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Tenth Workshop on Seedling Physiology and Growth Problems in Oak Plantings

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We also acknowledge the invited speakers, Stacy Clark, Philip O'Connor, Daniel Dey, and Martin Spetich, for providing informative presentations to lead each session.

Cover Photos

Figures on the front cover represent four critical phases in the artificial establishment of an oak (*Quercus* spp.) stand – acorn production, nursery practices, planting operations, and stand development. Clockwise from upper left: *(a)* An 8-year-old Shumard oak (*Q. shumardii* Buckl.) with maturing mast in Chicot County, AR; *(b)* Cherrybark oak (*Q. pagoda* Raf.) seedling nursery bed at the Delta-View Nursery, Washington County, MS; *(c)* A supplemental oak planting operation following a shelterwood harvest on the Three Rivers Wildlife Management Area, Concordia Parish, LA; and *(d)* A 20-year-old water oak (*Q. nigra* L.) plantation on the Yazoo National Wildlife Refuge, Washington County, MS. All photos are by Brian Roy Lockhart, U.S. Forest Service.

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TENTH WORKSHOP ON SEEDLING PHYSIOLOGY AND GROWTH PROBLEMS IN OAK PLANTINGS OCTOBER 16-17, 2007

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OAK RESEARCH AND TECHNOLOGY TRANSFER ACTIVITIES OF THE UNIVERSITY OF TENNESSEE'S TREE IMPROVEMENT PROGRAM

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The University of Tennessee's Tree Improvement Program is in its 49th year of conducting research and technology transfer activities with a special emphasis on hardwood species, particularly oak *(Quercus* spp.). Programs have included seed orchard construction and development, nursery studies, silviculture tests with genetic backgrounds, agroforestry, afforestation studies, and precision forestry. Cooperative research is being conducted in molecular genetics with scientists seeking pedigreed materials and pedigreed field studies. Afforestation and reforestation activities with the Tennessee Wildlife Resources Agency are being conducted to restore bottomland losses to agricultural sites. The program's work with seed orchard development and nursery practices is geared to provide locally adapted high quality seedlings to achieve land management goals. The program currently has plantings from New York state to Nebraska in various stages of development.

TWO-YEAR SURVIVAL OF PLANTED SEEDLINGS AS INFLUENCED BY PLANTING STOCK, PLANTING METHOD, FERTILIZATION OR COMPETITION CONTROL

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Oaks (*Quercus* spp.) are valued in the South both for timber production and wildlife habitat. Survival and rapid early growth of planted oak seedlings has long been a concern of forest managers in the South. More than 500,000 acres (200,000 ha) have been planted across the region, and survival in many of these plantings has been unacceptably low. U.S. Forest Service scientists developed a nursery protocol for production of "enhanced" oak seedlings which have demonstrated excellent survival, rapid early growth, and early acorn production when planted and managed under an intensive regime. The objective of this project was to evaluate the influence of planting stock, planting method, fertilization, and competition control on survival and early growth of Nuttall (*Q. nuttallii* Palm.) and white (*Q. alba* L.) oak seedlings.

In February 2005, a total of 6,560 1-0 bare-root seedlings were planted at two former agriculture fields (one bottomland and one terrace) in Mississippi. This total included 1,640 of both the "enhanced" and "nursery-run" seedlings of both species at each location. Survival was evaluated at the end of the first and second growing seasons. Survival did not differ by planting stock within a species. Neither planting method nor fertilization had a significant effect on survival. Survival did vary by site for white oak and varied by competition control.

RESULTS FROM A 20-YEAR-OLD BOTTOMLAND OAK SPECIES COMPARISON TRIAL IN WESTERN KENTUCKY

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Greater financial returns from hardwoods are primarily based on two factors: species and quality. Species such as red and white oak (*Quercus* spp.), black walnut (*Juglans nigra* L.), black cherry (*Prunus serotina* Ehrh.) and green ash (*Fraxinus pennsylvanica* Marsh.) traditionally bring the highest revenue. However, the key is the quality that individuals within these species exhibit.

The test site for this study is located along Mayfield Creek 8 km (5 mi) east of the Mississippi River in Ballard County, Kentucky. Open-pollinated seed from seven mother trees were collected during the fall of 1985 from each of five species of red oaks, which included cherrybark oak (*Q. pagoda* Raf.), Nuttall oak (*Q. nuttallii* Palm.), pin oak (*Q. palustris* Muenchh.), water oak (*Q. nigra* L.), and willow oak (*Q. phellos* L.). The test was planted March 27, 1987. Herbaceous and vine competition was controlled during the first and second year by disking.

