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INFLUENCE OF OAK ABUNDANCE AND DISTRIBUTION ON FUSIFORM RUST

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Abstract.--Abundance of water oak was found to be strongly correlated with rust incidence in slash pine, while both water and laurel oaks were moderately correlated with incidence in loblolly pine. Correlations of other oaks with rust incidence were not as strong and some were negative. Although further work is needed to prove a cause and effect relationship, we recommend that prevalence of oaks (especially water oak) and their potential for invasion be considered in evaluating site hazard. Very intensive, often-repeated mechanical site preparation can reduce abundance of oaks, but normal application of such treatments induces oak sprouting and can increase hazard. Prescribed burning and herbicide application have better potential for forestalling oak succession and lessening competition without increasing oak abundance. Maintaining a dense canopy of pines retards, but does not prevent, encroachment of oaks.

Additional keywords: *Cronartium fusiforme*, forest tree diseases.

Oaks (*Quercus* spp.) function as alternate hosts for fusiform rust (*Cronartium fusiforme* Hedgc. & Hunt ex Cumm.) of southern pines. The amount of inoculum and the abundance of both hosts are important factors in development of epidemics (Czabator 1971). There is a strong correlation between amount of inoculum (number of telia) and amount of susceptible oak tissue (Hollis and Schmidt 1977). Therefore, the abundance and distribution of oaks are expected to influence rust incidence and severity.

This paper examines the relationship of alternate host abundance and distribution to rust incidence on a regional scale. Also described are the effects of various management practices on oak abundance. A clear understanding of such relationships and effects is necessary for development of disease management strategies.

RELATION BETWEEN OAK ABUNDANCE AND RUST INCIDENCE

The relationships between the abundance of 7 oak species (table 1) and incidence of fusiform rust in loblolly (*Pinus taeda* L.) and slash pine (*P. elliottii* Engelm. var. *elliottii*) plantations across the South were analyzed recently by Squillace et al. (In press). Results of their work will be emphasized here. Information on other species of oaks is scanty and is mentioned only briefly.

Oak abundance data were obtained for each of 7 oak species from standard survey plots of the U.S. Forest Service. Average stem volumes in cubic feet per acre of commercial forest land were compiled by county for trees 1 inch d.b.h.

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Table 1.--Curvilinear correlations between volume of oaks and percent of trees infected with fusiform rust[a]

Oak species	Loblolly pine	Slash pine
Water (*Q. nigra* L.)	0.42**	0.68**
Laurel (*Q. laurifolia* Michx.)	.48**	.26**
Willow (*Q. phellos* L.)	-.16	.31**
Northern red (*Q. rubra* L.)	-.10	.23**
Black (*Q. velutina* Lam.)	-.30**	.29**
Post (*Q. stellata* Wangenh. var. *stellata*)	-.38**	.48**
Southern red (*Q. falcata* Michx. var. *falcata*)	-.32**	.43**
Total oaks	.07	.60**
Water and laurel oaks	.54**	.69**

[a] Positive values indicate a general direct or positive slope while negative ones indicate a general indirect or negative slope.
** Correlation is statistically significant at 0.01 level.

and larger. Incidence data were obtained from a recent southwide survey of infection in 8- to 12-year-old loblolly and slash pine plantations (Phelps 1973). Survey data consisted of the percentages of trees having either stem or branch galls. County averages were used in analyses whenever at least five plantations were sampled. Counties having fewer than five sample plantations were averaged with adjacent ones. Averaging resulted in a total of 187 counties (or sampling points) for loblolly pine and 156 for slash pine. Oak data were compiled in conformance with the pine data.

Preliminary examination of the data suggested that the relationship between rust incidence and oak volume was often curvilinear. For example, percent of infection in slash pine increased strongly with volume of water oak up to about 80 cubic feet of this oak per acre and then tapered off (fig. 1). Curvilinear correlations were therefore computed with squared as well as unsquared oak volumes as independent variables.

