United States
Department of
Agriculture

Forest
Service

North Central
Forest Experiment
Station

General Technical
Report NC-99

Second Workshop on Seedling Physiology and Growth Problems in Oak Planting

(Abstracts)

U.S. Department of Agriculture, Forest Service
North Central Forest Experiment Station
1992 Folwell Avenue
St. Paul, Minnesota 55108
Manuscript approved for publication April 6, 1984
December 1984

SECOND WORKSHOP ON SEEDLING PHYSIOLOGY AND GROWTH PROBLEMS IN OAK PLANTING, MISSISSIPPI STATE UNIVERSITY, FEBRUARY 8-9, 1983 (ABSTRACTS)

Edited by Paul S. Johnson and John D. Hodges

Sponsored by

Department of Forestry

Mississippi State University

North Central Forest Experiment Station

USDA, Forest Service

St. Paul, Minnesota

and

Southern Forest Experiment Station

USDA, Forest Service

New Orleans, Louisiana

PREFACE

On February 8-9, 1983, a group of foresters, forest scientists, and tree physiologists met at Mississippi State University for the Second Workshop on Seedling Physiology and Growth Problems in Oak Planting. The first workshop was held at Columbia, Missouri on November 6-7, 1979. The purpose of the workshop was to provide a forum for exchange of ideas and research results in three subject areas: (1) physiology and genetics, (2) seedling propagation and production methods, and (3) field performance of planted oaks. The last workshop was jointly sponsored by the Department of Forestry, Mississippi State University, the North Central Forest Experiment Station and the Southern Forest Experiment Station, USDA Forest Service. Abstracts of papers given at the workshop are presented here.

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J. W. Van Sambeek, *Research Plant Physiologist,*
and
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Early vigorous root growth of planted seedlings is critical for good establishment and early height growth in white oak (*Quercus alba* L.) plantations. Indolebutyric acid applied to roots before planting doubled or tripled early root growth of 1-0 seedlings in the greenhouse. However, that treatment failed to improve first-year survival or height growth on a graded mine spoil in southern Illinois. Survival ranged from 35 to 69 percent and new shoot growth from 4 to 12 cm. Only site variation significantly affected both survival and shoot growth.

Little is known about the variation in white oak's ability to survive and grow under environmental stress. Preliminary experiments with 6-week-old white oak seedlings established under factorial combinations of 2 levels of moisture stress (-0.5 and -0.7 bars), with and without fertilizer, and watered with either distilled water or leachate from tall fescue showed no differences in seedling shoot growth after 8 weeks; however, differences among half-sib progeny of 5 local trees were apparent.

Preliminary results of an acorn storage study suggest that short-term storage of acorns in sealed 4-mil plastic bags results in a rapid loss in viability. We are also studying rooting of white oak cuttings under aseptic conditions with various combinations of plant growth regulators and cultural regimes to find ways to vegetatively propagate white oak.

PHYSIOLOGICAL RESPONSES OF CONTAINER-GROWN MYCORRHIZAL BLACK OAK SEEDLINGS TO DROUGHT

David J. Moorhead, *Graduate Research Assistant, School of Forestry, Fisheries, and Wildlife, University of Missouri, Columbia, Missouri*

Growth, water relations, and photosynthesis were monitored during the 1980 growing season in a two-year-old outplanting of black oak (*Quercus velutina* Lam.); seedlings tested were container-grown (noninoculated), container-grown inoculated with *Pisolithus tinctorius* , and 2-0 bare-root stock (noninoculated). Seedling performance was evaluated during three periods: (1) pre-drought, (2) post-drought periods with abundant soil moisture and moderate air temperatures, and (3) a severe midseason drought period with low soil moisture and maximum daily air temperatures greater than 38°C. Despite conditions of low soil moisture and high evaporative demand during much of the growing season, mycorrhizal seedlings grown in containers grew significantly more in height and diameter than 2-0 bare-root seedlings ($P < .05$). Comparison among the three types of seedlings revealed no significant differences in water relations or photosynthesis during pre-drought and post-drought periods. However, during peak drought conditions, the inoculated and noninoculated container-grown seedlings maintained significantly greater rates of leaf conductance and photosynthesis than the 2-0 bare-root seedlings. Bare-root seedlings minimized water loss by reducing leaf conductance and limiting photosynthesis during peak drought. Containerization and mycorrhizal inoculation decreased calculated soil-plant bulk water flow resistance when soil moisture availability was low. This may have resulted from the greater root absorptive surface area of the container-grown seedlings. In addition, mycorrhizal roots may have reduced water flow resistance by further increasing root absorptive area by extension of fungal hyphae into the soil and thus providing a lower resistance for water flow through the root cortex.