At age 20, differences in survival and growth among species were limited but form characteristics differed greatly among the five species. For all species mortality was highest between ages 1 and 3 during plantation establishment until tree-to-tree competition began increasing between the ages of 10 and 20 years. At age 20, willow oak had the highest survival, water oak the overall best growth and cherrybark oak the best form. Although suppressed trees quickly fell out of the stand there has been little regeneration in grasses and forbs due to the thick leaf litter and insufficient sunlight reaching the forest floor.

The general trend in height and diameter growth indicates a rather slow establishment period between ages 1 and 3. Height growth, on a yearly basis, peaked for all species between the ages of 5 and 10 years with water oak averaging 1.2 m (4 ft) of height growth per year. Correlations between age-1 height and age-20 height for all oak species were poor, with Nuttall oak exhibiting a negative correlation. As expected, correlations strengthened as age increased toward age 20. Currently, age-10 height exhibits fairly strong correlations with age-20 height, making crop tree selection effective at age 10.

The early self-pruning ability of cherrybark oak provided a cleaner bole than the other oak species. In addition, water oak was found to have more than eight times the number of form type defects as cherrybark oak at age 20. This striking difference in form quality between these two species indicates that if the site is suitable for cherrybark oak it would be advantageous to plant this species rather than water oak.

ENHANCING NATURAL BLUE OAK REGENERATION IN CALIFORNIA

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For almost a century there has been concern that blue oak (*Quercus douglasii* Hook. & Arn.), a California endemic, is not regenerating adequately in portions of its range. For the last 20 years, there have been concerted efforts to develop successful procedures for artificially regenerating this species so that it can be planted in areas where natural regeneration is unsuccessful, or in areas where it once grew but has been lost. These efforts have been successful in identifying procedures that will work, but unfortunately, such procedures often require intensive management and are costly. Since 80 percent of the oak woodlands in California are privately owned and the principal activity is livestock grazing, many large woodland owners and managers have marginal incomes and are reluctant to spend much money to regenerate oak trees.

An alternative, but untested, approach is to use naturally regenerating oak seedlings and take measures to promote their advancement to the sapling stage. This could be critical since research has demonstrated that the bottleneck for successful regeneration is often getting seedlings to grow into saplings. If successful, using natural seedlings could result in considerable savings because no effort or cost would be expended to collect acorns, or to grow and plant seedlings. An additional advantage would be that only genetically adapted plant material would be used, alleviating concerns about using "offsite" planting stock. Because of these economic, ecologic, and low input (i.e., less work) advantages, the development of techniques to advance natural regeneration holds great promise for being adopted and implemented by landowners.

To test this strategy, a study was recently initiated at six sites in the range of blue oak throughout the state. At each site, 144 naturally occurring blue oak seedlings were identified. Half of these were under the canopy of onsite trees and half were in the open. In addition, treatments included protecting seedlings with tree shelters and controlling weeds. When the plots were established the height of each seedling was recorded. Yearly assessments of survival, height and diameter will be made to evaluate the efficacy of the treatments.

It is hoped that results from this study will yield meaningful information relating to approaches that can be used to enhance the natural regeneration of blue oak in California. If successful techniques are identified, they could help promote increased blue oak regeneration and thereby enhance the conservation of this critical species throughout the state.

DOING MORE WITH LESS: EFFICIENCIES AT VALLONIA STATE NURSERY

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In today's economic environment, it takes some innovation and ingenuity to continue to produce seedlings of the high quality that has become our standard, with costs of production rising and budgets shrinking.

Our standard operating procedures include use of fallow field cover crops specifically chosen for compatibility with our programs to suppress weeds and pathogens. We fall sow our tree/shrub crop seeds with an overseeding of rye or wheat to hold the seedbeds in place against erosion caused by wind and rain. We mulch all our large seeded species [oaks (*Quercus* spp.), hickories and pecans (*Carya* spp.), walnuts (*Juglans* spp.)] with a 10 to 15 cm (4 to 6 in) layer of straw to protect them from seed predation and deep temperature injury during germination. We follow integrated pest management procedures in nursery beds and seed orchards. We scarify, stratify and treat our own seed as necessary. We follow a carefully tailored nutrient-loading regime based on research conducted by Purdue University at our site. We test every lot of seed bought or collected by the nursery to determine the total volume of "pure live seed". We use this information to calibrate our shop-fabricated specialty planters in order to strictly control our seedbed density.