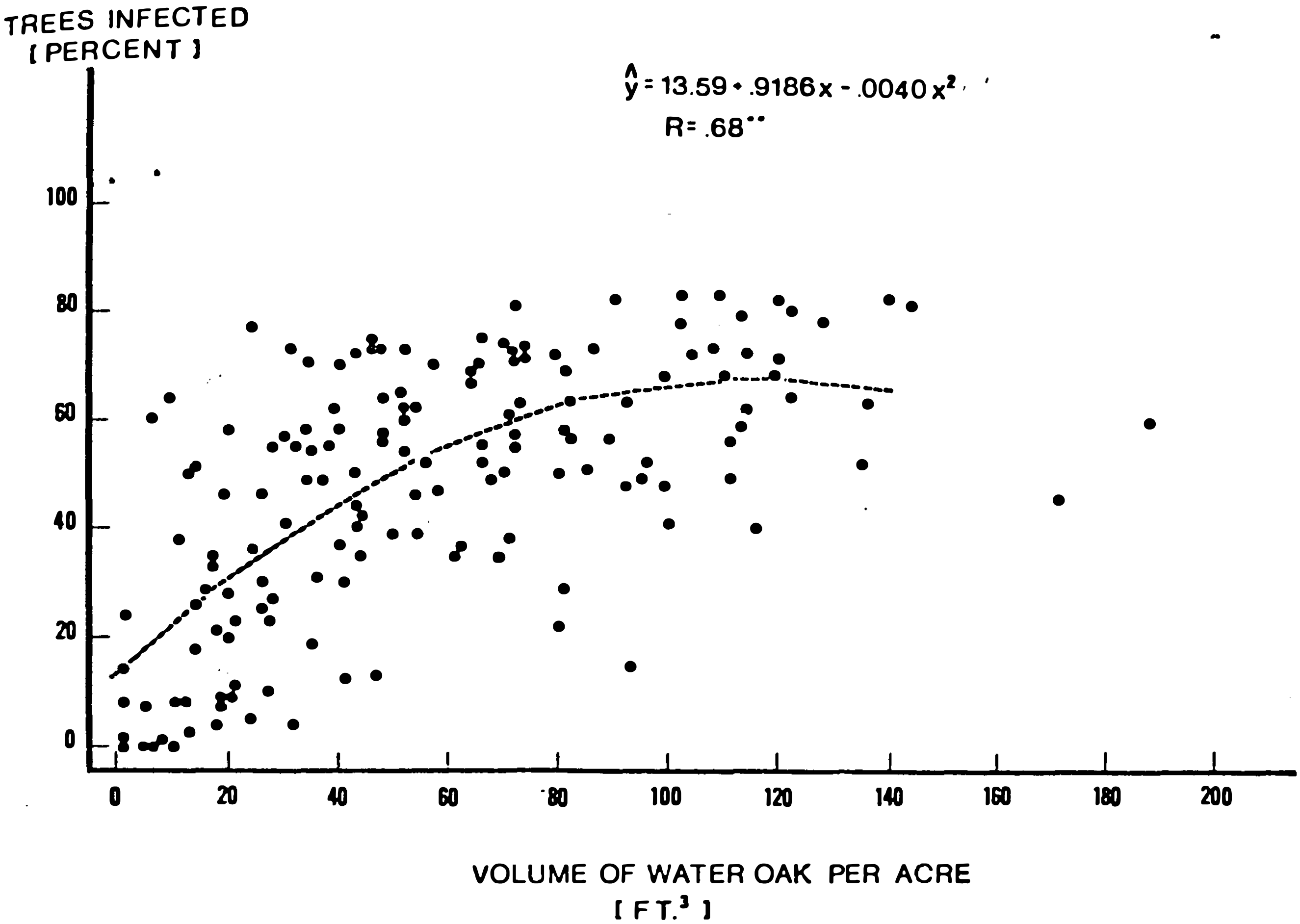

Figure 1.--Scatter diagram and curvilinear (quadratic) regression of percent infected slash pines and volume of water oak per acre on commercial forest lands.

Intensity of infection in slash pine was found to be positively and significantly correlated with volumes of all of the oak species (table 1). But the correlation with water oak (0.68) was considerably larger than with other oaks. When water oak was used in combination with other oaks in multiple regression analyses, the relationships with infection were no stronger than when water oak alone was used. Within the planted range of slash pine, water oak volumes were moderately correlated with volumes of other oaks (r varied from 0.19 to 0.29), all species tending to show a general south to north trend. The correlations of these other oaks with infection were perhaps partly due to this association. When total volume of all oaks was used, the resulting correlation with infection (0.60) was less than that for water oak alone.

