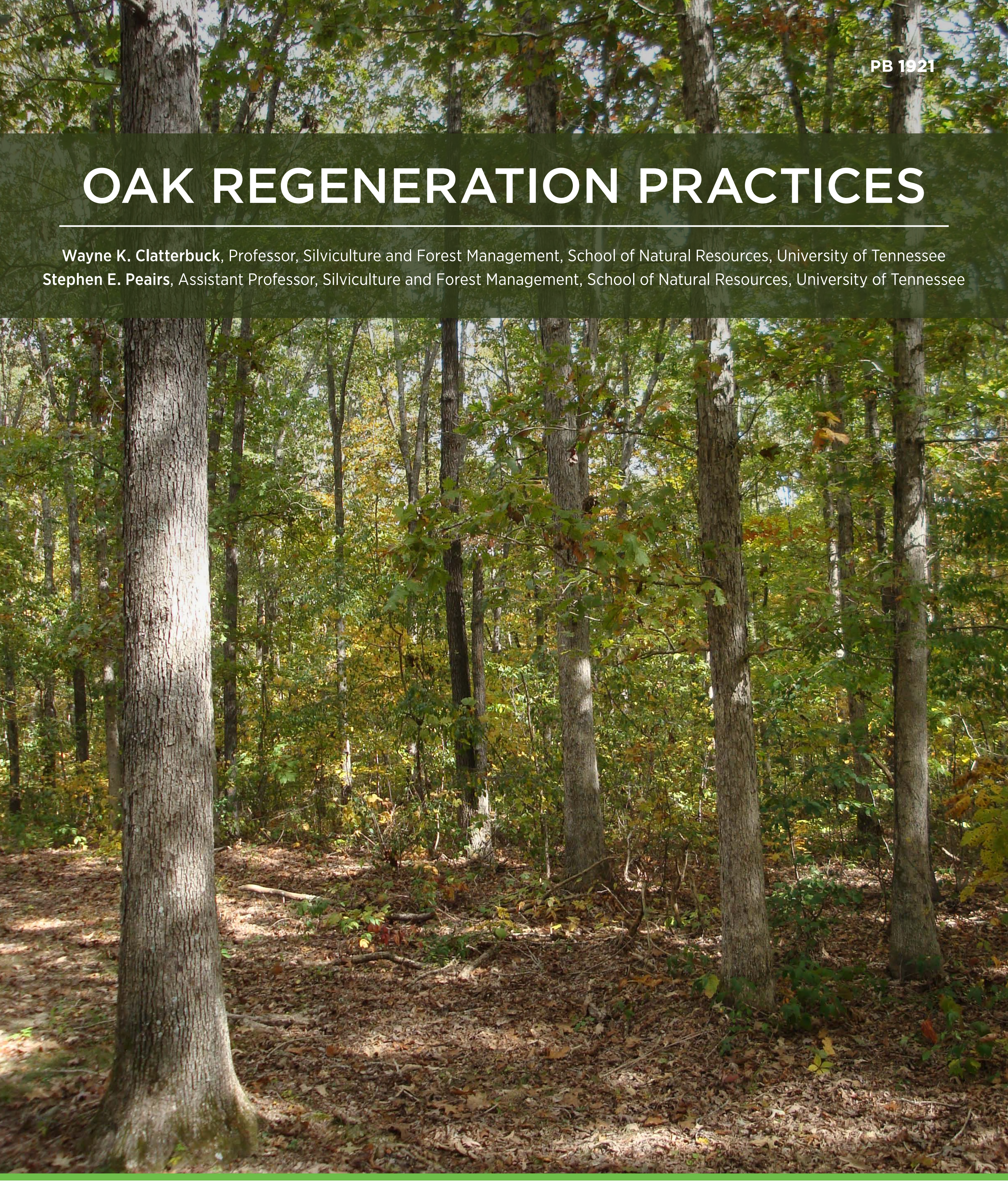
PB 1921

OAK REGENERATION PRACTICES

Wayne K. Clatterbuck, Professor, Silviculture and Forest Management, School of Natural Resources, University of Tennessee
Stephen E. Peairs, Assistant Professor, Silviculture and Forest Management, School of Natural Resources, University of Tennessee



Real. Life. Solutions.™

UT EXTENSION
INSTITUTE OF AGRICULTURE
THE UNIVERSITY OF TENNESSEE

Progressive Practices for Red and White Oak Regeneration

Wayne K. Clatterbuck, Professor, Silviculture & Forest Management
Stephen E. Peairs, Assistant Professor, Silviculture & Forest Management
School of Natural Resources

HISTORICAL IMPACT ON OAK REGENERATION

Many hardwood forests are dominated by oaks. In upland forests, oaks filled the niche formerly held by American chestnut at the turn of the previous century. Oaks regenerated easily under an environment of frequent disturbance: fires, grazing, and harvesting. However, since the 1960s, that environment has changed, and the historic disturbance regime has been altered. Fire is now more controlled, not as frequent or completely absent from the landscape; open range laws have been suspended and fencing is the norm; and harvesting is less frequent and often more intense. The outcome is environmental conditions that favor other, less desirable species that are often competitors of oak, resulting in a decline in oak regeneration.