REGENERATION AND GROWTH OF BOTTOMLAND HARDWOODS: STUDIES IN PROGRESS

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Regenerating Bottomland Hardwoods by Underplanting.--Stands in 5 bottomland hardwood types were studied in southeastern Louisiana. Designation of types was based on relative basal area and relative density of tree species. Types studied included: Sugarberry-Sweetgum-Boxelder, Red Maple-Swamp Tupelo-Green Ash, Sweetgum-American Hornbeam, American Beech-Swamp Tupelo-Spruce Pine, and Swamp Tupelo-Sweetbay. Within each type, ten 0.2-ha plots were established over a range of basal areas from 19.8 to 46.2 m^2 per ha. In all plots, trees and shrubs less than 10 cm dbh were severed near ground line. Five plots from each type were not further thinned. The remaining five plots in each type were further thinned by removing 12, 24, 36, 48 or 60 percent of the remaining plot basal area. One-year old seedlings of *Quercus nigra* L., *Q. michauxii* Nutt., *Q. nuttallii* Palmer, *Fraxinus pennsylvanica* Marsh., *Liquidambar styraciflua* L., and *Taxodium distichum* L. were underplanted at 4.57 x 4.57 m spacing on the interior 0.1 ha of each thinned plot and 1 unthinned plot in each type. Changes in understory light intensity, crown coverage, seedling survival, seedling height and diameter growth, and growth of competing trees will be measured annually to determine the feasibility of underplanting for regenerating bottomland hardwoods that have little desirable natural regeneration.

Effect of Shading on Seedling Growth and Survival.--One-year-old seedlings of *Q. falcata* var. *pagodifolia* Ell., *Q. nigra* L., *Q. nutallii* Palmer, *F. pennsylvanica* Marsh. and *L. styraciflua* L. were transplanted to nursery beds. Zero, 63, and 73 percent shade were applied by covering or not covering the plots with neutral density black woven shade cloth. Forty seedlings of each species were included in each plot and all treatments were replicated three times within the nursery. The effects of shading on seedling survival and growth will be monitored for two years.

Effects of Environmental Factors on Seedling Growth.--We are also studying optimum conditions and limits of seedling tolerance in controlled environments. Species include *Q. falcata* var. *pagodifolia* Ell., *Q. nuttallii* Palmer, *F. pennsylvanica* Marsh., and *L. styraciflua* L. We are varying air temperature, relative humidity, light intensity, and soil moisture over a range of conditions common to seedlings in their natural environments. Under these conditions, photosynthesis, stomatal conductance, components of plant water potential, and transpiration are monitored at each stage of growth. This study will provide information about conditions necessary for survival and growth of seedlings.

ECOLOGICAL FACTORS, MORPHOLOGICAL CHARACTERISTICS, AND PHYSIOLOGICAL PROCESSES AFFECTING ESTABLISHMENT AND GROWTH OF NORTHERN RED OAK-- A NEW RESEARCH PROGRAM

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and
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We recently initiated a research program to determine the biological and environmental factors that influence establishment and growth of northern red oak (*Quercus rubra* L.). Ecological factors, morphological characteristics, and physiological processes affecting establishment will be studied. Our premise is that if the mechanisms of the processes regulating oak seedling growth are more clearly understood, silviculturists and geneticists will be able to use this knowledge to increase growth through improved cultural practices and varieties.

An integrated approach will be used in the physiological experiments. This approach includes collecting data on crown morphology, photosynthesis, respiration, photosynthate distribution, and growth analysis for the same or morphologically comparable trees. Initial experiments will be conducted on plants grown in controlled environments (e.g., growth room, greenhouse, and biotron). Emphasis will be on physiological aspects of leaf aging and recurrent flushing in oak seedlings. The potential of using plant growth regulators to stimulate early growth will also be investigated. Hypotheses resulting from these studies will be tested in subsequent field experiments.

Vegetative propagation of oak will also be studied and resultant techniques will have application to silviculture and genetics. With vegetatively propagated plants it will be easier to determine plant responses to multiple environmental factors than in plants raised from seed because of reduced variation among plants.

Primary objectives of the ecological research will be to better define the reproductive strategies of northern red oak and the conditions that permit the establishment, growth, and development of advance reproduction. The critical factor in regenerating oak is not in the ability of seedlings to survive for a year or two, but in the ability of regeneration to reach a size that can grow rapidly after final harvest cutting. The role of disturbances (especially fire) in reproducing oak will also be studied. The ecological research will be designed to complement the physiological studies.