Isograms were drawn to depict the geographic patterns of oak volumes, and these, as expected, agree well with the correlation analyses. The pattern for water oak (fig. 2) corresponds very well with the pattern of rust incidence in slash pine (fig. 3)--volumes are low in southern regions, increase to a ridge running generally northeast-southwest across the planted range of slash pine, and then decrease to the north. Patterns for laurel oak (fig. 4) and the remaining five oaks showed considerably less similarity to rust incidence.

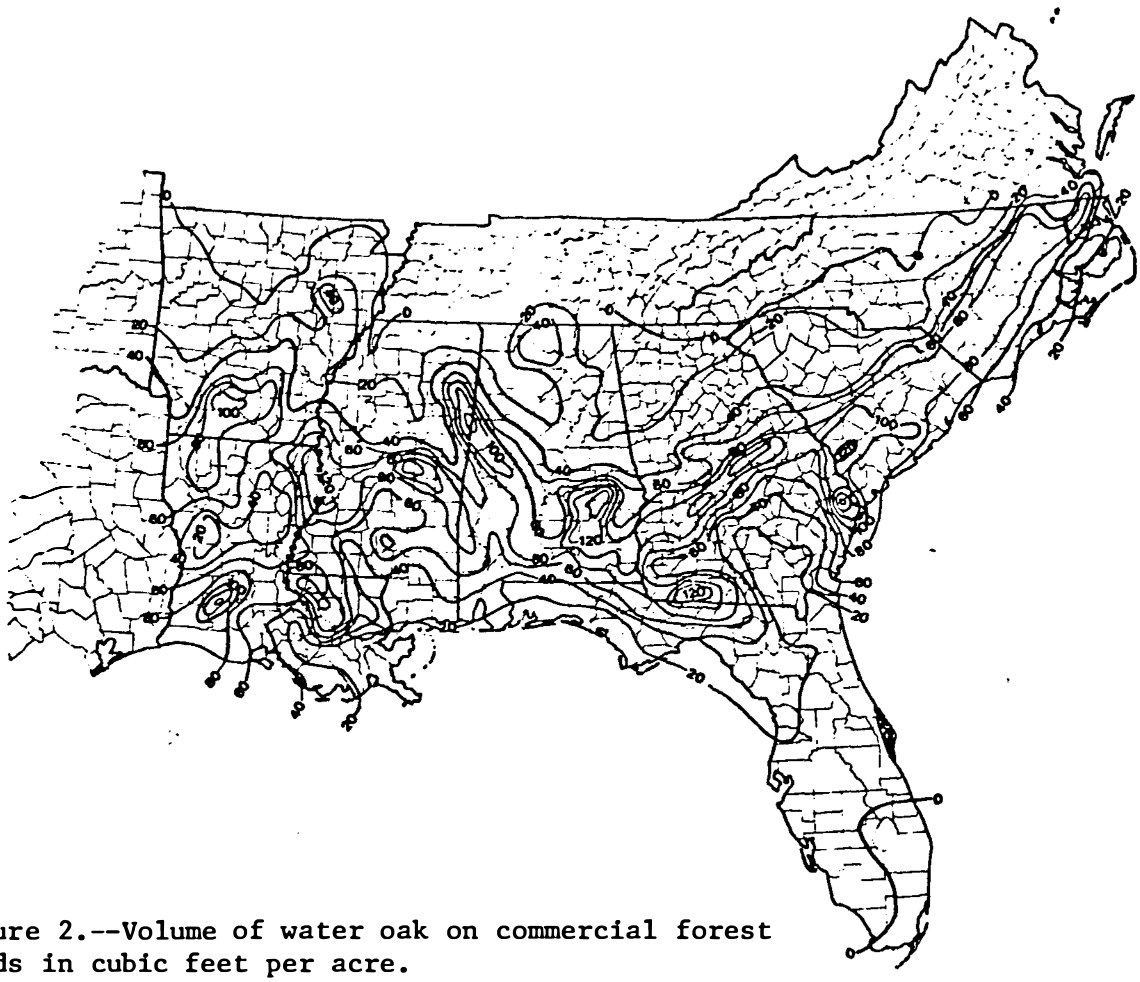

Figure 2.--Volume of water oak on commercial forest lands in cubic feet per acre.

Thus, geographic variation in the abundance of water oak is more strongly associated with intensity of infection in slash pine plantations than is abundance of any of the other oaks tested. Our findings agree with Hollis and Schmidt (1977), who found a correlation of 0.87 between water oak volumes and infection within Florida, and also with Dwinell's (1974) ranking of water oak as the most susceptible to infection in response to artificial inoculation.