IDENTIFYING CHALLENGES

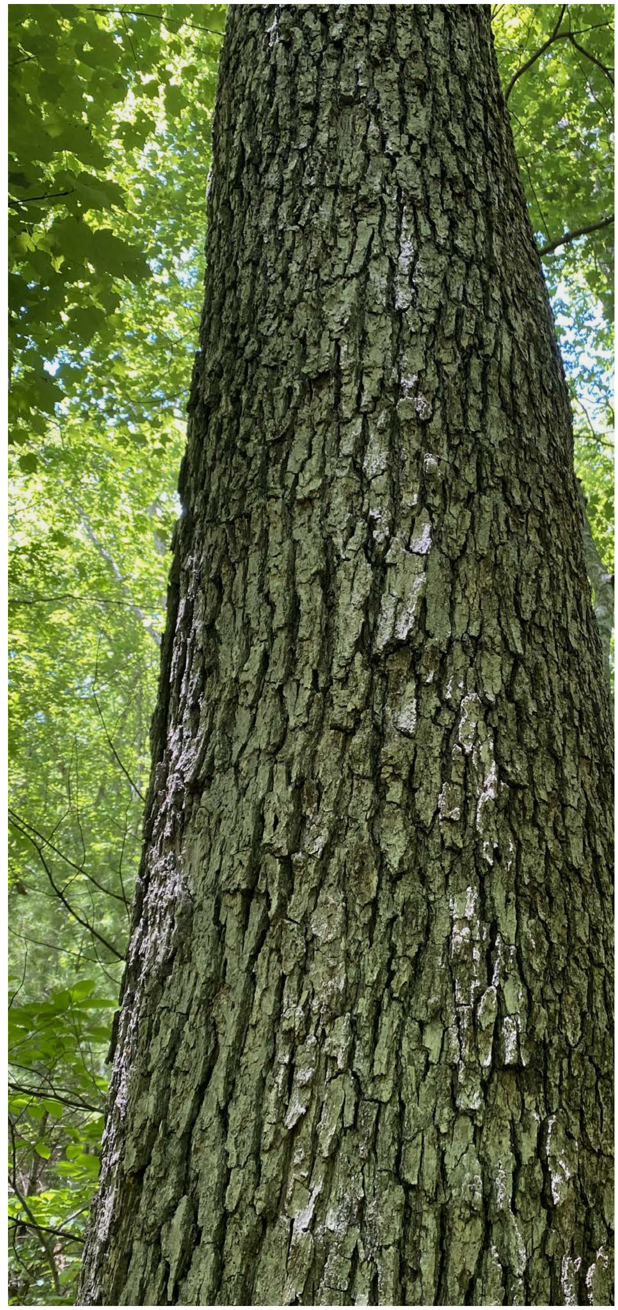
Evidence is mounting that the composition of eastern hardwood forests is slowly shifting from oaks to other species. The USDA Forest Service Forest Inventory and Analysis program has been monitoring the growth, utilization, and composition of eastern hardwood forests since the 1940s. Their data shows a gradual decrease in the volume and number of oaks. Many forests that were predominantly oak are not regenerating to a similar proportion of oak after harvest but changing to a composition with more shade-intolerant species such as yellow-poplar and sweetgum in open canopies or shade-tolerant species such as beech, maples and elms in closed canopies. Oaks are considered a shade-intermediate species that prosper in partial light environments. Although oaks are long-lived and will not disappear anytime soon, their abundance is gradually diminishing without these partial light settings.

Securing oak regeneration is a difficult proposition with the present decreased frequency of disturbance. Oaks are “advance reproduction dependent” meaning that oak seedlings must be established and have enough growth to be in a competitive position before the disturbance or harvest to have a chance to flourish in the presence of other competing tree species and succeed in becoming an overstory tree. Oak seedlings established at the time of disturbance, including harvesting, grow too slowly to compete with a faster-growing species, such as yellow-poplar, maple, or sweetgum after a disturbance. However, if already established before a disturbance, oaks have a greater probability of contending with these faster-growing species.

LANDOWNER PERSPECTIVE

However, conditions to secure this advance reproduction of oak must occur well before the regeneration harvest, sometimes as much as six to 12 years. This interval is required to allow oak seedlings to establish and provide them time to grow in height and build vigor. This growth and vigor can only be achieved by gently increasing the amount of partial light reaching them through planned disturbances. Management techniques have been developed to provide this condition without allowing faster-growing species to prosper. Most hardwood stands are now disturbed infrequently.

Shade on the forest floor is so excessive that oak advance reproduction that establishes fails to grow and eventually dies. Thus, when most stands are harvested, the future species composition shifts to other species. Most landowners are not willing to invest in management actions and wait six to 12 years to develop oak advance reproduction when they desire to harvest the stand and secure income today.



FINDING SOLUTIONS

The answer to the question of how to ensure adequate oak reproduction in hardwood stands is the recognition that all management actions should have as an objective the creation of an environment, primarily partial light conditions, that favor oak seedlings. Furthermore, cuttings should occur frequently enough to establish and maintain growth of oak reproduction. Presently, stands are not disturbed frequently enough to ensure that oak component. Most stands have closed canopies and/or dense midstories and understories creating shady environments unsuitable for oak reproduction, development, and growth.

Oak regeneration is a process, not an event. The environment that favored oak regeneration earlier is no longer present. Frequent fire, grazing, chestnut blight, non-mechanized logging, and other past disturbances cannot be replicated in today's environment. Simply expecting oak regeneration after a harvest without adequate oak reproduction developed from advance reproduction will not perpetuate oaks in future stands. Regeneration practices should be employed to increase advance oak reproduction prior to harvest cuts.

The ten fact sheets that follow provide various silvicultural practices to regenerate oak:

1. Site Preparation for Natural Oak Regeneration
2. Prescribed Burning for Oak Regeneration
3. Soil Scarification
4. Midstory Removal
5. Oak Shelterwood
6. Small (Gap) Openings
7. Two-Age Deferment System
8. Intermediate Practices to Maintain Open Forests
9. Oak Enrichment or Supplemental Plantings
10. Planting Oak for Afforestation

The oak regeneration practices and recommendations described in this publication are based on forested environments common in Tennessee and adjacent areas. The environment may differ in other areas, for example, where yellow-poplar is not as prevalent. Practitioners and landowners should assess their local environments and make modifications in prescribing practices to successfully regenerate oak, especially considering the suite of competing species. In addition to different environments, climatic variations such as the amount of precipitation, growing season length, and temperature fluctuations may necessitate alteration of oak regeneration practices for desirable results.