WHITE OAK ARTIFICIAL REGENERATION IN INDIANA

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The Indiana Department of Natural Resources, Division of Forestry, in cooperation with the U.S. Forest Service, recently initiated studies in artificially regenerating white oak (*Quercus alba* L.). Studies include determination of variation in annual seed production and growth of white oak seedlings in plantations. To study seed production, a 5-acre stand located on a state forest in southeastern Indiana was designated as a seed production area. The 150 trees in this stand will be treated with systemic insecticides and fertilized to test treatment effects on seed production and quality. Growth of white oaks in plantations will be studied in relation to nursery culture. Two short-term studies were established to determine the best combination of seedling age, seedbed density, seedbed fertilization, and method of seedling storage for maximizing survival and growth of outplanted seedlings. Effects of the mycorrhizal fungus *Thelephora terrestris* on seedling survival and growth will also be studied. In addition, a limited range, combined provenance/progeny test for white oak will be established at 5 locations in Indiana in 1983. A total of 90 Indiana open-pollinated families, plus families from other states in the Midwest will be included. These test plantations will identify the best seed sources for use in northern and southern Indiana and will later be converted to seed orchards.

ALLELOPATHIC EFFECTS OF GOLDENROD ON OAK SEEDLINGS

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Goldenrod (*Solidago* spp.) is a perennial weed that often forms dense stands in old-fields and open areas in Ohio. These areas are resistant to invasion by oak and other hardwoods. Previous studies have shown that tall goldenrod (*S. altissima*) contains compounds toxic to black locust (*Robinia pseudoacacia* L.) and red maple (*Acer rubrum* L.) seedlings.

In preliminary tests to determine whether tall goldenrod foliage contained compounds allelopathic to oak seedlings, we added various amounts of air-dried, mature goldenrod shoots to soil media of 1-0 northern red oak (*Quercus rubra* L.) nursery stock. Adding 4 grams of litter to 1-quart containers reduced both root regeneration and leaf weight by one-third, and 8 grams reduced growth to less than half that of control trees after one month.

A mung bean rooting assay was used to test for inhibitory compounds in water extracts of leaves, stems, flowers and roots. Results indicated that only leaves of goldenrod contained significant amounts of rooting inhibitor. In a direct test using white oak (*Q. alba* L.) seedlings, water extracts of leaves, stems, flowers and roots were applied to 6-day-old plants growing in slanted glass tubes where root growth could be observed. As with mung beans, only water extracts of leaves were strongly inhibitory; taproot elongation rates were reduced 30 percent three days after the initial watering. Although inhibition of nutrient uptake is a commonly reported allelopathic effect, the rapid reduction of root elongation observed suggests that the allelochems affected physiological processes directly related to extension growth.

Goldenrod foliage was collected in July, September, and November and tested for seasonal differences in inhibitor levels. The results indicated that by November goldenrod leaves contain little if any inhibitors.

In addition, soil from cleared (goldenrod removed) and uncleared plots in a goldenrod stand was also collected at different seasons and stored. The cleared plots remained nearly barren of new weed plants except in the shallow pits where soil samples were removed. Here, numerous weed seedlings appeared in the fall. Inhibitor levels of the seasonally collected soil samples will be determined in the spring of 1983.

GENETIC COMPETITION STUDY FOR WATER OAK

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A study to evaluate intergenotypic competition among open-pollinated families of water oak (*Quercus nigra* L.) was established in March 1978 in northeastern Mississippi. One-year-old nursery seedlings from eight mother trees (three from eastern Mississippi and five from western Mississippi) were planted in a Nelder's Wheel design. Trees along a spoke in the wheel design were planted at spacings approximating the following:

(1) Interior border,
(2) 8 feet x 8 feet,
(3) 9.3 feet x 9.3 feet,
(4) 11 feet x 11 feet,
(5) 12.8 feet x 12.8 feet, and
(6) Exterior border.

The same family was used for all six positions on a spoke. Families were assigned to adjacent spokes in a particular order to provide competition among trees of only a single family (pure stands) and competition among trees of different families (mixed stands).

After five growing seasons in the field, survival was 99.2% and height averaged 12.7 feet. Crown closure had occurred only for the largest trees at the closest spacings. The effects of stand density and intergenotypic competition were not yet apparent.