When we have problems or issues that need to be addressed we make use of any available expertise. We can rely on the National Tree Seed Lab, and our local Plant Pest Diagnostic Lab, as well as a commercial soil and plant fertility testing lab. Often, however, there is no source of expertise available on the issues we have. In such cases we conduct our own studies. We have developed a spray protocol for herbicide control of broadleaf weeds in our seedbeds. We have developed a fungicide rotation protocol to decrease the build-up of resistance in the pathogens. We have developed seed treatment protocols to increase the level of germination in dry-stored seed. Finally, we have combined several methods to develop a successful program to reduce bird predation of seeds, and have evaluated several chemicals for reducing weevil infestation in our seed orchards.

The Vallonia State Nursery strives to increase its level of efficiency. If we can produce a higher percentage of viable seed, get a higher percentage of the seed to germinate, and raise a higher percentage of the germinated seed to a saleable size, within our budget, then we can reach that goal.

A CONCEPTUAL MODEL FOR DEVELOPING MIXED-SPECIES PLANTATIONS IN THE LOWER MISSISSIPPI ALLUVIAL VALLEY

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Oak (*Quercus* spp.) afforestation in the Lower Mississippi Alluvial Valley has involved planting 1-year-old bareroot seedlings on a relatively wide spacing in single species stands or planting light-seeded species with oaks to form mixed-species stands. In the former case, the developing single-species stands have limited future management options because they do not provide structures that favor quality wildlife habitat or quality sawtimber production. In the latter case, species mixtures are being planted with little knowledge of subsequent stand development, leading to an inability to predict future stand composition for management purposes. We present a conceptual model to determine bottomland tree planting mixtures that will create single-cohort, mixed-species stands with a component of high quality bottomland oak. Using individual species' ecological life-history characteristics, such as early height growth patterns, relative twig diameter and durability, and developmental patterns in natural stands, bottomland species are rated for their ability to provide beneficial training effects that will lead to the development of quality oak boles. Incorporating such a system to determine species value in mixtures should provide an increased number of future options to meet explicit management objectives and promote improved bottomland hardwood restoration.

INTEGRATING A WOOD QUALITY COMPONENT WITH THE SYLVAN STAND STRUCTURE MODEL FOR COMPARING CHERRYBARK OAK PLANTATION MANAGEMENT SCENARIOS

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Plantations will occupy an increasing proportion of the landscape in the future. This is particularly true for temperate hardwood plantations in the southern United States as reflected by the recent increases in afforestation activities in the Lower Mississippi Alluvial Valley. Hardwood plantation management has been constrained by limited information. The result has been the reliance on a paradigm derived from and dominated by pine plantation science and generally limited to monocultures. Anecdotal and empirical evidence suggests this approach may not be optimal for hardwood plantations where wood quality is a significant determinant of stand and stem value. One alternative to monospecific hardwood plantation management is a mixed-species approach. Although mixed species plantations have a long history and some convincing research exists, little operational or commercial adoption has been realized. An argument with significant economic implications will be necessary to increase the utilization of mixed species hardwood plantations.

A simulation system was developed by integrating a wood quality module within the Sylvan Stand Structure Model. The simulation system, CherrybarkSQ, was developed to investigate the impact of plantation design on the development of clear wood within cherrybark oak (*Quercus pagoda* Raf.) stems. Of particular interest was the difference, if any, between pure and mixed species designs of similar density. After simulations of approximately 50 years, the mixed species design resulted in trees with a higher proportion of clear wood than the pure design of the same initial planting density. In addition, a widely spaced pure cherrybark oak plantation produced more clear wood per tree than pure plantations at a denser spacing.

CherrybarkSQ simulations of mixed species hardwood plantations resulted in higher quality cherrybark oak stems than monocultures of the same planting density. The increase in stem quality improves stand-level value. The knowledge that a mixed-species approach to cherrybark oak plantation management may improve stand-level value and therefore increase investment opportunities and returns, should play a role in increasing research and commercial establishment of mixed species hardwood plantations.

THE USE OF RELATIVE GROWTH RATES TO ASSESS FLOOD TOLERANCE IN OAK SEEDLINGS

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Planting oak seedlings in bottomland restoration plantings has received increased attention in recent years. While specific species have been favored, little or no attention has been focused on the potential genetic variation in flood tolerance that may exist within different oak (*Quercus* spp.) species. Knowledge of intraspecific variation, if it exists, would be an important factor to consider insuring the long-term survival and growth of newly planted trees on flood-prone sites. The objective of this study was to characterize the variation in relative growth rates of seedlings from multiple families of two native oak species within three topographic positions in response to flooding.