When the text refers to oak, this will include oaks from both the white oak and red oak families. Features that distinguish white and red oak families are summarized in the table below. White oak is longer lived and slower growing than red oaks and presently more in demand by the wood products industry. The fact sheets incapsulate both red and white oaks, but regeneration of white oak with its slower growth and establishment period is a more immediate concern. For more information about the national White Oak Initiative, visit: **https://www.whiteoakinitiative.org/**. The Tennessee Forestry Association is sponsoring the Tennessee White Oak Initiative (**https://www.tnforestry.com/**). The University of Tennessee School of Natural Resources Extension is also a contact for further information (**https://naturalresources.tennessee.edu/extension/**).

Identification features distinguishing between oak species in the white oak and red oak families

	White Oak Family	Red Oak Family
Oak Species	White, post, chinkapin, chestnut, swamp chestnut, swamp white, bur, overcup	Northern red, black, pin, willow, water, cherrybark, southern red, shingle, Shumard, Nuttall, scarlet, blackjack
Leaves	Rounded leaf tips without bristles	Leaf tips with end bristles
Bark	Lighter color, flaky and textured	Darker color, tight bark with furrows
Acorns	Matures in one growing season, usually longer than wide, knobby and bowl-shaped acorn cap	Matures in two growing seasons, usually wider than long, acorn cap is flat and saucer-like
Longevity	Longer-lived, > 120 years	Shorter-lived, < 120 years
Growth	One of the slower-growing hardwoods	Faster growth compared to white oaks
Wood	Tylosis is the distinguishing feature of white oak (*Quercus alba)* species, not the white oak family, plugging wood pores and making them water-tight and leakproof	Does not have tylosis, not liquid-tight

FURTHER READING

Johnson, P.S., Shifley, S.R., Rogers, R., Dey, D.C., Kabrick, J.M. 2019. The Ecology and Silviculture of Oaks. 3rd Edition. Boston, MA: CABI. 612 p.

Keyser, P.D., Fearer, T., Harper, C.A. (editors) 2016. Managing Oak Forests in the Eastern United States. Boca Raton, FL: CRC Press. 289 p.

PB 1921-A

OAK REGENERATION PRACTICES: SITE PREPARATION FOR NATURAL OAK REGENERATION

Jack Wilkerson, MS Student, Tennessee State University
Wayne K. Clatterbuck, Professor, Silviculture and Forest Management, School of Natural Resources, University of Tennessee

INTRODUCTION

Regeneration of desired species following a harvest is a key component of forest sustainability. Often undesirable trees, those of small diameter or larger non-commercial trees with little economic value after a harvest, if left, will ultimately compose the next forest. Site preparation is a silvicultural practice that removes these unwanted trees, as well as grasses and weeds, to encourage the regeneration of desirable species such as oaks. Site preparation can be performed before, during, or after a harvest or regeneration event.

Site preparation is commonly considered when planting trees and should equally be considered before and after a harvest to establish and promote natural regeneration. A stand inventory and regeneration survey should be conducted several years before a timber harvest to determine if desirable regeneration is present in sufficient size classes and numbers or if site preparation is necessary to establish and develop natural regeneration. Oaks, being advanced growth dependent, should be present in the stand before the harvest is conducted. The development of small, advance reproduction of oak to a larger size involves site preparation to control competing or undesirable species using herbicide, fire, or mechanical methods.

CONTROL OF UNDESIRABLE VEGETATION INCLUDING INVASIVE SPECIES

Several site preparation techniques are available to remove or deaden stems of unwanted species. Aboveground control methods of undesirable species include cutting, girdling, frilling, or burning. Mechanical methods that scalp or scrape the soil, removing the organic matter or the use of heavy equipment that compacts the soil are not recommended. These aboveground methods will not control sprouting from roots or stumps. Most all hardwoods sprout. Application of herbicide to the plant and translocation of the herbicide to the roots will prevent resprouting of undesirable vegetation and kill the roots and thus the plant.

HERBICIDE APPLICATION METHODS

Herbicide is usually applied on a stem-to-stem basis, not broadcasted, using equipment such as a backpack sprayer or squeeze/spray bottle. Common herbicide treatment types include foliar sprays, basal bark application, cut-stump sprays, as well as tree injections. The type of herbicide application depends on the size of the targeted stem as suggested in the accompanying table.

Table 1. Herbicide application method that is most appropriate for the target stem being controlled.

Application Method	Effective Size of Target Stems
Basal bark applications	Less than 3 inches in diameter
Cut stump spray	All sizes

When using a backpack sprayer, use Personal Protective Equipment (PPE) for safely applying herbicide. Photo Credit: *Wayne K. Clatterbuck*

BASAL BARK APPLICATIONS

When trees to be controlled reach a height of six feet or greater, foliar sprays are no longer feasible for safe application. Oil-based herbicides to penetrate the bark are applied as a basal spray on the lower one to two feet of the stem, encircling the entire stem. Basal herbicide sprays are recommended for many thin-bark, midstory species such as maples that are greater than six feet tall but less than three inches in diameter at breast height (DBH).

A thin stream of herbicide is applied encircling this small red maple stem as a basal bark treatment.
Photo Credit: *Wayne K. Clatterbuck*

CUT-STUMP SPRAYS

Cut-stump treatments are particularly useful with larger stems and stumps that sprout. Herbicide should be directly applied within an hour of a fresh cut so that the stump can absorb the herbicide before it begins to seal its wounds. The outer 1 to 2 inches of the stump rings (live tissue) should be sprayed. If application occurs more than an hour following a cut, apply herbicide around the entire circumference of the stump surface and outer bark to ensure herbicide effectiveness.

