can be defoliating insects (Tryon and True 1958, Nichols 1968, Kegg 1971, Dunbar and Stephens 1975), drought (Balch 1927, Bassett et al. 1982, Tryon and True 1958, Rhodes and Tainter 1980, Lewis 1981, Mistretta et al. 1981, Tainter et al. 1983, Tainter et al. 1984), or late spring frost (Beal 1926, Balch 1927, Staley 1965, Nichols 1968). Secondary disease and insect pests acting in conjunction with stress agents are Armillaria root disease [Armillaria mellea], other root disease fungi such as Clitocybe tabescens, Corticium galactinum (Toole 1960, Filer and McCracken 1969), Ganoderma lucidum (Lewis 1981) and Polyporus dryadeus (Fergus 1956), canker fungi such as Hypoxylon spp. (Bassett et al. 1982, Lewis 1981) and the 2-lined chestnut borer (Agrilus bilineatus; Balch 1927, Dunbar and Stephens 1976, Cots and Allen 1980, Lewis 1981).

Trees react to stress of defoliation or prolonged drought by converting starch (stored in the roots) to sugar to support continued metabolism. This conversion is recognized by Armillaria mellea (Wargo 1972). This fungus commonly lives as a saprophyte on stumps and roots of dead trees in oak stands and can successfully colonize living tree root systems under stress. Other non-aggressive root disease fungi may act similarly. The 2-lined chestnut borer preferentially attacks weakened trees (Cots and Allen 1980, Haack and Benjamin 1982). The adult oviposits in bark crevices; the larvae then bore into the inner bark and create meandering galleries that partially or completely girdle the tree.

Root disease and stem girdling impair the internal water and food relations in the tree resulting in a progressive dieback of branches from the upper and outer crown, downward and inward. Other accompanying symptoms of these injuries may include chlorotic, dwarfed or sparse foliage; development of epicormic sprouts on the main bole and larger branches; premature autumn coloration; marginal leaf scorch; foliage wilt; foliage death; and sudden total tree mortality. Reduced shoot and diameter growth occurs in severely affected trees. While some dead trees show little evidence of prior decline, most have declined for 2 to 5 years or more before succumbing. Because of differences in the dynamics of internal water and stored food budgets (Kramer and Kozlowski 1960), physiologically mature trees may not be able to resume normal growth with the return of good growing conditions but continue to decline, while other physiologically less mature trees recover and rebuild their crowns. Patterns of decline and mortality may be easy or difficult to discern in forest stands, depending on the inciting stress factors, site conditions and species affected.

In the early 1980's, we received many reports which indicated that the southern U.S. sustained a substantial increase in oak mortality and decline. Inquiries of federal land managers and state foresters were made in late 1984 concerning the current status of oak decline in their areas of jurisdiction. Oak decline was reported across the south from Virginia to Arkansas, with concentrations in the Appalachian and Ozark Mountains (Starkey 1985). Damaged stands reported to us provided a population for evaluation. The main objective of this evaluation was to characterize oak decline sites with regard to species and size classes affected, the severity of decline and mortality, and site and stand factors associated with damage. A preliminary report of this evaluation has been published (Starkey and Brown 1986).

MATERIALS AND METHODS

Thirty-eight sites were chosen for evaluation from the population of damaged stands (Starkey 1985). Criteria for selection included the absence of recent site disturbances (e.g., fire, logging, road construction), species composition predominantly oak, and an area uniform enough to be considered a stand-sized management unit (15-100+ acres). We attempted to achieve a dispersion of stands across the region where decline was reported (figure 1). Surveyed stand location by state and number were: Virginia (11), North Carolina (4), South Carolina (3), Georgia (2), Tennessee (5), Alabama (2), Illinois (2), Missouri (2), and Arkansas (7).