Relationships of infection in loblolly pine plantations (fig. 5) to oak volumes were not as clear. Moderately strong, positive correlations were found for water oak (0.42) and laurel oak (0.48) (table 1). Correlations for the remaining oaks were mostly significant, but negative. The appreciable negative correlations for black, post, and southern red oaks reflect the fact that these oaks are abundant in the extreme northern and northwestern portions of the planted range of loblolly pine where infection is low, and less abundant in the corridor of high infection to the south. Dwinell (1974) ranked black and post oaks as being of low susceptibility, and the lack of a positive relationship for them is not surprising. Dwinell ranked willow oak as highly susceptible, but its occurrence is relatively scanty and patchy, which may be one reason for the lack of a positive correlation.

When water oak and laurel oak were used together in a multiple correlation analysis, the correlation with rust infection in loblolly pine was 0.54,

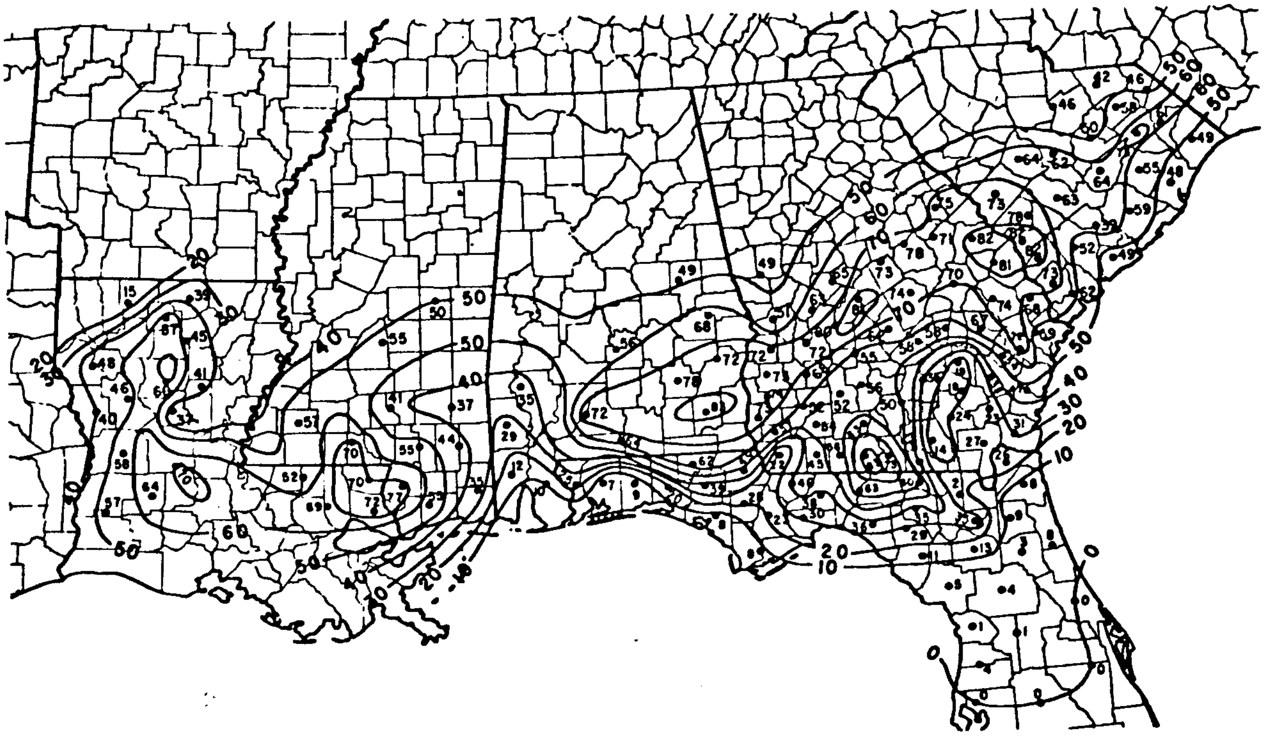

Figure 3.--Percentage of trees infected with fusiform rust in 8- to 12-year-old slash pine plantations (from Squillace 1976).

moderately higher than when either oak was used alone. All oaks combined showed little correlation with incidence, as expected, because some of them were individually negatively correlated. In considering the correlations we must note that the survey of rust incidence for loblolly pine did not include south Georgia and north Florida. Supplementary data obtained in seed source studies suggest that if these areas had been included, the correlation between infection on loblolly pine and volume of water oak would likely have been greater than that obtained here. Also, the correlation of infection on loblolly with laurel oak volume would likely have been reduced. In other words, if sampling of loblolly plantations had been more complete, the correlations would probably have been more similar to those obtained for slash pine.