TREE INJECTION

For trees greater than three inches in diameter, hack and squirt treatments can be conducted. Downward hacks with a hatchet are made one inch apart on the stem and herbicide is applied with a squirt bottle to each hack. Follow herbicide label instructions. Continuous frills (girdling) rather than spaced notches are used on more difficult to kill species such as beech.

USE OF HERBICIDES

Glyphosate, triclopyr, and imazapyr are herbicides that are frequently used to control undesirable hardwood stems. Glyphosate and triclopyr (water-based amine and oil-based ester formulations) are preferred because they have little soil activity. Other herbicides may be equally effective and should be considered as options for use. These three herbicides are readily available at supply stores under various tradenames. Make sure to follow the label instructions for applying each herbicide. Personal Protective Equipment (PPE) should be worn by applicators.

Glyphosate – Herbicide has no soil activity and will not injure desirable plants via root uptake; rapidly deactivated and biodegradable in the soil by micro-organisms; broad spectrum, non-selective herbicide that is absorbed by plant leaves; and is a systemic herbicide that is translocated within the plant. Glyphosate has low health and environmental risks. For more information about possible threats associated with glyphosate, refer to **UT Extension publication W 827 Frequently Asked Questions: Glyphosate**.

Triclopyr - Systemic herbicide is in two formulations, water-based amine (foliage, hack, and squirt) and oil-based ester (basal spray); does not kill grasses or sedges; interferes with normal expansion and division of plant cells resulting in distorted growth such as cupped leaves, twisted stems, and plugged vascular tissues; and is not translocated in the soil.

Imazapyr - Herbicide does move in the soil; should be used for stem injections without dripping chemical on the ground; inhibits amino acid protein synthesis; and has a delayed response after application.

This fact sheet focuses on site preparation to control grasses, weeds, and woody plants that may interfere with regeneration of oaks. Herbicides to control woody plants differ with their mode of action and application compared to herbicides that control annuals and some grasses. Most annuals should be controlled before they seed to create the generation for the next year. Contact your local Extension office or university for herbicide recommendations.

FURTHER READING

Clatterbuck, W.K., Armel, G.R. 2010. Site preparation for natural regeneration of hardwoods. Extension Publication PB1799. Knoxville, TN: University of Tennessee Extension, Institute of Agriculture. 12 p. (**https://utia.tennessee.edu/publications/wp-content/uploads/sites/269/2023/10/PB1799.pdf**)

INSTITUTE OF AGRICULTURE
THE UNIVERSITY OF TENNESSEE

TN WHITE OAK INITIATIVE

PB 1921-A 03/24 24-0091 Programs in agriculture and natural resources, 4-H youth development, family and consumer sciences, and resource development. University of Tennessee Institute of Agriculture, U.S. Department of Agriculture and County governments cooperating. UT Extension provides equal opportunities in programs and employment.

PB 1921-B

OAK REGENERATION PRACTICES: PRESCRIBED BURNING FOR OAK REGENERATION

Wayne K. Clatterbuck, Professor, Silviculture and Forest Management, School of Natural Resources, University of Tennessee
Stephen E. Peairs, Assistant Professor, Silviculture and Forest Management, School of Natural Resources, University of Tennessee

To burn or not to burn for oak regeneration? More burning is conducted in hardwood forests today than at any time since fire suppression policies were implemented in the 1950s. Many people have mixed opinions about burning to regenerate oak. These views are often conflicting, founded on personal perspectives, preferences, experience, or relegated to the local landscape that is being managed and investigated. Frequent cultural burning was certainly one disturbance in combination with others (chestnut blight, grazing, less intensive harvesting) that favored oaks before fire suppression policies. However, replicating those same burning conditions from 70+ years ago to perpetuate oak with today's environment, climate variability and management practices is not possible. In addition, contemporary forest composition and structure differ greatly compared to those in the past, and response to fire will also vary. One burning prescription seldom has application in all environments or situations with stands occurring on a wide variety of site productivities and having different stand structures, compositions, and fuels.

A prescribed burn that killed oak seedlings that sprouted from a burn four years ago. Top-killed oak seedlings will continue to sprout after each burn. Prescribed fire should cease for > 10+ years to allow oak seedlings to become large enough to withstand additional burns.
Photo Credit: *Wayne K. Clatterbuck*

Prescribed fire is a silvicultural tool commonly implemented for site preparation for natural or artificial regeneration, fuel reduction, enhancing wildlife habitat, perpetuating fire-dependent species, improving site access and appearance, and providing early successional vegetation structure. Mineral soil exposed by burning supports the introduction of wind-blown, light-seeded species that often affects oak reproduction. Prescribed burning has environmental impacts on vegetation, soil, water, air, wildlife, and visual appeal. Burning to promote successful oak regeneration remains challenging in facilitating and not harming oaks yet impeding species that compete with oak.

Burning for oak regeneration on lower quality, poorer productivity sites (Site Index (SI) < 65 feet tall at 50 years for oak) is not necessary because oak already proliferates in both the overstory and in the understory. Oak competition is sparse on these sites. Prescribed burning may be appropriate for other purposes such as wildlife habitat but not for oak reproduction that is already in place. On the better, more mesic hardwood sites (SI >80 feet), burning is difficult and rarely occurs. These better sites in cove hardwood areas, lower slopes, and near stream valleys and floodplains are usually too moist throughout the year to ignite and carry a fire. Typically, faster-growing species will dominate oak on these sites. Burning for the purpose of regenerating oak on these higher productivity sites is not realistic. The best opportunity for burning to benefit oak regeneration is on the average or mediocre site productivities (SI 65 to 80 feet). Burning for competition control may benefit oak, but oak growth also may be delayed through top kill of seedlings and damaging larger stems. Advance oak reproduction of sufficient number and size must be present to progress oak beyond the competition.