Each stand was sampled with 12 BAF 10 prism plots. Trees 5.5" and larger were tallied and classified according to crown position, and crown decline condition class (slight, <1/3 dieback; moderate, 1/3 - 2/3; severe, >2/3). Stand data recorded were elevation, slope, aspect, topographic position, soil depth and texture to 24 inches, and site index. The percentage of dominant and codominant trees in the various crown decline condition classes was compared for individual species and species groups and various site factors using analysis of variance, Duncan's Multiple Range Test, and occasionally chi-square analysis. The sampling

method used (probability of tree selection proportional to size) results in differences between the number of trees observed and the actual stocking (i.e. trees per acre) they represent. Therefore, data were transformed to reflect stocking rather than basal area. Crown decline condition classes were combined for some analyses. Suppressed and intermediate crown classes were omitted from analyses, because dieback and mortality caused by decline cannot be separated from that caused by overstory competition in these crown classes.

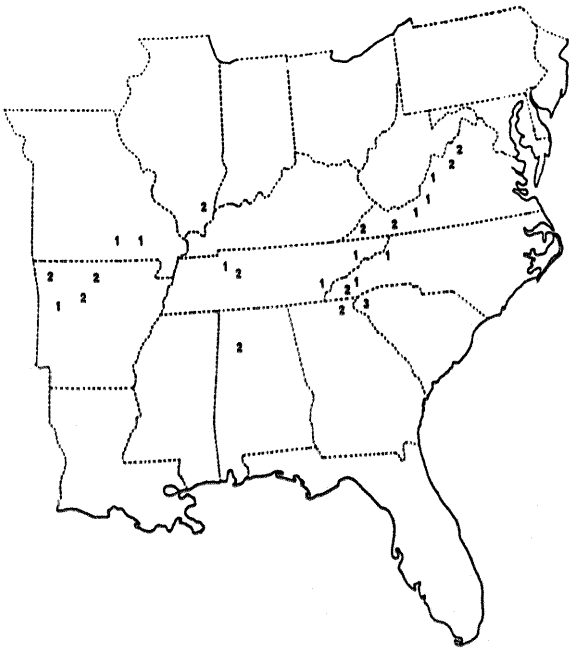

Figure 1.--Location and number of stands evaluated for oak decline severity, site and stand conditions.

RESULTS

A total of 3,623 trees were observed in the 456 plots in 38 stands affected by oak decline. Of these, 2,810 were dominant or codominant and consisted of 84% oak (Quercus spp.), 6% hickory (Carya spp.), and 10% other species. The predominant species in the other category were maple (mostly red maple, Acer rubrum), yellow-poplar (Liriodendron tulipifera), black locust (Robinia psuedoacacia), and blackgum (Nyssa sylvatica). Evidence of 2-lined chestnut borer, other borers, Armillaria root rot and Hypoxylon canker were often seen. No symptoms typical of oak wilt (caused by Ceratocystis fagacearum) were observed.

Severity of Decline

Eighty percent of all trees in oak decline areas showed some degree of decline or mortality (table 1). Twenty percent of these had advanced decline (> 1/3 crown dieback; moderate and severe classes combined) and 17% of the stocking was killed. We combined moderate and severely declined trees into an advanced decline condition class for analyses because of the relative infrequency of severely declined trees and because tree growth and vigor are most likely reduced when decline reaches these levels. Healthy and slight crown decline condition classes were likewise combined for some analyses.

Site Factors

Associations were explored between damage severity and topographic position, slope class, aspect, soil texture, soil depth, and site index.

Topographic Position

Decline and mortality were present on all topographic position categories (ridge, slope, bench, terrace, and bottom), but there were adequate numbers of observations on only slope and ridge positions. Statistically significant differences occurred for mortality with ridges exceeding slopes (table 2). The inverse relationship was present for advanced decline but was not significant.

Table 2.--Percent of dominant and codominant trees in various crown condition classes for various site factors associated with affected stands

Site Factors	Advanced	Dead
Topographic Position		
Ridge	17a[1/]	20a*
Slope	20a	16b
Slope Class		
0-20%	15a	20a*
21-40%	24a	12b
>41%	19a	5c
Soil Texture		
Stony/Gravelly	9a**	26a**
Other	25b	12b
Soil Depth		
<18"	14a*	25a*
>18"	27b	8b
Site Index		
<65	13a*	22a*
65-75	21ab	16ab
>75	27b	10b

1/ Values in each group within a column are significantly different at the p = .05 (*) or p = .01 (**) level when followed by a different letter (analysis of variance or Duncan's Multiple Range Tests).