A further point to consider in the loblolly relationships is that the pattern of abundance of water oak (fig. 1) is strikingly similar to the pattern of abundance of loblolly pine given by Sternitzke and Nelson (1970). This similarity suggests that fusiform rust may have evolved in harmony with this species combination and supports our findings on the importance of water oak.

Taking all points into consideration, we conclude that abundance of water oak, and possibly laurel oak, are associated with variation in infection of loblolly pine plantations. However, the relationships are apparently not as great as in slash pine, possibly because temperature and other factors become relatively more important in loblolly pine.

Figure 4.--Volume of laurel oak on commercial forest lands in cubic feet per acre.

Oaks other than those included in our analyses may, of course, be associated with intensity of infection on the pines. Among these, Dwinell (1974) ranked blackjack (*Q. marilandica* Muenchh.), cherrybark (*Q. falcata* var. *pagodaefolia* Ell.), bluejack (*Q. incana* Bartr.), running (*Q. pumila* Walt.) and turkey (*Q. laevis* Walt.) oaks as being moderately to highly susceptible. Blackjack and cherrybark oaks occur over much of the pine region and hence could be important to spread of fusiform rust. Turkey oak occurs over much of the coastal plains and could be important in those areas. Bluejack and running oaks also occur in the coastal plains but because of their small size, with low total leaf surface area, they would probably not be greatly associated with infection. Further work is needed with these species. Finally, we must recognize that correlations are not necessarily cause and effect relationships. For example, the conditions which favor establishment of water oak may also be conducive to spread of the disease. Further study is needed to clarify the relationship of oak abundance to incidence and to more precisely evaluate the oaks involved.