Prescriptions to successfully regenerate oak using prescribed fire are indefinite. An intensive regeneration survey is necessary before the harvest and the burn to evaluate whether oak advance reproduction is present in conjunction with other species. If not present, oak regeneration will not occur. The question remains how oak can be encouraged by burning with the presence of other species. Most all hardwood species resprout. Providing partial sunlight for shade-intermediate oaks and managing oak development on the average productivity sites may give oaks an advantage over other species.

Several factors that influence burning properties and oak resiliency compared to other species include fire duration, residence time, rate of spread, frequency, air temperature, intensity, and season and timing of the burn; as well as type, amount, size and moisture content of the fuels; and individual species tolerances to burning based on size and age. The range of these burning properties and combinations vary across the landscape making prescribed burning results to promote oaks difficult to replicate across stands and sites. A successful prescription that favors oaks selectively at the expense of other species is easier said than done.

Will repeated burning favor oaks compared to other species? Research has indicated that just one burn is not enough to promote oak over other species. In theory, repeated burning would tend to gradually reduce the sprouting ability of some species (progressively reducing root reserves until they no longer sprout) and enhance other species (primarily oaks) that may be better adapted to burning through their re-sprouting ability. Depending on size of oak reproduction (as well as other species), small seedlings (< 1-foot tall) are as likely to be killed as perpetuated by prescribed burning.

Controlling burning intensity can be difficult. Excessive temperatures can injure and kill oak saplings. Photo Credit: *Ray Ward, TN Division of Forestry*

Oak seedlings often resprout vigorously after top kill from a burn. Photo Credit: *Ray Ward, TN Division of Forestry*

Most hardwood species will continue to sprout after burning, especially small-diameter trees with thinner bark that are more susceptible to stem damage. Repeated burning also increases the risk of bole damage and decay to standing trees that decreases their value.

A program of prescribed burning should not be undertaken without a full appreciation of the purpose, difficulty, and risks/liabilities involved with each burn. The meteorological windows for safe burning are becoming more limited and smoke management is more of an issue. Creating more open canopies with partial light environments to sustain shade-intermediate oaks may be more beneficial. Periodic burning is one practice to maintain partial light conditions. Care should be taken to ensure that prescriptions using fire are successful for both meeting oak regeneration objectives and increasing the probability for oaks to emerge into the overstory in mixed species stands.

FURTHER READING

Arthur, M.A., Alexander, H.D., Dey, D.C. [and others]. 2012. Refining the oak-fire hypothesis for management of oak-dominated forests in the eastern United States. Journal of Forestry 110(5):257-266 (https://www.fs.usda.gov/research/treesearch/40972).

Keyser, T.L., Arthur, M.A., Loftis, D.L. 2017. Repeated burning alters the structure and composition of hardwood regeneration in oak-dominated forests in eastern Kentucky, USA. Forest Ecology and Management 393:1-11 (https://www.fs.usda.gov/research/treesearch/54074).

Schweitzer, C.J., Dey, D.C. 2023. Prescribed fire for upland oaks. FOR 165. Lexington, KY: Cooperative Extension Service, University of Kentucky, Department of Forestry and Natural Resources. 13 p. (https://www.fs.usda.gov/research/treesearch/67074)

UTIA INSTITUTE OF AGRICULTURE THE UNIVERSITY OF TENNESSEE

TN WHITE OAK INITIATIVE

PB 1921-03/24 24-0091Programs in agriculture and natural resources, 4-H youth development, family and consumer sciences, and resource development. University of Tennessee Institute of Agriculture, U.S. Department of Agriculture and County governments cooperating. UT Extension provides equal opportunities in programs and employment.

PB 1921-C

OAK REGENERATION PRACTICES: SOIL SCARIFICATION

Wayne K. Clatterbuck, Professor, Silviculture and Forest Management, School of Natural Resources, University of Tennessee
Stephen E. Peairs, Assistant Professor, Silviculture and Forest Management, School of Natural Resources, University of Tennessee

Annual acorn crops to regenerate oaks are erratic. In some years, few, if any, acorns are produced and in other years, bumper amounts of acorns are generated. Bumper acorn crops, also called mast crops or mast years, are considered those where the number of acorns produced exceeds the amount consumed by predators or affected by insects. The remainder of sound acorns are available to germinate into oak seedlings. Since bumper crops of white oak acorns only occur on average every four to six years or more, oak regeneration through seedling advance reproduction should capitalize on these infrequent acorn crops with abundant acorns. When stands do not have oak advance reproduction, a bumper acorn crop is often the opportunity to begin the oak regeneration process.

Soil scarification enhances acorn germination and seedling establishment following a bumper acorn crop by establishing greater acorn to soil contact after seed dissemination. The method is most effective when there are ample, viable acorns on the ground following a bumper acorn crop.

Scarification reduces acorn exposure on the soil surface to predators and protects acorns from desiccation during extreme temperatures (drying or freezing). Protection also is provided by the shedding of leaves in the fall to cover the acorns and scarified soil.

After dissemination in the fall, acorns are incorporated into the forest duff and ground by mechanized equipment such as a disk pulled by a farm tractor or a root rake on a dozer. Depth should be no more than four inches to ensure that the hypocotyls (stem of germinating acorn) can emerge from the soil. Using this equipment in forested settings has many obstacles with resident trees and other vegetation, dead stems and woody debris on the ground, as well as topographic features such as exposed rocks and steeper slopes. Do not expect to scarify 100 percent of the soil surface on a treated area. In the woods, safely meander equipment where numerous acorns are present. Operate carefully in more open and accessible areas with limited midstories and other ground vegetation or land obstacles. Be sure not to injure valuable, mature trees. Some acorn damage is expected in using scarifying equipment, but the excessive amount of acorns from bumper crops should compensate for the limited acorn damage.