OAK SEEDLING PROPAGATION AND PRODUCTION METHODS

CORRELATING ACORN QUALITY WITH SEEDLING QUALITY

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The objective of this research was to evaluate tetrazolium (TZ) staining and several germination response variables as indicators of seed vigor in southern oaks. Multiple lots of white oak (*Quercus alba* L.) and cherrybark oak (*Q. falcata* var. *pagodifolia* Ell.) were used to relate seed vigor tests to seedling growth in nursery beds. In general, seed tests could not predict oak seedling growth. Two seed tests, TZ stain percent and peak value (PV) (a measure of germination rate) were significantly correlated with nursery germination of cherrybark oak. However, there were no significant correlations for white oak. TZ stain percent was significantly correlated with germination capacity in lab tests on both species. We thus recommend using a measure of germination rate such as PV or mean germination time for evaluating relative quality of acorns. However, TZ staining is an acceptable method for testing cherrybark oak.

OAK REGENERATION RESEARCH IN INDIANA

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Oak regeneration research by the North Central Forest Experiment Station is just getting under way in Indiana. We have recently established a study in natural regeneration to determine the effects of three overstory density treatments (40, 50, and 60 percent stocking) and three understory treatments (check, cut all except oak, and cut all more than 2 meters tall except oak). A fourth understory treatment uses prescribed burning in the 50 percent stocking density.

Other studies initiated include determining: (1) effects of undercutting in the nursery bed on root fibrosity and subsequent growth of outplanted northern red (*Quercus rubra* L.) and white oak (*Q. alba* L.) seedlings; (2) how to increase white oak acorn production by fertilization and systemic insecticides; (3) how to increase growth of planted red, white, and black (*Q. velutina* Lam.) oaks by interplanting with nitrogen-fixing shrub and tree species; and (4) when to collect and how to handle white oak seed for optimum germination and seedling production.

Results from the germination study (4) above showed that seed stored in 4-mil plastic bags lost viability rapidly with increased storage time. But seed stored in 1.75-mil plastic bags and cloth bags did not lose viability with increased storage time. Apparently, the 4-mil bags did not permit adequate gas exchange. Thus, if 4-mil bags are used they should be perforated or kept partially open.

INITIAL ISOLATES OF INSECT AND FUNGAL PREDATORS FROM QUERCUS ACORNS

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Freshly collected acorns of white oak (*Q. alba* L.), cherrybark oak (*Q. falcata* var. *pagodifolia* Ell.), water oak (*Q. nigra* L.), and willow oak (*Q. phellos* L.) all contained acorn weevils (*Curculio*). In addition, *Milissopus latiferreanus* (LEPIDOPTERA: Tortricidae) was isolated from cherrybark oak and water oak. The pericarp of water oak was excessively cracked and also contained *Ephestia* (LEPIDOPTERA: Pyralididae). Undertermined species of *Valentinia* (LEPIDOPTERA: Blastobasidae) emerged in large numbers from all species of acorns observed here.

Two fungal spores observed with lactophenol blue from sectioned gut of *Curculio* resembled *Fusarium* but were not identified. No *Fusarium* spores were observed from *Curculio* gut smear on slides. PDA isolates were recovered from head, gut, and carcass of *Curculio* larvae. *Pennicillium* was isolated from head and carcass portions, while an undetermined white, sterile mycelia was isolated from head, gut, carcass, and the whole larvae. Additionally, *Fusarium solani* and *Epicoccum purpurascens* were isolated from acorns of white oak and water oak.

Although these isolations are believed to be from acorn surface contaminants, it should be noted that acorn pericarps were cracked. These cracks may have allowed internal cotyledon contaminants to have grown on the agar medium. However, the cracks are quite common on both freshly collected as well as stored acorns. If a separate group of organisms is specific for the pericarp surface, as opposed to the cotyledon-embryo tissues, they would have potential infection capability through these commonly occurring, natural fissures in the pericarp. It is also possible that symbiotic or beneficial associations between seed germination and seed contamination occur.

Additional studies are appropriate to determine the functional role of each of these isolated predators. After this initial screening to determine contaminants, pure culture inoculations onto surface-sterilized seed are in order to observe fungal effects on acorn germination.

ECTOMYCORRHIZAL FUNGUS INOCULATION IMPROVES QUALITY OF OAK SEEDLINGS USED FOR ARTIFICIAL REGENERATION

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In experimental plantings, most oak seedlings planted by conventional techniques survive but growth for 2 to 3 years after planting is usually slow. During this period, dense competing vegetation supresses oak seedling growth. Poor ectomycorrhizal development on planting stock may account for some of this slow initial growth.

At the Institute for Mycorrhizal Research and Development, we have increased survival and growth of pine seedlings on various sites by inoculating nursery beds and container growing medium with the ectomycorrhizal fungus *Pisolithus tinctorius*. We are now attempting to learn if similar treatments with that and other symbionts will benefit oak seedlings.