Table 1.--Percent of stocking of dominant and codominant trees by species and crown condition[1/]

Crown Condition	Species							
	BLO	SCO	NRO	WHO	CHO	H	Other	All Species
Healthy	9.5	8.0	8.5	31.4	13.5	23.4	63.5	20.4
Slight	40.5	39.4	52.5	38.6	60.6	47.6	22.9	42.8
Advanced(*)	16.5a[2/]	29.7b	28.6b	18.5a	21.3ab	17.0a	10.0	20.2
Dead(**)	33.5a	22.9a	10.4b	11.5b	4.6b	12.0b	3.6	16.6
TOTAL	100	100	100	100	100	100	100	100

[1/] Species with > 100 observations (> 5% of the stocking).

[2/] Significance applies within but not among crown condition classes. Values followed by different letters are significant at the .01 level (**) or .05 level (*), as indicated for the crown condition class. Where no letters appear, F statistics were not significant and no Duncan's was performed.

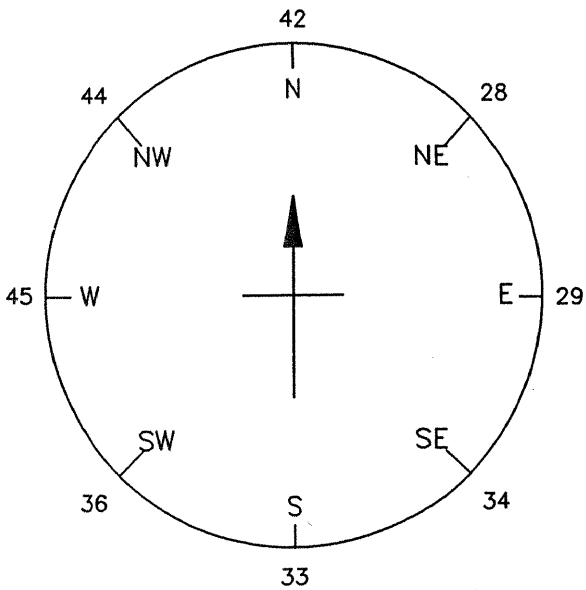

Figure 2.--Average percent of dominant and codominant trees in the advanced and dead crown classes on various aspects.

Slope Class

The effects of slope class were examined only for plots with a slope topographic position (65% of all plots). No significant differences in the percentage of healthy plus slight or advanced decline were found for slope class. Mortality, however, decreased significantly with increasing slope class (table 2).

Aspect

Associations of damage with aspect were also examined only for plots with a slope topographic position. While no statistically significant differences existed, overall damage (advanced decline plus dead) was greatest in west to north aspects, least on northeast and east aspects, and intermediate in southeast to southwest aspects (figure 2).

Soil Texture

Two broad soil texture categories were established because of the small number of observations in many individual classes. Stony or gravelly soils had significantly greater mortality than other soil textures (table 2; 26 vs. 12%; p = .01). The converse was true for advanced decline (9% for stony or gravelly soils, 25% for other textures). The healthy plus slight crown condition classes were approximately equal.

Soil Depth

Soil depth classes were also combined into two classes, shallow (< 18" deep) and deeper soils (>18" deep). Results were similar to those for soil texture. Shallow soils had higher mortality levels than deeper soils (25 vs. 8%) while converse was true for advanced decline (27 vs. 14%; table 2). Both of these relationships were highly significant (p = .01).

Site Index

All the factors previously discussed contribute to site index, the most commonly used measure of site productivity. Most individual factors associated with low site indices (i.e., shallow, stony soils on ridges) had the highest levels of correlation with mortality. This was also the case when site index of plots was analyzed (table 2). Mortality was 22% of stocking on low site indices (< 65 ft. at age 50) and only 15% on the highest site indices (> 75 ft. at age 50). Advanced decline, however, was higher on productive sites (28%) than on the least productive (18%). Both of these relationships were significant.

Stand Factors

Species Composition

Scarlet oak (Q. coccinea) accounted for over 20% of all trees on decline sites, followed by black oak (Q. velutina; 17%), white oak (Q. alba; 15%), and chestnut oak (Q. prinus; 12%). Hickories accounted for 7% of the stocking and the remainder was other species.