A bumper white oak acorn crop. Photo Credit: *Wayne K. Clatterbuck*

A small dozer with a toothed blade or a small farm tractor with a disc can scarify the ground to improve acorn-ground contact after a bumper acorn crop. Photo Credit: *Wayne K. Clatterbuck*

WHEN TO IMPLEMENT SOIL SCARIFICATION TO ESTABLISH OAK GERMINANTS: A NARROW WINDOW

Little oak advance reproduction present, wait until bumper acorn crop (could be several years)

Apply soil scarification as soon as possible after acorns fall from the trees to minimize the number of acorns consumed by wildlife

Scarification should be completed before leaf shedding in the fall, about 2 or 3 weeks after

Soil scarification has been proven in numerous studies to enhance the number of germinating oak seedlings. However, scarifying the soil and obtaining successful germination is just the first step. These oak germinants are cultured to a sufficient size and number of advance reproduction to eventually become a component of the overstory. Partial light conditions should be provided that promote shade-intermediate oaks and discourage growth of shade-tolerant and intolerant species. Practices such as midstory removal or shelterwood will continue oak growth and development.

BENEFITS

- A greater number of oak germinants are available to culture advance reproduction to a size and number required to successfully regenerate oak.
- Germination and establishment of new oak seedlings are enhanced following a bumper acorn year.
- Scarification can protect acorns from predators and desiccation and improve seedling survival.

WEAKNESSES

- Soil scarification should follow a bumper acorn year which occurs infrequently. Otherwise, the cost of the practice does not justify the number of seedlings promoted.
- Once acorns have germinated, other treatments to promote and develop oak seedlings are necessary. Competing vegetation in the understory should be addressed. Providing sunlight to the ground for shade-intermediate oaks through various practices is necessary to promote growth and development of seedlings.
- Soil scarification is a cost without accompanying revenue. However, if adequate oak advance reproduction is not present, and oaks are desired in the next generation, soil scarification following a bumper acorn crop will quickly establish new seedlings initiating the oak regeneration process.

FURTHER READING

Lhotka, J., Stringer, J. 2013. Soil scarification to enhance oak seedling establishment. Kentucky Woodlands Magazine 8(3): 8-11. (https://kywoodlandsmagazine.ca.uky.edu/sites/kywoodlandsmagazine.ca.uky.edu/files/soil_scarificationpg8.pdf).

UTIA INSTITUTE OF AGRICULTURE THE UNIVERSITY OF TENNESSEE

TN WHITE OAK INITIATIVE

PB 1921-C03/2424-0091 Programs in agriculture and natural resources, 4-H youth development, family and consumer sciences, and resource development. University of Tennessee Institute of Agriculture, U.S. Department of Agriculture and County governments cooperating. UT Extension provides equal opportunities in programs and employment.

PB 1921-D

OAK REGENERATION PRACTICES: MIDSTORY REMOVAL

Canaan Dugger, MS Student, School of Natural Resources, University of Tennessee
Wayne K. Clatterbuck, Professor, Silviculture and Forest Management, School of Natural Resources, University of Tennessee

Natural regeneration of oak is limited during seedling establishment and growth by the amount of sunlight received through the canopy as well as the influence of competitor species. Oaks are both disturbance and advanced growth dependent, that is their slower growth requires a head start when competing with faster-growing species. When sufficient light is lacking, shade-tolerant species such as maples and beech perpetuate in low light while retarding oak seedling growth due to shady understory conditions and competition. Disturbances that reduce tree density and allow increased light to reach the forest floor can stimulate shade-intolerant species like yellow-poplar and suppress slower-growing oak seedlings. Targeted disturbances, such as midstory removal, provide partial sunlight that aids oak growth, development, and recruitment into more competitive size classes. By leaving the overstory intact and removing the midstory canopy level (stratum), the intermediate sunlight received stimulates oaks and discourages the shade intolerant as well as the shade-tolerant species.

Small, advance reproduction of white oak from a bumper acorn crop directly after midstory control treatment. Photo Credit: *Wayne K. Clatterbuck*

With a prominent midstory allowing < 10% of sunlight to reach the ground, growth and survival of 3-year-old white oak advance reproduction is deterred. Photo Credit: *Wayne K. Clatterbuck*

Two conditions are necessary to implement a midstory removal to enhance oak regeneration. First, oak advance seedlings must be present so they can be cultured to increase their size and compete with residual species. If advance seedlings are not present, then implementation should be delayed until oak acorns have germinated, usually after a bumper acorn year that occurs every three to five years on average when the number of acorns exceed that consumed by predators. Second, additional time (several years) is necessary to recruit the shade-intermediate oak germinants into larger size classes by adjusting the amount of sunlight received while other species with different light-tolerance requirements are deterred. These two steps should take place well before the anticipated overstory harvest to establish oak seedling reproduction from acorns. By removing the midstory canopy layer, defined as the trees with crowns beneath the overstory trees, more sunlight infiltrates to the ground. Leaving most of the overstory intact provides the partial light conditions required to recruit small oak advance reproduction into more competitive positions as well as to position those oaks to be more competitive once the overstory is removed or harvested.

Once a sufficient number of large oak seedlings (> 4 feet in height) is attained, the overstory can be harvested releasing the seedlings. Regenerating oak is a process involving foresight, patience, and upfront investments when establishing and developing advance reproduction before the overstory is harvested.