Initial studies have shown that inoculation procedures developed for pines are easily adapted to bare-root and container-grown northern red (*Quercus rubra* L.), white (*Q. alba* L.), black (*Q. velutina* Lam.), bur (*Q. macrocarpa* Michx.), pin (*Q. palustris* Muenchh.), and sawtooth (*Q. acutissima* Carruthers) oaks. From this study we should learn when bare-root seedlings will commence and how long they will sustain height growth when roots are colonized by ectomycorrhizal fungi before planting. We are also investigating using mycorrhizal container-grown oak seedlings for selected planting sites. Using properly grown container stock with suitable ectomycorrhizal development may avoid many problems encountered with bare-root seedlings. Root pruning is not required with container stock and all roots and ectomycorrhizae developed in the container are retained and remain intact at planting. Storage generally is not a problem because container stock is held in the greenhouse or lath house until conditions are appropriate for planting. The planting operation is easier because of the uniformity among seedling root systems.

We plan to solve the problem of slow early seedling growth of planted oaks by developing planting stock, both bare-root and container-grown, with appropriate ectomycorrhizal fungi and root morphology that are better adapted for outplanting.

Oak Seedling Propagation and Production Methods

MYCORRHIZAE AND THE ARTIFICIAL REGENERATION POTENTIAL OF OAK

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Container-grown and bare-root black oak (*Quercus velutina* Lam.) seedlings inoculated with *Pisolithus tinctorius* were grown for one season in 750 cc Spencer-Lemaire containers in the greenhouse or in a nursery, respectively; noninoculated seedlings were also grown in containers and in the nursery for comparison. Examination of seedlings before planting revealed that 38 and 45 percent of the roots of the container-grown and 1-0 bare-rooted seedlings, respectively, were infected with *Pisolithus*. Bare-root seedlings were significantly larger than container-grown seedlings. However, total root system length of the container-grown seedlings was significantly greater.

Three years after outplanting on two Missouri Ozark clearcut sites, survival of the container-grown seedlings inoculated with *Pisolithus* was significantly greater than the inoculated and noninoculated bare-root stock. Root weight, shoot length and weight, and leaf area of the inoculated container-grown seedlings increased significantly during the first three years in the field. The inoculated and noninoculated bare-root stock suffered from repeated shoot dieback and leaf area remained relatively small. Percent infection with *Pisolithus* on roots of the container-grown stock was 25 percent after three years. Mycorrhizal infection of the bare-root stock declined to less than 15 percent during the same period. Total root system length and yearly increments of new root growth were significantly greater for container-grown stock inoculated with *Pisolithus* than for other seedlings.

Seasonal evaluation of seedling xylem pressure potential, leaf conductance, and microenvironment indicated that container-grown stock inoculated with *Pisolithus* better avoided water stress during droughts than noninoculated seedlings. Soil-plant liquid flow resistance was significantly lower in the *Pisolithus* inoculated seedlings than the noninoculated stock.

Preliminary greenhouse and field screening trials with five other species of mycorrhizal fungi with black, white (*Q. alba* L.), and English oak (*Q. robur* L.) indicate an expanded potential for the use of mycorrhizae technology in artificial regeneration.

Oak Seedling Propagation and Production Methods

METHODS FOR PRODUCTION OF OAK SEEDLINGS

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and
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After five growing seasons in the field, the best container system produced seedlings that were taller and larger than bare-root seedlings of the same age even though the bare-root seedlings were larger at the end of the first season. This was true for Nuttall oak (*Quercus nuttallii* Palmer), Shumard (*Q. shumardii* Buckl.), cherrybark (*Q. falcata* var. *pagodifolia* Ell.), and water (*Q. nigra* L.) oaks.

Results of nursery studies, using the same four species showed that seedlings of acceptable size can be grown in one season if density of seedlings in the nursery bed is about 8 seedlings per square foot and sowing is done with stratified seed by early April. A density of 8 seedlings per square foot yielded more plantable seedlings than lower densities and as many as at higher densities; however, the largest seedlings occurred at a density of 8 per square foot. If sowing is done after mid-April, seedlings will not be of plantable size at any density.

Methods for modifying the root system of hardwood seedlings in nursery beds are being studied in cooperation with International Paper Company. Methods include: (1) early undercutting (taproot pruned), (2) late undercutting, (3) lateral root pruning, and (4) early undercutting plus lateral root pruning. In addition, one-half of all treatment plots were inoculated with mycorrhizae. Cherrybark oak, green ash (*Fraxinus pennsylvanica* Marsh.), and sweetgum (*Liquidambar styraciflua* L.) were used in the study. Early results indicate that the treatments, particularly treatment 4, may improve growth of outplanted seedlings.