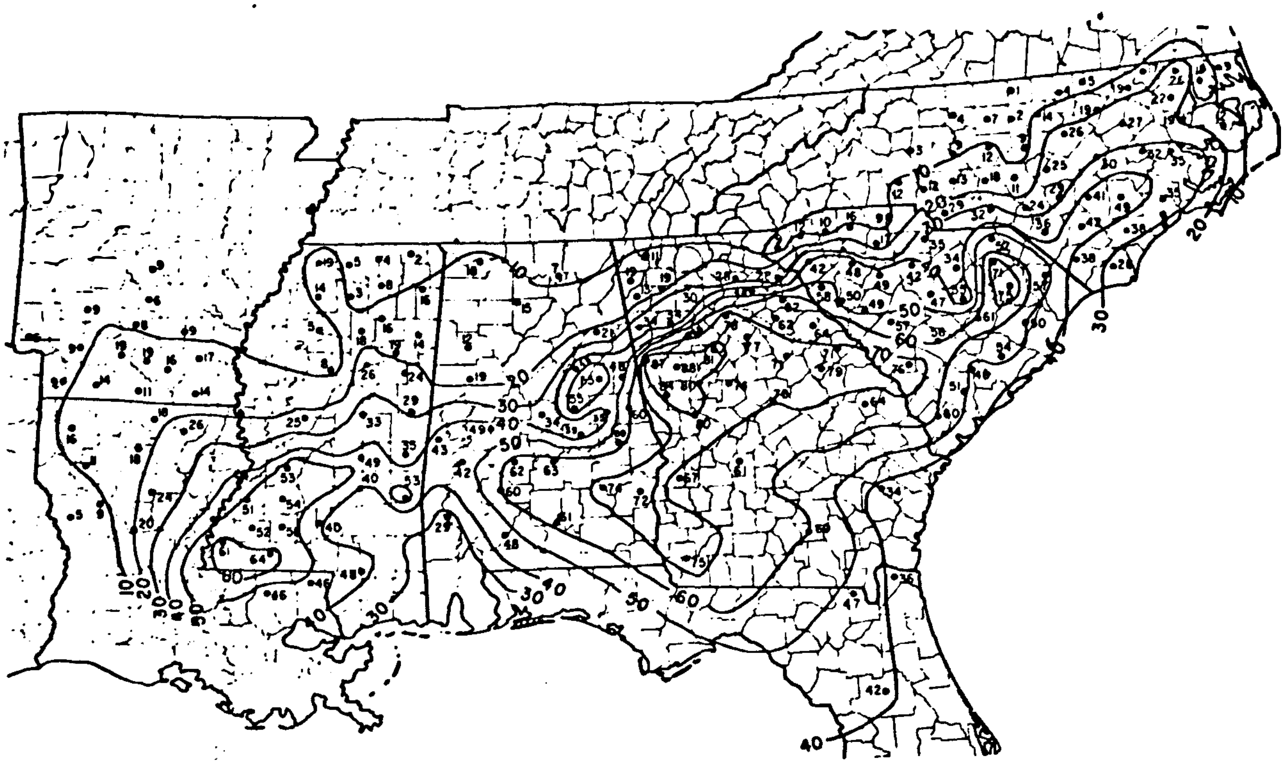

Figure 5.--Percentage of trees infected with fusiform rust in 8- to 12-year-old loblolly pine plantations (from Squillace 1976).

MANAGEMENT PRACTICES AND OAK ABUNDANCE

In removing the once extensive stands of longleaf pine, man often released oaks. Subsequent fire protection led to further oak development as well as natural and artificial establishment of loblolly and slash pines, the two species most susceptible to rust. The current rust problem presumably resulted from our having brought together susceptible pine and oak hosts. Cultivation and fertilization of pine sites further increased the problem (Siggers 1955).

Most of the sites now supporting loblolly or slash pine stands would succeed to hardwood stands, with oaks as important components, if the hardwoods were not controlled (Shelford 1963). Managers of commercial pinelands control oaks because they are often of low commercial value and compete with the pines, but control to reduce losses to fusiform rust might also be feasible.

Oak succession and abundance can be altered by mechanical site preparation, prescribed burning, herbicide application, and altering stand density and rotation length. Application of fertilizers undoubtedly also alters the oak component on pine sites, but we could find no information on this in the literature.

Other papers in these Proceedings discuss disease management strategies in site preparation and in plantation management. We will make a few recommendations on oak control, but the major purpose of the remainder of this paper is to present background information for the papers dealing with management strategies.

Mechanical Site Preparation

In the Coastal Plain of Virginia, disking prior to the harvest cut of loblolly pine only temporarily controlled oaks and other hardwoods (Trousdell and Langdon 1967). In the Georgia Piedmont, burning plus disking killed the aboveground portions of small hardwoods, but apparently killed few rootstocks (Brender 1973).

In the Sandhills of west Florida, chopping, rootraking, bulldozing, or disk-harrowing temporarily controlled oak stands composed of turkey oak, bluejack oak, sand post oak (_Q. stellata_ var. _margaretta_ (Ashe) Sarg.), sand live oak (_Q. virginiana_ var. _maritima_ (Michx.) Sarg.), and runner oak (_Q. minima_ (Sarg.) Small). Hundreds of oak sprouts per acre developed, however, even after the best of these treatments: a spring burn just after the oak leaves had fully expanded, a chopping several weeks later after new leaves had expanded, and a second chopping several weeks after that when more new leaves had expanded (Burns and Hebb 1972).

On flatwoods sites in Florida, runner oak is often the only oak present. It was reduced, but not eliminated, by double chopping (Moore 1974) or by double disking plus bedding (Schultz and Wilhite 1974). Some of the drier flatwoods sites support turkey, bluejack, Chapman (_Q. chapmanii_ Sarg.), and myrtle (_Q. myrtifolia_ Willd.) oaks, and some of the more moist sites support water oak. The junior author has observed sprouting from the rootstocks of these species after prescribed burning plus three diskings.

It appears that mechanical site preparation must be repeated several times to eliminate or reduce abundance of oaks, while moderate application of the treatment may increase it.

Prescribed Burning

In a review of the literature, Langdon (1971) found that headfires generally topkill more hardwoods than backfires, summer fires topkill more stems than winter fires, and small stems are more easily topkilled than larger stems. He found that periodic winter or summer prescribed burns completely kill only a relatively small number of rootstocks, and that repeated annual summer burns killed more rootstocks than did repeated annual winter burns.

Under a mature loblolly-shortleaf stand in Arkansas, a winter burn followed by twelve annual summer headfires or seven biennial summer headfires topkilled about 99 percent of the southern red oaks, but about 25 percent of the rootstocks resprouted (Grano 1970).