Research at the University of Tennessee Forest Resources Research and Education Center at Oak Ridge investigated the growth and survival of natural white oak reproduction that was established from a previous bumper acorn crop. By removing the midstory canopy layer that consisted primarily of maple, beech, and yellow-poplar, ground diameter of oak seedlings was improved and height more than doubled (height from 6 inches to > 30 inches) after three growing seasons compared to controls that did not receive the treatment. Study areas that received the midstory removal treatment average 15 to 25% of full sunlight, while the sunlight in controls was < 10% full sunlight. Response of potential competitor species after midstory release was minimal. Shade-tolerant species such as maples and beech and shade-intolerant species such as yellow-poplar were discour-aged with the level of sunlight provided by the midstory removal and leaving the overstory intact. These results confirm that a midstory removal treatment is a viable option for enhancing size and number of oak reproduction.

Released white oak seedlings from a midstory removal after three growing seasons. Photo Credit: *Wayne K. Clatterbuck*

Once oak reproduction becomes 4 to 5 feet tall, they can be released through an overstory harvest or shelterwood operation where the overstory is removed in stages (refer to shelterwood fact sheet) securing a future cohort of oaks in the upper forest canopy. If too many saplings (oaks and other species) are present, then a crop tree release is recommended to increase growing space for selected oaks.

BENEFITS

- Oak reproduction is secured before the overstory harvest. Midstory removal will encourage the partial light conditions to increase size of slower-growing oak seedlings/saplings while constraining growth of other species.

WEAKNESSES

- Cost of implementing midstory removal with little, if any, associated revenue.
- Midstory removal is implemented three to 10 years before the overstory harvest. Small, advance oak reproduction must be cultured and recruited to larger sizes to compete with faster-growing species and successfully allow ascendance of oak to the upper canopy.

UTIA INSTITUTE OF AGRICULTURE
THE UNIVERSITY OF TENNESSEE

TN WHITE OAK INITIATIVE

PB 1921-D03/24 24-0091 Programs in agriculture and natural resources, 4-H youth development, family and consumer sciences, and resource development.
University of Tennessee Institute of Agriculture, U.S. Department of Agriculture and County governments cooperating. UT Extension provides equal opportunities in programs and employment.

OAK REGENERATION PRACTICES: OAK SHELTERWOOD

Jack Wilkerson, MS Student, University of Tennessee
Wayne K. Clatterbuck, Professor, Silviculture and Forest Management, School of Natural Resources, University of Tennessee

Oak shelterwood method to manipulate the amount of partial sunlight reaching the forest floor to promote growth of oak advance seedlings. Photo Credit: *Wayne K. Clatterbuck*

The shelterwood method of regeneration is an even-aged silvicultural practice that involves a series of disturbances (harvests) that are timed to meet regeneration objectives of species desired. A 'shelter' of overstory trees remains to influence the regeneration process. Shelterwoods are flexible because the amount of sunlight that reaches the ground can be manipulated by the amount of canopy retained to meet the light tolerance of the desired regenerating species. The purpose of the shelterwood method is to culture larger size of advance reproduction prior to removal of the overstory. The partial sunlight provided by the shelterwood method favors development of oak advance reproduction while discouraging undesirable species.

Treatment of undesirable midstory and understory vegetation by herbicide or cutting allows penetration of sunlight for the development of slower-growing oak seedlings. Midstory removal can be conducted separately or in conjunction with the shelter-wood method being careful not to introduce an excessive amount of sunlight that will encourage growth and competition from other species. Otherwise, oak advance reproduction that may establish after a bumper acorn year under these dense, midstory canopies grow minimally in height and eventually die. Partial light conditions (20 to 35 percent of full sunlight) should be maintained for several years to assure ascendance of shade-intermediate oak seedlings to larger sizes. Too much sunlight favors development of faster-growing shade-intolerant species (yellow-poplar, cherry, sweetgum) rather than oak, while too little sunlight encourages more tolerant and less desirable species (beech, maples, many midstory species).

Oaks also will regenerate from stump and seedling sprouts. These sources of reproduction should also be considered when assessing oak regeneration potential. Oaks up to 10 inches in diameter stump sprout readily, while stump sprouting progressively declines with increasing diameter on those stumps greater than 10 inches. Since large diameter oaks do not sprout well and smaller oaks are infrequent in mature stands, most oak regeneration comes from advance reproduction and not from sprouting.

Oak seedlings become established after a bumper crop of acorns that occurs every three to five years. Shelterwood should not be considered unless oak seedlings are present to be recruited to a larger size.
The practice should be delayed until an acorn crop and germination occur. Although other species will still be present and will respond somewhat to an increase in sunlight, the number of oak seedlings after a bumper acorn crop should overcompensate for the number of seedlings of other species. If these few larger seedlings of other species begin to negatively impact the growth of oak advance reproduction, then they should be controlled by herbicides.

Table 1. Decision Model for Oak Shelterwoods (AR= Advance Reproduction)

Oak AR Absent	Small Oak AR Present	Large Oak AR Present
Wait Until Bumper Acorn Crop and Germination	↓	↓
Provide Intermediate Light Conditions Conducive for Growth of Oak AR. Control Unwanted Vegetation.		
Once Oak AR is 4-to-5-Feet Tall, Remove Overstory to release Oak Seedlings.		

Poorly formed and too few shelter trees remain after the harvest allowing direct sunlight to the forest floor. The regeneration is composed of competing species that are growing faster and displacing the slower-growing oaks. Photo Credit: *Wayne K. Clatterbuck*

Shelterwood and midstory removal (if needed) increases the amount of diffuse light levels that benefits the slower-growing oak seedlings and limits the growth of competing species. This practice is conducted without opening gaps in the overstory which allow increased light penetration that would support the growth of faster-growing, shade-intolerant species rather than oaks. The small-diameter, undesirable midstory trees are removed first, then ascending to larger-diameter midstory trees without removing overstory trees that would create canopy gaps.