Species in the red oak group (ARO) were much more frequently damaged than those in the white oak group (AWO; table 3). The percentage of healthy red oaks was one-third that of white oaks, while the percentage of dead red oaks was three times that of white oaks. These differences were highly significant (p = .01). Advanced decline differed between the oak groups (similar to mortality) but the difference was not significant.

Table 3.--Percent of dominant and codominant red and white oak trees in various crown condition classes

Crown Condition	Red Oaks	White Oaks
Healthy	7a[1/]	24b
Slight	44a	48a
Advanced	24a	19a
Dead	24a	9b

[1/] Significance applies within crown condition class. Values followed by different letters are significantly different at the p = .05 level according to analysis of variance.

Among oaks, black (BLO) and scarlet (SCO) oaks sustained the highest mortality levels (34 and 23%, respectively), followed by white oak (WHO), northern red oak (NRO), and chestnut oak (CHO; table 1). Among non-oak species, hickories (H) were most severely affected (12% mortality). Advanced decline was worst in scarlet, northern red (Quercus rubra), and chestnut oaks.

Age

Evaluated stands were mainly sawtimber-sized with ages ranging from 50 to 110 years. Most were in the 60- to 80-year-old age class (31 of 38 stands). A few poletimber-sized stands of advanced age were encountered. Since our sampling did not include a wide range of ages, no firm conclusion can be drawn regarding age and decline. However, we limited our sampling to known areas of decline and can infer that damage is probably more common and severe in these older age and larger size classes. We received no reports of young poletimber-sized stands being affected.

Basal Area

Basal area per acre (all crown classes) of evaluated stands averaged 87 square feet and varied little among stands (range from about 70 to 110 square feet). Several statistical analyses were performed on plot basal areas versus advanced decline and mortality but no significant relationships were detected. A representative portion of these data is presented in table 4.

Table 4.--Average percent of trees in various crown condition classes and basal area categories

Basal Area (Sq. Ft. per Acre)	Advanced	Dead
<70	17[1/]	17
70-80	17	17
90-100	13	21
110-120	12	18
>120	18	19

[1/] Values in columns are not significantly different.

Risk Classification

The association of site and stand factors with decline severity can be used to construct a rudimentary classifcation for mortality (figure 3). We made no attempt to weight each of the individual site and stand factors according to the strength of the association with mortality. However, of the factors studied, aspect was not statistically correlated and should be

considered the weakest component of the rating system. Other analyses of these data (not presented here) indicate that some factors are more important in one geographic area and less important in another. Thus, risk rating systems may eventually be tailored to limited geographic areas where conditions may be more uniform.

LOW DAMAGE POTENTIAL (MORTALITY RISK LOW)		HIGH DAMAGE POTENTIAL (MORTALITY RISK HIGH)
ADEQUATE GROWING SEASON MOISTURE	<---->	ACUTE SUMMER DROUGHT (2-3 YRS. PRIOR)
NO RECENT OR REPEATED SPRING DEFOLIATION	<---->	RECENT OR REPEATED SPRING DEFOLIATION
PHYSIOLOGICALLY IMMATURE (POLE-SIZED, <50 YRS OLD)	<---->	PHYSIOLOGICALLY MATURE (SAWTIMBER, >50 YRS OLD)
COMPOSITON PREDOMINANTLY WHITE OAK GROUP	<---->	COMPOSITION PREDOMINANTLY RED OAK GROUP
HIGH SITE INDEX (>70)	<---->	LOW SITE INDEX (<70)
MESIC SITE CONDITIONS Loamy soils, few rocks Deeper (>18in) soils Coves, terraces, bottoms, lower slopes Northeast and east aspects	<---->	XERIC SITE CONDITIONS Rocky soils Shallow (<18in) soils Ridges or upper slopes South and West aspects

Figure 3.--Classification system for oak mortality in the southern upland hardwood region.

DISCUSSION

These results suggest that while decline may occur on all types of sites, it more commonly results in high mortality levels on sites of lower productivity. These are associated with ridges, gentler slopes, shallow, rocky soil and a predominance of red oak species. More productive sites may, however, exhibit high mortality if stand conditions are conducive to it (e.g., older stands with a predominance of black and/or scarlet oaks) and if stresses are severe or persist for long periods.