A total of 357, 1-0 bare-root seedlings of bur oak (*Q. macrocarpa* L.) and swamp white oak (*Q. bicolor* Willd.) grown from seed collected on wet, mesic, and dry topographic positions were established in pots. Half of the seedlings were flooded for 5 weeks in six large water tanks starting 65 days after potting. Six tubs served as a nonflooded control. Timing of the flood coincided with the completion of the first growth flush in late May. About one half of the trees were harvested immediately following flooding (100 day post-potting) while the remaining trees were retained in pots within the tubs until the end of the growing season (200 day post-potting). Data for leaf area and dry weight and for seedling dry weight (root, shoot, and leaves) were recorded for each tree. In addition, a subset of 90 bare-root seedlings of each species was used to develop a simple linear regression equation to determine initial seedling dry weights as a function of root collar diameters (RCD). Initial seedling dry weights were calculated using the formula: $y = 4.047x - 18.784$ ($R^2 = 0.68$), where y = initial seedling dry weight (g), and x = root collar diameter (mm). Relative growth rate (RGR) was calculated as the weight gain divided by number of days and final seedling dry weight.

In general, there was a trend for RGRs to decrease with increasing RCD for both species. The smaller seedlings of bur oak tended to exhibit a decrease in their RGR values when flooded while larger seedlings exhibited similar growth patterns regardless of flooding treatment or seed origins. These trends should be viewed with caution since there were only 142 bur oak seedlings and few seedlings flushed following flooding. Nonflooded seedlings of swamp white oak from wet and dry, but not mesic, topographic positions increased in dry weight. When flooded, the larger swamp white oak seedlings from mesic and wet, but not dry, topographic positions increased in post-flood dry weight. Because of the differential RGR responses observed, initial seedling size and acorn origin will play an important role in defining the flood tolerance of oak seedlings used in bottomland restoration plantings.

AFFORESTING OAKS IN BOTTOMLANDS

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Several factors are critical when regenerating oak in agricultural bottomlands: species selection, site ydrology, soil characteristics, nursery stock types, competing vegetation, and animal damage. First, species selected must be adapted to site environment, and in particular, hydrology and soil. Flood regime (frequency, duration, season, depth, flow) in combination with soil character and topography determine the influence of water on trees. The flood tolerance of a species and other silvical characteristics are valuable for determining the suitability of a species. Flood lab studies help to better quantify the flood tolerance of seedlings and cuttings for given flood regimes; and to determine the genetic variability in flood tolerance for a species.

Disking, ripping, and bedding are used to improve structure, drainage and increase the rooting zone on clayey and silty soils, and soils with traffic pans. Soil bedding did not improve oak (*Quercus* spp.) survival and growth on well drained silt loam soils that flooded for up to a month in May-June. Decades of crop production can deplete nitrogen and organic matter that limits tree physiological function. Tree nutrition is further limited by high soil pH (e.g., 7.8 to 8.0). Bur oak (*Q. macrocarpa* Michx.) and Shumard oak (*Q. shumardii* Buckl.) can tolerate high soil pH; Nuttall oak (*Q. nuttallii* Palm.), cherrybark oak (*Q. pagoda* Raf.), pin oak (*Q. palustris* Muenchh.), and water oak (*Q. nigra* L.) are very sensitive to alkaline soils. Fertilizing with ammonium nitrate or urea slow release fertilizer has not been sufficient to overcome low foliar nitrogen and chlorosis in pin oak and swamp white oak (*Q. bicolor* Willd.) on high pH soils. Studies are under way to evaluate the usefulness of ammonium sulfate to acidify soils, improving nitrogen, and micronutrient uptake in oak.

High quality, large oak seedlings grown as bareroot or container seedlings have performed well in bottomland plantings. Seedlings that are greater than 1.5 m (5 ft) tall at planting are less susceptible to browsing by large mammals and are more likely to maintain their live crowns above growing season floods. These seedlings have a substantially larger root structure and mass than traditional bareroot. They are also capable of early acorn production. Regardless of stock type, competing vegetation must be controlled. Disking, herbicides and cover crops have improved oak regeneration success. Managing competing vegetation also provides indirect benefits to planted trees by reducing the habitat of small mammals, and their herbivory on planted trees. Plantations can be fenced or individual trees can be protected from herbivores. We have sufficient knowledge and guidance to successfully afforest bottomlands. Research continues to work on the unknown and discover more effective and efficient methods for establishing oaks in floodplains.