In two loblolly stands on the Coastal Plain of South Carolina, the rootstocks of small understory post, blackjack, willow, and southern red oaks ceased resprouting sometime between the fifth and twentieth annual summer fire (Lewis and Harshbarger 1976), but many of the oak stems more than 3 inches in diameter were not topkilled and survived 30 annual summer fires.

Thus, repeated summer fires can eliminate most or all of the small oaks from an area. However, many sites do not accumulate fuel quickly enough to support annual fires, and frequent burning might lead to accelerated erosion on sloping land. Another limitation is that burning cannot be safely prescribed in loblolly and slash pine stands for 3 to 6 years after planting, by which time most rust damage has occurred (Dinus 1974).

Herbicide Application

Chemicals that kill plant tissues through immediate contact, such as the arsenate herbicides and ammonium sulfamate, are not translocated readily. Hence, they are seldom used against woody plants, such as oaks, that sprout profusely from the rootcollar (Peevy and Brady 1972).

Soil sterilants, such as bromacil and picloram, are applied as pellets to the soil surface. The banding of soil sterilants around individual blackjack and post oaks resulted in 90 to 100 percent topkill with negligible sprouting (Peevy 1971).

Hormone-type herbicides, such as 2,4-D; 2,4,5-T; silvex and picloram are readily absorbed into the sap stream and translocated, and thus are more likely to reduce sprouting from the rootcollar. Spraying picloram onto post oak saplings has resulted in up to 100 percent kill with no sprouting (Brady 1975). Injecting 2,4-D into stems has resulted in 100 percent kill of the rootstocks of water oak, 97 percent kill of white oak (Q. alba L.), and 87 percent kill of post oak (Peevy 1968).

Romancier (1965) and Byrnes and Holt (1975) comprehensively review the use of herbicides in forestry. Because of frequently changing Federal and State Regulations, no herbicide should be used on forest land before consulting the responsible agency.

Stand Density and Rotation Length

A dense pine overstory will not prevent invasion by oaks, which are shade tolerant, but it will retard their growth (Wahlenberg 1960). Thinnings, natural mortality, and final harvesting of the pines accelerate the development of the oaks. Hence, rapid reestablishment of a dense stand of pines after final harvest, cultural treatments that achieve rapid crown closure, and single-harvest-cut rotations should retard oak development. Such treatments are not always compatible with each other, however. For example, fertilization to accelerate closure of the pine canopy might also accelerate oak succession, and establishing a pine stand of high density might later necessitate precommercial or commercial thinnings. Thus, compromises in treatments may be necessary.

Under many pine stands, the oaks and other climax-type hardwoods do not increase greatly until 30 or even 60 years after pine establishment. Short rotations on such sites would retard oak development, provided that site preparation or other cultural treatments set back succession of oaks more than final harvesting encouraged it.

Other Considerations

Before attempting oak control to reduce rust hazard, several points should be considered. Because of multiple sprouting from rootstocks, inadequate control measures can actually increase the number of oak stems per acre. Some treatments might reduce the number of oaks yet increase rust infection of pines.

For example, Dinus and Schmidtling (1971) tentatively concluded that cultivation and fertilization increase rust infection through physiological changes in the pines. Elimination of oaks from a site does not necessarily mean elimination of rust, for oak-free borders up to 1,500 feet wide around nurseries have not prevented moderate to high percentages of infected pine seedlings (Czabator 1971). Elimination of oaks from a site is probably temporary, for oaks do reinvade. Finally, complete oak elimination is not desirable on all loblolly and slash pine sites, for oaks have esthetic and wildlife habitat values, and oak and other hardwood litter contribute more to soil improvement than does pine litter (Brender 1973).

CONCLUSIONS

1. Abundance of oaks is a strong contribution to the current pattern of rust incidence in slash and loblolly pines. Water oak seems to be the most important, although laurel oak may be equally important in loblolly pine.

2. Prevalence of oaks and their potential for invasion should be considered in evaluating site hazard.

3. Mechanical site preparation usually induces oak sprouting and may therefore increase rust hazard.

4. Of the techniques available for site preparation, prescribed burning and herbicide application have the best potential for forestalling succession of oaks and lessening competition without increasing oak abundance.

5. Maintaining a dense canopy of pines retards, but does not prevent, natural succession toward oaks and other hardwoods.

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