The simple mortality classification system presented here should be of use to managers in identifying stands and sites prone to decline and in prioritizing these for regeneration, preventive or remedial treatments. However, more information is needed to help make management decisions. For instance, data are needed to modify the risk rating to more accurately account for defoliation episodes by insects such as the gypsy moth. Since they tend to feed selectively on certain tree species, decline and mortality may develop differently than these results now indicate (Herrick and Gansner 1987). Also, risk rating needs to be tailored to more limited geographical areas such as the Ozarks, or the southern and northern Appalachians. A broader range of damage levels need to be examined to determine if decline as well as mortality can be included in a more sophisticated risk rating system. Such data are available from a recent survey of three upland hardwood areas in the South and will be incorporated in future analyses.

The implications of these data for the management of hardwood forests are several. Beyond the obvious loss of volume due to mortality and to reduced growth rates of severely declined trees, large losses of dominant oaks may greatly reduce mast yields for wildlife and reduce recreational values. On the other hand, small losses may be beneficial to wildlife in that extra den or cavity trees may be provided and small openings in an otherwise dense canopy created. Severe decline and mortality also makes the decision to carry or regenerate such stands a difficult one. If regeneration is delayed too long, affected stands may not develop the advanced reproduction necessary for regeneration, diseased root systems may not sprout with normal vigor or frequency and undesireable understory species may outcompete oak reproduction for newly available growing space. The species composition of declining stands is likely to shift away from the faster growing red oaks to the less-affected, slower growing white oaks. This may not be a problem if higher white oak compositions are desireable and adequate stocking of white oaks is present. Where white oaks are less abundant, other less desireable species will probably increase contributing to a reduction in timber and wildlife value.

Though oak decline has been a recurring condition with a long history in the east, it is not known if the current situation represents a permanent increase in damage occurrence or severity. More likely it is the result of short-term climatic stress and will dissipate before recurring again in the future. Past cutting practices, fire, woods grazing and the chestnut blight epidemic have had enormous impacts on the condition and species composition of southern oak forests. The resulting forests and species and trees we manage today may be less well adapted to the prevailing conditions than previous forests, especially under management regimes often being applied (i.e. long, sawtimber rotations). We have initiated other surveys which will provide data relative to the frequency and severity of oak decline over several upland hardwood areas in the South and provide a wider spectrum of data on the relationship of site and stand conditions to decline and mortality.

LITERATURE CITED

Balch, R. E. 1927. Dying Oaks in the Southern Appalachians. Forest Worker 3:13.

Bassett, E. N.; Fenn, P.; Mead, M. A. 1982. Drought-Related Oak Mortality and Incidence of Hypoxylon Canker. Arkansas Farm Research 31:8.

Beal, J. A. 1926. Frost Killed Oak. Journal of Forestry 24:949-950.

Chapman, R. N. 1915. Observations on the Life History of Agrilus bilineatus. Journal of Agricultural Research 3:283-293.

Dunbar, D. M.; Stephens, G. R. 1975. Association of Two-lined Chestnut Borer and Shoestring Fungus with Mortality of Defoliated Oak in Connecticut. Forest Science 21:169-174.

Feder, W. A.; Moorman, G. W.; Tattar, T. A. 1980. English Oak Decline on Cape Cod. MA. (Abstr.) Phytopathology 70:062.

Fergus, C. L. 1956. Some Observations About Polyporus dradeus on Oak. Plant Disease Reporter 40:748-749.

Fergus, C. L.; Ibberson, J. E. 1956. An Unexplained Extensive Dying of Oak in Pennsylvania. Plant Disease Reporter 40(12):1121-1123.

Filer, T. H.; McCracken, F. I. 1969. Clitocybe tabescens Associated With Decline and Death of Chinese Elm and Water Oak. Plant Disease Reporter 53:840.

Gillespie, W. H. 1956. Recent Extensive Mortality of Scarlet Oak in West Virginia. Plant Disease Reporter 40:1121-1123.

Haack, R. A.; Benjamin, D. M. 1982. The biology and ecology of the two-lined chestnut borer, Agrilus bilineatus (Coleoptera: Buprestidae), on oaks Quercus spp., in Wisconsin. The Canadian Entomologist 114 (5):385-396.