ENHANCING OAK GROWTH AND DEVELOPMENT ON LOUISIANA WETLANDS RESERVE PROGRAM EASEMENTS

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The Wetlands Reserve Program (WRP) provides the technical and financial assistance to restore agricultural land to a functional wetland state. The restoration process addresses soil, water, wildlife and other related natural resource concerns in an environmentally beneficial and cost-effective manner. Current tree establishment practices in Louisiana fail to provide the vertical structure and hard mast production in a "near-immediate time frame" necessary for sustaining avian and deer populations. Field trials in Georgia and Arkansas have shown that planting large 1-year-old potted seedlings enhances oak performance. The purpose of this conservation field trial was to evaluate the potential of potted and containerized seedlings for special applications on WRP restoration projects and determine the impact of comprehensive site preparation on bare-root, potted and containerized seedling survival and growth.

The trial was established in 2003 on a WRP easement north of Natchitoches, LA, which included three soil texture components: Severn sandy soil, Gallion loamy soil, and Moreland clayey soil. Nuttall oak (*Quercus nuttallii* Palm.) was chosen as the potted and containerized seedling species and the bare-root seedling species included Nuttall, water (*Q. nigra* L.) and willow oak (*Q. phellos* L.); and sycamore (*Platanus occidentalis* L.) and green ash (*Fraxinus pennsylvanica* Marsh.). Pre-plant site preparation practices included mowing, herbicide treatment and a deep-rip plus herbicide treatment. In addition, half of each pre-plant treatment received a post-plant herbicide treatment. The pre-plant herbicide was applied at 75.7 l ha^{-1} (20 g ac^{-1}) as a tank mix of glyphosate and sulfmeturon methyl (9.4 l ha^{-1} and 220 ml ha^{-1}, or 4 qt ac^{-1} and 3 oz ac^{-1}, respectively). Post-plant herbicide application was a banded spray of sulfmeturon methyl at 146 ml ha^{-1} (2 oz ac^{-1}).

Containerized Nuttall oak seedlings were susceptible to animal predation. By the fall of 2004, container survival on all soil texture components was less than 10 percent. Pre-plant herbicide treatment increased bare-root seedling survival rates by 15 percent, while post-plant treatment had no apparent impact. Deep-ripping had no impact on potted Nuttall oak or bare root green ash survival but did improve bare-root oak and sycamore survival by 20 percent.

EVALUATION OF ROOT FORCE™ CONTAINER SEEDLINGS OF FOUR OAK SPECIES FOR BOTTOMLAND FOREST RESTORATION IN SOUTHERN INDIANA: 5-YEAR RESULTS

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Bottomland forest restoration has become an area of interest in the last 10 to 15 years due to large scale bottomland flooding. Seed sources for heavy seeded species, such as the various native bottomland oaks (*Quercus* spp.), are nonexistent, thus planting seedlings is needed to increase the proportion of heavy seeded trees to diversify bottomland forests. Nursery-grown bareroot seedlings are not usually competitive and do not survive well in areas with heavy vegetation and grass, especially where herbicides cannot be used for competition control. Larger container-grown seedlings may be more competitive than bareroot seedlings in afforesting productive bottomlands.

We tested the field performance of 1-year-old, large-rooted Root Force™ seedlings grown in 3.8 liter (1 g) and 11.4 liter (3 g) containers and compared them with 1-0 bareroot seedlings at a bottomland restoration project along Otter Creek on the Hoosier National Forest in southern Indiana. Four bottomland oak species were used: bur (*Q. macrocarpa* Michx.), pin (*Q. palustris* Muenchh.), Shumard (*Q. shumardii* Buckl.), and swamp white (*Q. bicolor* Willd.). Seedlings were planted in a fescue-dominated bottomland pasture. Half of the seedlings had a weed control treatment that consisted of placing a 1.2 m by 1.2 m (3.9 ft by 3.9 ft) weed barrier mat around each seedling. The remaining seedlings grew in direct competition with fescue grass and other vegetation.