FIELD PERFORMANCE OF PLANTED OAKS

SURVIVAL AND HEIGHT OF BLACK OAK PLANTED IN EIGHT LOCATIONS

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Planted oaks usually survive but grow poorly on upland sites in the South. This general observation was reinforced by the survival and growth of black oak (*Quercus velutina* Lam.) planted from 1967 to 1971 in the Cumberland Plateau and Highland Rim Region.

Seedlings from a Tennessee Valley Authority nursery were planted at a 7- x 7-foot spacing on 8 sites within four landtypes. Site quality ranged from poor to moderately good. Each site supported mixed hardwood stands prior to outplanting. The hardwoods were felled and individual stems injected with herbicide.

When the seedlings were 6 to 8 years old, three weeding intensities and a control were imposed: (1) a single weeding, (2) an annual weeding, and (3) a weeding every two years. Weeding consisted of cutting all vegetation within 2 feet of the planted oak and injecting all non-planted hardwoods on the plot.

Survival of the oaks over the study averaged 75 percent when weeding treatments were initiated. Survival of trees present at the time of weeding ranged from 57 to 100 percent. Heights of the 11- to 14-year-old oaks averaged 1.7 to 8.5 feet. There were no consistent effects of the cleaning treatments on height growth. In fact, at three locations height of unweeded oaks surpassed the height of weeded oaks.

As part of another study, yellow-poplar (*Liriodendron tulipifera* L.) was planted near the oaks. Heights of these yellow-poplars showed that site quality ranged from poor to moderately good.

These results indicate that black oak should not be planted on a broad scale in the uplands.

FIELD PERFORMANCE OF PLANTED OAKS

EXPERIENCES AT THE SOUTHERN HARDWOOD LABORATORY ON GROWING OAKS IN PLANTATIONS AND NURSERY

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Planting studies at the Southern Hardwoods Laboratory tested Nuttall oak (*Quercus nuttallii* Palmer), water oak (*Q. nigra* L.), and cherrybark oak (*Q. falcata* var. *pagodifolia* Ell.) under three levels of cultural intensity: disking, mowing, and no treatment (control).

Height and diameter growth were 2½ times greater in disked plots than in mowed or control plots and survival was increased by 30 to 40 percent. However, one study showed that these oaks cannot survive on soils with a pH exceeding 8.0.

Leaves of trees in disked plots had significantly higher N concentrations than trees in other plots. Foliar nutrient concentrations of P, K, Ca, and Mg were not affected by cultural treatment. However, if we assume that leaf weight is related to D^2 or D^2H, then from 3 to 12 times more of each nutrient accumulated in trees in disked plots than those in other treatments.

Moisture measurements indicated that trees in disked plots utilized available soil moisture that was used by weeds and grasses in other plots. This could mean up to 50 percent more available moisture for use by trees in disked plots.

Recently, research was initiated on growing large seedlings in the nursery and in large containers for outplanting. No problems have been encountered in growing oaks in the nursery, and outplantings of two-year-old seedlings up to seven feet tall look promising. If a relatively large planted seedling could effectively supplement natural regeneration by increasing the oak component in a stand, it would eliminate the need for expensive site preparation and cultural treatments.

RESPONSES OF PLANTED NORTHERN RED OAK TO THREE OVERSTORY TREATMENTS

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Northern red oak (*Quercus rubra* L.) were planted in upland oak forests of the Missouri Ozarks. The 2,304 planted trees consisted of four classes of nursery stock: small 1+0, large 1+0, 1+1 and container-grown. Shoots were clipped on half of the trees in each class. Plantings were made in 8 clearcut plots and in 16 plots thinned to 60 percent stocking. Stumps of overstory trees (trees 4 cm dbh and larger) removed in clearcutting and thinning were treated with a herbicide to prevent sprouting; similarly, all woody stems from 1.3 to 3.9 cm dbh were cut and treated.

After three field growing seasons, the overstory was removed on one-half of the underplanted plots. After five field growing seasons, average survival was 84 percent. Average heights of survivors were: 118 cm for trees planted directly into clearcuts, 97 cm for underplanted/released trees, and 59 cm for underplanted/unreleased trees. Planted oaks that averaged 30 to 40 cm in net height growth per year after complete overstory removal were at least codominant with the briars (*Rubus* spp.) which formed a closed canopy about 1.5 m tall on the clearcut plots after 5 years.