Herrick, O. W.; Gansner, D. A. 1987. Mortality risks for forest trees threatened with gypsy moth infestation. NE-RN-338. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 4 p.

Kegg, J. D. 1971. The Impact of Gypsy Moth: Repeated Defoliation in New Jersey. Journal of Forestry 69:852-854.

Kramer, P. J.; Kozlowski, T. T. 1960. Physiology of Trees. New York: McGraw-Hill Book Company; 642 pp.

Lewis, R., Jr. 1981. Hypoxylon spp., Gonoderma lucidum and Agrilus bilineatus in Association with Drought Related Oak Mortality in the South. (Abstr.) Phytopathology 71:890.

Long, W. H. 1914. The Death of Chestnuts and Oaks Due to Armillaria mellea. U.S. Dept. Agric. Bull. 89. Washington, DC: U.S. Department of Agriculture, Bureau of Plant Industry; 9 pg.

Mistretta, P. A.; Affeltranger, C. E.; Starkey, D. A.; Covington, S. A.; Wortham, Z. M. 1981. Evaluation of Oak Mortality on the Ozark National Forest, Arkansas, 1981. Rep. No. 81-2-26. Alexandria, LA: U.S. Department of Agriculture, Forest Service, State and Private Forestry; 15 p.

Nichols, J. O. 1958. Oak Mortality in Pennsylvania - A Ten-Year Study. Journal of Forestry 66:681-694.

Rauschenberger, J. L.; Ciesla, W. M. 1966. Evaluation of Oak Mortality on the George Washington and Jefferson National Forests, Virginia. Asheville, NC: U.S. Department of Agriculture, Forest Service, State and Private Forestry; 13 p.

Rhodes, J. D.; Tainter, F. H. 1980. Precipitation Extremes and Tree Growth. Arkansas Farm Research 29:12.

Skelly, J. M. 1974. Growth Loss of Scarlet Oak Due to Oak Decline in Virginia. Plant Disease Reporter 58:396-399.

Staley, J. M. 1965. Decline and Mortality of Red and Scarlet Oaks. Forest Science 11:2-17.

Starkey, D. A. 1985. Current Status of Oak Mortality and Decline in the South. Abstract In: Proceedings of the Southwide Forest Disease Workshop, 1985, June 11-13; Wrightsville Beach, NC.

Starkey, D. A.; Brown, H. D. 1986. Oak Decline and Mortality in the Southeast: An Assessment In: Proceedings of the Fourteenth Annual Hardwood Symposium of the Hardwood Research Council; 1986 May 18-21; Cashiers, NC: 103-105.

Tainter, F. H.; Williams, T. M.; Cody, J. B. 1983. Drought as a Cause of Oak Decline and Death on the South Carolina Coast. Plant Disease 67:195-197.

Tainter, F. H.; Fraedrich, S. W.; Benson, J. D. 1984. The Effect of Climate on Growth, Decline, and Death of Northern Red Oaks in the Western North Carolina Nantahala Mountains. Castanea 49:127-137.

Toole, E. R. 1960. Root Rot of White Oak in Arkansas. Plant Disease Reporter 44:783.

Tryon, E. H.; True, R. P. 1958. Recent reductions in Annual Radial Increments in Dying Scarlet Oaks Related to Rainfall Deficiencies. Forest Science 4:219-230.

Walters, J. W.; Munson, A. S. 1980. Detection of Oak Mortality on Sherburne Wildlife Refuge, Minnesota - 1979. NA-FB/P-7. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Area, State and Private Forestry; 8 p.

Wargo, P. M. 1972. Defoliation-Induced Chemical Changes in Sugar Maple Roots Stimulate Growth of Armillaria mellea. Phytopathology 62:1278-1283.

Wargo, P. M. 1977. Armillaria mellea and Agrilus bilineatus and Mortality of Defoliated Oak Trees. Forest Science 23:485-492.

Yeiser, J. L.; Burnett, F. 1982. Fate of Forest Trees Stressed by Heat and Drought in Southeastern Arkansas. Southern Journal of Applied Forestry 82:194-195.