Survival for all species and stock types was similar after the first year, 99 to 100 percent, respectively. By the fifth year, survival ranged from 46 to 88 percent for all species and stock types, respectively. Although the 3.8 liter container-grown seedlings [shoot height, 30.9 cm (12 in), and diameter, 5.6 mm (0.22 in)] were the smallest at planting, their survival after 5 years was highest. Survival for the 11.4 liter container-grown seedlings was lowest even though their initial shoot diameter was larger than the 3.8 liter container-grown seedlings. Shumard oak had the lowest survival rate. Weed control had no influence on survival.

All stock types showed positive height growth the fifth year. After 5 years, the container-grown seedlings remained the shortest in total height [77.6 and 77.4 cm (30.6 in and 30.5 in)] for the small and large containers, respectively) while the bareroot seedlings were tallest (84.9 cm or 33.4 in). For all four species, bareroot seedlings had the lowest net height growth after 5 years. In the 5 years, the 3.8 l (1 g) container-grown seedlings grew 47.8 cm (18.8 in); the 11.4 liter container-grown seedlings grew 29.8 cm (11.7 in), and the bareroot seedlings grew 24.7 cm (9.7 in) in height. The height growth for all seedlings was influenced by deer browsing; thus there appeared to be no preference for any stock type. Five-year field performance provides no clear superior stock type.

OAK SEEDLING OUTPLANTING PERFORMANCE

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Outplanting performance is often examined through direct growth and survival measures. Additionally, a seedling's success relative to its competitors, its competitive capacity, can be quantitatively expressed as the probability that a planted tree will attain dominance among competitors after a specified period. These dominance probabilities encompass traditional growth and survival measures while further integrating the planted tree's initial characteristics, and characteristics of competitors together with the planted tree's growing environment. The growing environment includes site quality and environmental changes resulting from silvicultural practices such as weeding and thinning before and after planting. We define competitive capacity as "a tree's ability to survive and grow at a rate sufficient to attain and maintain dominance among its competitors." This talk examined the concept and application of competitive capacity as applied to outplanted 2-0 northern red oak (*Quercus rubra* L.) seedlings. Oak planting by methods similar to those described in these examples may provide viable silvicultural alternatives for maintaining oaks on sites where oaks are threatened through species displacement or where they are now absent.

Additional information on these methods can be found at:

1. Science Paper: www.srs.fs.fed.us/pubs/4719
2. A Technical Transfer "How To" Article: www.srs.fs.fed.us/pubs/6543
3. Interactive OAKUS Program: www.ncrs.fs.fed.us/OAKUS/

FIRST-YEAR EVALUATION OF TWO NORTHERN RED OAK (*QUERCUS RUBRA* L.) PLANTINGS DURING A DROUGHT YEAR

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Oak (*Quercus* spp.) reproduction can be introduced artificially through seedling planting on sites where natural reproduction is absent or when large oak reproduction is desired within a short time span. Specific parameters affecting early seedling performance are not well understood. The objectives of this study were 1) to determine if nursery seedling grade and characteristics can be used to predict first-year survival and dieback of outplanted seedlings; 2) to determine differences between seedling grade in first-year height and ground diameter growth; and 3) to characterize the relationship between competition, light and outplanting performance.

Nursery seedlings were lifted from one large family seed lot at the Georgia State Nursery in February 2007, and two seedling grades, premium and nursery-run, were visually distinguished. Seedlings from each grade were planted at two study sites located on the Royal Blue Wildlife Management Area, TN. The first site was treated with a midstory herbicide injection the first growing season after planting and the second site was a 1-year-old shelterwood harvest. Seedling performance was evaluated after one growing season.

Premium grade seedlings were significantly taller, larger in basal diameter and had more roots than Nursery-run seedlings at time of planting. Extreme drought during the growing season likely resulted in delayed leaf-out and increased mortality of the midstory treatment (31 percent) and the shelterwood stand (25 percent). Occurrence of dieback for both plantings was 25 percent and was negatively related to planting height. Taller seedlings at planting may have had increased stem dehydration during a particularly dry growing season resulting in mortality and contributing to the occurrence of stem dieback. However, other nursery variables used in selection of premium seedling grade, particularly number of roots, positively impacted first-year survival. Seedling grade did not significantly impact height or diameter growth in the midstory treatment, but nursery-run seedlings did have more height growth than premium seedlings in the shelterwood stand. Although the amount of light did not significantly differ between free-to-grow and suppressed seedlings in the shelterwood stand, free-to-grow seedlings had significantly more diameter growth. This research will provide important information for prediction of seedling performance given easily measured nursery and field characteristics, and will provide probability estimates for expected seedling success for a range of seedling sizes and competition control measures.