Based on net shoot growth of trees after overstory removal, success probabilities were estimated using logistic regression analysis. Success probabilities were based on net annual height growth of planted trees after complete overstory removal (i.e., 5 years growth for trees planted directly into clearcuts and 2 years growth for underplanted/released trees). Among all classes of stock and overstory treatments, estimated success probabilities were greater for clipped than unclipped stock. The most successful trees were clipped 1+1 stock with initial shoot diameters (2 cm above the root collar) of 10 mm or more that were underplanted and subsequently released. For clipped 1+1 stock, success probabilities for a success criterion of 30 cm net height growth per year after overstory removal ranged from .61 to .77 for 10 to 16 mm diameter trees, respectively; for a success criterion of 40 cm, success probabilities were .42 to .63, respectively. Success probabilities for the same nursery stock planted directly into clearcuts ranged from .31 to .49 and .12 to .24 for 30 and 40 cm success criteria, respectively. Success probabilities for underplanted/released 1+0 stock 10 to 16 mm in diameter with clipped shoots ranged from .47 to .64 and .26 to .44 for 30 and 40 cm success criteria, respectively. Among trees planted directly into clearcuts, success probabilities were greater for container-grown stock than for any class of bare-root stock for a given initial shoot diameter.

OAK SEEDING AND PLANTING EXPERIENCES

E. C. Burkhardt, *Consulting Forester, Vicksburg, Mississippi*

Twenty-two years of experiences in artificially establishing cherrybark oak (*Quercus falcata* var. *pagodifolia* Ell.) and Shumard oak (*Q. shumardii* Buckl.) on loess bluff soils near Vicksburg, Mississippi have shown:

A. Initial development is slow.

B. On cleared forest sites four methods can be used: (1) planting large 1-0 seedlings, (2) planting five-month-old to one-year-old container-grown stock, (3) direct seeding, and (4) planting two- to three-year-old nursery stock.

C. On old fields, large 1-0 stock can be planted with success and it is possible that the other methods listed above will work.

D. Each establishment method has its advantages and disadvantages and it is likely that all the methods will be used with success in the future.

E. Competition varies among sites of equal quality but in general competition is more severe on the better sites.

The oldest of these plantings now have dominant cherrybark oaks in excess of 8 inches dbh. This uncultivated old field was planted to 1-0 nursery stock 22 years ago and appeared to be a complete failure for the first five years. Similar results were experienced using the other methods without cultivation.

Field Performance of Planted Oaks

ESTABLISHMENT OF NUTTALL OAK ON DIFFICULT SITES

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Two sites that are subject to flooding were planted to Nuttall oak (*Quercus nuttallii* Palmer) prior to the 1981 growing season. Both sites were on heavy clay soils in the Mississippi River floodplain in Mississippi. Flooding occurs annually at site A and once every two to three years at site B. Nuttall oak seedlings grown in 8-cubic-inch Styroblock containers were planted on both sites. Acorns were also direct-seeded on site A, and bare-root seedlings were planted on site B.

First-year survival of container-grown Nuttall oak seedlings was 66 and 20 percent on sites A and B, respectively. Both sites were planted in early June after floodwaters had receded. At the time of planting, site B soils were quite dry. Growth was poor at both sites, probably because of dry soils and hot weather. Rainfall was 80 percent of average in the study areas during the 1981 growing season.

Acorns were direct-seeded on site A in 1981 after the first spring flood which lasted 31 days. Ninety percent of acorns germinated and had grown approximately 8 inches in height when a second 21-day flood occurred. All seedlings originating from the direct seeding were killed by this flood.

In 1982, 1-0 bare-root Nuttall oak seedlings were planted in mid-May at site B. With growing season rainfall during 1982 at 124 percent of average, survival was 88 percent and trees maintained good vigor throughout the first year.

OAK PLANTATIONS: AN INDUSTRY SUCCESS STORY

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Thousands of acres of operationally established hardwoods are being tended by forest industries across the Southeast, and more acreage is being designated for future plantations. Approximately 2,000 acres of the water-willow oak complex (*Quercus phellos* L., *Q. nigra* L., *Q. laurifolia* Michx.) have been planted over the past decade in the Southeast. Technologies have rapidly developed for site preparation, spacing, fertilization, cultivation, chemical weed control, and coppicing methods. Simultaneously, a tree improvement program has begun to select and screen superior phenotypes.

To date the cooperators of the North Carolina Hardwood Research Program have identified approximately 30 superior trees and maintain tests containing 31 water-willow oak families, 7 replicated fertilization trials, 3 seedling seed orchards, 11 growth and yield plots, and have established over 100 species-site trials of which oak was usually a component.