PERFORMANCE OF FOUR HARDWOODS ON A GOOD PREHARVESTED SITE, WITHOUT WEED CONTROL, TREATED WITH FIRE BEFORE PLANTING AND WITH AND WITHOUT TREE SHELTER

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The performance of four hardwoods, black walnut (J*uglans nigra* L.), northern red oak (*Quercus rubra* L.), white oak (*Q. alba* L.), and cherrybark oak (*Q. pagoda* Raf.), is being studied on an upland landform in southern Illlinois. The soil is a deep (solum thickness > 160 cm or 63 in), well drained Alford silt loam (fine-silty, mixed mesic Typic Hapludalfs) occupying slopes ranging from 6 to 18 percent. Merchantable trees were harvested, and all remaining trees, shrubs, and grapevines (*Vitis* spp.) were removed manually. No other site preparation was done until 2 years later when it was estimated that forest floor vegetation was sufficient to support a sustained fire to kill most of the regeneration. The area covered by the burn was inconsistent and will not be discussed further.

Seedlings were planted in rows spaced at 2.43 m (8 ft) apart and 1.8 m (6 ft) apart within rows. The six treatments included 1) control; 2) tree shelters (clear and amber in color); 3) tree mats (1.2 by 1.2 m or 4 ft by 4 ft) alone, and in combination with each other; 4) tree shelter x tree mat, and with slow-release fertilizer (16N-6P-8K) packet (Right Start™); 5) tree shelter x slow-release fertilizer; and 6) tree mat x slow release fertilizer. Treatments were randomized within rows. No weed control was provided nor was any precaution taken against deer browsing. The experiment was analyzed as an incomplete factorial design analysis of variance.

Nine years after planting, survival of all four tree species was better with tree shelters than without them. Except for black walnut, survival was better for trees enclosed in clear shelters than for trees enclosed in amber color shelters. One 10 g (0.4 oz) packet of fertilizer improved survival for all species. Tree mats decreased survival for all species.

Tree shelters did not affect height growth the same for all species. Ninth-year height of black walnut was not affected, but it was for red oak, white oak, and cherrybark oak. Both northern red oak and cherrybark oak were taller in clear shelters than in amber shelters. The height of black walnut, white oak, and cherrybark oak was greater with fertilizer at planting than without it. The height of northern red oak was less with fertilizer than without fertilizer. Trees with tree mats were shorter than trees without them.

POSTER PRESENTATION

CONTROL OF ACORN WEEVILS IN A BUR OAK SEED ORCHARD

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Acorn weevils in the genus *Curculio* present a ubiquitous problem. In seed orchards that are managed to promote increased cropping and reduced alternate bearing, populations of these insects are seldom in decline. The weevils overwinter and pupate in the soil. In mid-summer adults begin to emerge and crawl or fly to the trees where they chew through the acorn's seed coat and deposit one to several eggs. Developing larvae feed on the cotyledonary tissue and often render the acorns unviable.

No chemical controls are currently registered for use in controlling acorn weevils. This study evaluated the efficacy of a single application of each of four chemicals:

- Safari® (Dinotefuran) at two rates applied basally with a penetrant
- Merit® (Imidacloprid) applied as a soil drench
- Orthene® (Acephate) applied both basally with a penetrant and as a foliar spray
- Dursban® (Chlorpyrifos) applied as a foliar spray

A mid-summer application of the first three insecticides was made in an 8-year-old grafted bur oak (*Quercus macrocarpa* Michx.) seed orchard. The orchard was supporting a bumper crop of acorns. Simultaneously, conical wire-screen weevil traps were set out in areas of the orchard that had produced seed the prior year. Weevil emergence was monitored semiweekly with the traps. At peak emergence a foliar application of Dursban was made.

At maturity, the acorns from each treatment were collected, dissected, and evaluated for weevil infestation. All treatments were statistically better than the control. All the systemic treatments (Safari, Orthene, Merit) performed better than the contact and surface residual treatment (Dursban).

This study is also ongoing in a northern red oak (*Q. rubra* L.) planting, however, later seed maturation in that species has precluded those results from being reported here.

FIELD TOUR SYNOPSIS

Participants of the 10th Workshop on Seedling Physiology and Growth Problems in Oak Plantings toured selected sites in the Lower Mississippi Alluvial Valley (LMAV) and Bluff Hills on October 17, 2007. The first stop was on the U.S. Fish and Wildlife Service's Carter Tract, where the group examined operational afforestation of bottomland oaks on former agricultural land with discussion on site preparation, seedling quality, competition control, stocking, and species mixture issues. The second stop was on the Sharkey Restoration Research and Demonstration Area. The group examined an alternative afforestation system involving eastern cottonwood (*Populus deltoides* Bartr. ex Marsh.) and Nuttall oak (*Quercus nuttallii* Palm.) for restoring bottomland hardwood forests. The group also toured the Flooding Research Facility, which is used to study the ecophysiology of bottomland species in response to hydroperiod and light availability.

In the afternoon, the group examined a 30-year-old direct seeded Nuttall oak plantation on the Delta National Forest. Discussion centered on use of direct seeding in LMAV afforestation and the influence of natural reproduction in plantation development. The final stop was at Anderson-Tully Company's "Big Holloman Place" tract at the base of the Bluff Hills. The group examined an 18- to 20-year-old cherrybark oak (*Q. pagoda* Raf.) plantation mixed with natural sweetgum *(Liquidambar styraciflua* L.). Discussion centered on the development of single-species plantations versus mixed-species stands.

INDEX TO OAK (*QUERCUS*) SPECIES INCLUDED IN ONE OR MORE ABSTRACTS

Sub-genus and species[1]	Common Name	Pages
RED OR BLACK OAK GROUP (SECTION *LOBATAE*)		
Q. nigra L.	water oak	3, 9, 10
Q. nuttallii Palmer	Nuttall oak	2, 3, 9,10
Q. pagoda Raf.	cherrybark oak	3, 7, 9,14
Q. palustris Muenchh.	pin oak	3, 9, 11
Q. phellos L.	willow oak	3, 10
Q. rubra L.	northern red oak	12, 14, 15
Q. shumardii Buckl.	Shumard oak	9, 11
WHITE OAK GROUP (SECTION *QUERCUS*)		
Q. alba L.	white oak	2, 14
Q. bicolor Willd.	swamp white oak	8, 9, 11
Q. douglasii Hook. & Arn.	blue oak	4
Q. macrocarpa Michx.	bur oak	8, 9, 11, 15

[1]Duncan, W. B.; Duncan, M.B. 2000. Trees of the southeastern United States. Athens, GA: University of Georgia Press. 336 p.

PAST WORKSHOPS ON SEEDLING PHYSIOLOGY AND GROWTH PROBLEMS IN OAK PLANTINGS

No.	Location	Date	Proceedings
1st	Columbia, MO	November 6-7, 1979	http://ncrs.fs.fed.us/pubs/gtr/gtr_nc062.pdf
2nd	Mississippi State, MS	February 8-9, 1983	http://ncrs.fs.fed.us/pubs/gtr/gtr_nc099.pdf
3rd	Carbondale, IL	February 12-13, 1986	http://ncrs.fs.fed.us/pubs/gtr/gtr_nc121.pdf
4th	Columbus, OH	March 1-2, 1989	http://ncrs.fs.fed.us/pubs/gtr/gtr_nc139.pdf
5th	Ames, IA	March 4-5, 1992	http://ncrs.fs.fed.us/pubs/gtr/gtr_nc158.pdf
6th	Rhinelander, WI	September 18-20, 1995	http://ncrs.fs.fed.us/pubs/gtr/gtr_nc182.pdf
7th	Lake Tahoe, CA	September 27-29, 1998	http://ncrs.fs.fed.us/pubs/gtr/gtr_nc206.pdf
8th	Hiawassee, GA	September 9-12, 2001	http://ncrs.fs.fed.us/pubs/gtr/gtr_nc224.pdf
9th	West Lafayette, IN	October 18-20, 2004	http://ncrs.fs.fed.us/pubs/gtr/gtr_nc262.pdf
10th	Jackson, MS	October 16-18, 2007	http://nrs.fs.fed.us/pubs/gtr/gtr_nrs-p-32

Lockhart, Brian Roy; Gardiner, Emile S.; Dey, Daniel C., eds. 2008. **Tenth workshop on seedling physiology and growth problems in oak plantings**; 2007 October 16-17; Jackson, MS. Gen. Tech. Rep. NRS-P-32. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 18 p.

Research results and ongoing research activities in field performance of oak plantings, seedling propagation, genetics, acorn germination, and natural regeneration of oaks are described in 15 abstracts.

Keywords: Plantations, propagation, regeneration.

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