Experience has shown that water-willow oak seedlings should have a 3/8-inch or larger diameter at the root collar and should be in good physiological condition when planted. Planting has been confined to the more clayey soils of the Coastal Plain that have limited internal drainage and a fairly high water table. Successful establishment only occurs following intensive site preparation and regular control of competing vegetation. Depending on soil test results, phosphorus may need to be applied at planting, but nitrogen usually will provide a significant response when applied a few years into the rotation. Another application of fertilizer may be necessary halfway through the rotation. Research is continuing to improve competition control and nursery stock management, and to determine nutritional and site requirements.

THE INFLUENCE OF SITE PREPARATION METHODS ON OAK REGENERATION IN BOTTOMLAND STANDS

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An evaluation of first year natural regeneration of East Texas bottomland hardwoods was conducted on three ten-acre clearcuts. The study evaluated the influences of the following site preparation treatments: shear, shear and broadcast burn, total injection (stems > 4.5 ft. height), partial injection (stems > 3.0 in. diameter), and control (no site preparation). Data were collected from a pre-harvest inventory and from a final inventory after the first growing season. Inventory of the pre-harvest overstory layer showed that bottomland oak species dominated the stands. Oaks comprised 54 percent of the mean total of 70 ft^2 of basal area per acre. The pre-harvest inventory of regeneration revealed that oaks comprised 813 stems per acre of the mean total of 2,787 stems per acre. The final inventory of the regeneration revealed that oaks comprised 560 stems per acre. This decrease was significant ($p < 0.10$) and resulted from a significant decrease in oak regeneration in one ten-acre stand. The other stands remained at or above pre-harvest levels. Oak species composition changed, as cherrybark oak (*Quercus falcata* var. *pagodifolia* Ell.) decreased from 193 stems per acre before harvest to 14 stems per acre after the first year. Overcup oak (*Q. lyrata* Walt.) regeneration increased from 60 stems per acre before harvest to 140 stems per acre after the first year and thus replaced cherrybark oak as a major regeneration constituent. Comparison between the pre-harvest and the first-year oak regeneration inventories showed that oaks declined as site preparation intensity increased. Control areas showed a 24 percent increase in oaks while shear and burn areas showed a 65 percent decrease. Sprouting was also inhibited by the more intensive site preparation treatments. This study suggests that to facilitate oak development after clearcutting, only low-intensity treatments or no site preparation should be used on bottomland sites.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1984—767-145/10061

INFLUENCE OF SITE AND MYCORRHIZAE ON THE ESTABLISHMENT OF BARE-ROOT AND CONTAINER-GROWN RED OAK SEEDLINGS

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Site condition plays a major role in determining the survival and growth of planted oak seedlings. However, seedling production and planting techniques that minimize planting shock or ameliorate the planting micro-site can reduce negative site effects. The objective of this study was to determine the influence of seedling production method (bare-root or container-grown) and the presence or absence of mycorrhizal endophyte (*Pisolithus tinctorius* (Pt)) on the establishment of 1-0 northern red oak (*Quercus rubra* L.) seedlings planted on sites typically available for reforestation in the Midwest. Sites selected for study were an abandoned old field (AOF), a clearcut (C), and a recently cultivated field (RCF) on marginal farmland.

Three years after planting, seedling survival was greatest on the AOF site (94 percent) followed by sites C (89 percent) and RCF (82 percent). Conversely, 3-year volume growth was greatest on the RCF site (142 cm^3) followed by sites C (78 cm^3) and AOF (67 cm^3). Survival and 3-year volume growth of inoculated and noninoculated container-grown and inoculated bare-root seedlings was significantly greater than noninoculated bare-root seedlings. Foliar N concentration was not significantly influenced by any of the variables tested but tended to be greatest for container-grown seedlings; however, N decreased with time among all classes of seedlings. For a given site, inoculated seedlings had greater concentrations of foliar P than noninoculated seedlings. The persistence of Pt on inoculated seedlings varied depending on site and seedling production method. After 3 years, inoculated seedlings planted on the RCF site had more Pt than noninoculated seedlings. On all sites the correlation (r) between Pt infected roots and annual volume increment or percent foliar P declined with time. Mycorrhizal infection potential of the soil was adequate on the clearcut and old field sites at the initiation of the study and showed little change with time. The RCF site, which initially had low mycorrhizal infection potential, showed large increases in infection potential with time.

U.S. Department of Agriculture, Forest Service. Johnson, Paul S.; Hodges, John D., eds. In: Abstracts, 2d workshop on seedling physiology and growth problems in oak planting; 1983 February 8-9; Mississippi State, MS. Gen. Tech. Rep. NC-99. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1984. 21 p.

Research results and ongoing research activities in oak planting and related physiology and genetics studies are described in 21 abstracts.

KEY WORDS: Plantations, propagation, regeneration.