Development of oak advance reproduction to a larger size is essential to have oaks in the next generation. Most managers accept ≈200 oak advance reproduction per acre that are greater than 4-feet in height as sufficient to have a proportion of oaks in the future overstory. Once the desired number and size of oaks are present, the overstory can be harvested completely or in stages gradually releasing the developing oaks. A future crop tree release may be necessary to reduce the number of stems and provide more growing space for desirable oaks.

The oak shelterwood regeneration method is an effective tool to regenerate shade-intermediate oaks and discourage competitive growth of both intolerant and tolerant species.

Determining the partial light conditions that will encourage the growth of oak reproduction and constrain growth of competing species is tricky. These competing species should be suppressed by management actions. The keys to success are developing 4- to 5-foot-tall, advance reproduction of oak and control of competing vegetation before removal of the overstory. The benefit is oak reproduction is secured and developed before the overstory harvest. The weakness is small, advance oak reproduction must be cultured to larger sizes to compete with faster-growing species and allow ascendance of oak to the upper canopy. This process is applied 3 to 10 years before the overstory harvest. Implementing an oak shelterwood is a cost that is carried forward until revenue is generated by the final harvest cut.

FURTHER READING

Stringer, J. 2006. Oak shelterwood: A technique to improve oak regeneration. Extension Publication SP676. Knoxville, TN: University of Tennessee Extension, Institute of Agriculture. 8 p. (https://utia.tennessee.edu/publications/wp-content/uploads/sites/269/2023/10/SP676.pdf)

PB 1921-E03/2424-0091Programs in agriculture and natural resources, 4-H youth development, family and consumer sciences, and resource development.
University of Tennessee Institute of Agriculture, U.S. Department of Agriculture and County governments cooperating. UT Extension provides equal opportunities in programs and employment.

PB 1921-F

OAK REGENERATION PRACTICES: SMALL (GAP) OPENINGS

Wayne K. Clatterbuck, Professor, Silviculture and Forest Management, School of Natural Resources, University of Tennessee
Stephen E. Peairs, Assistant Professor, Silviculture and Forest Management, School of Natural Resources, University of Tennessee

Small, harvested openings can provide partial sunlight that would favor development of oak advance reproduction, if reproduction is present. The partial sunlight is from two sources. The edge trees will cast shade into the harvested opening. Side light also can penetrate forested edges, creating the partial light for oak regeneration and development.

The size of the harvested opening will affect the amount of sunlight received and thus influence the species that will regenerate based on species' light tolerance. Research by John Lhotka at the University of Kentucky1 followed for 48 years the species composition of various-sized openings. Harvest openings with diameters of 50 feet (0.05 acres) supported shade-tolerant species such as maples; 150 feet (0.40 acres) favored more shade-intermediate species such as oaks; and 250 feet (1.1 acres) advanced intolerant yellow-poplar. Opening size and shape can vary to promote oaks based on objectives and cost. For example, a larger opening would support intolerant species in the center of the harvest that is not being impacted from the shade cast by edge trees. More shade-intermediate species would emerge at the margin of the harvest opening under the influence of edge trees.

Gap openings are defined as an opening where the regeneration for the entire opening is affected by the edge trees, that is, no area receives full sunlight for the entire day. Opening size is generally 0.5 to 1.0 acres which provides the partial sunlight microenvironment that benefits oak. Harvest openings can be placed in areas where oak advance reproduction is present. If not present, measures should be taken before the harvest to establish advance reproduction. When harvests are larger than an acre, they are known as patch openings or patch clearcuts.

Another practice, expanding gap or femelschlag (German term), takes advantage of the side light that infiltrates from the edge of the harvest. This partial side light aids establishment (if oak seed trees are present) and growth of oak advance reproduction. Once the advance reproduction is large enough to be released, the gap is expanded through an additional harvest encompassing the 40+ feet perimeter where there was side light from the original harvest.

A regeneration opening about 1.5 acres in size. Direct sunlight in the middle of the opening supports shade-intolerant, sun-loving species such as cherry and yellow-poplar. However, the perimeter of the opening receives partial sunlight from edge trees that favors growth of oak seedlings. Photo Credit: *Wayne K. Clatterbuck*

This process would continue with development and subsequent release of advance reproduction by expanding the gap at each entry consisting of a small width, harvested swath around the perimeter of each opening. Harvesting expanded gaps with their limited areas and volumes is usually not economically feasible. Another disadvantage associated with expanding gap is that edge trees are phototrophic and will lean and bend toward the ample sunlight in the opening causing larger branches and crooked boles that diminish tree form and value. Additionally, although older edge trees will protect young, advance reproduction to a degree, the larger root system of older trees may adversely impact moisture relationships of young seedlings in their vicinity.

Partial sunlight in a small gap opening less than 0.4 acres in size with vigorous 4-year-old white oak seedlings. Photo Credit: *Wayne K. Clatterbuck*

The following example is an illustration of how gap openings could be systematically implemented in a stand. The structure would be an uneven-aged stand composed of several even-aged units distributed across the stand.

Example: Harvesting an 80-acre stand in four separate entries spaced 15-years apart, 60-year rotation

First Entry: Harvest 20 acres (25 percent of stand) in small gap openings

Second entry: Harvest another 20 acres in small gap openings after 15 years. Age of trees in opening from first entry is now 15-years-old.

Third entry: Harvest another 20 acres in small gap openings after 30 years. Age of trees in the opening from first entry is now 30-years-old, age of trees in openings created from second entry is 15-years-old.

Fourth entry: Harvest remaining 20 acres in small gap openings after 45 years. Age of trees in openings from first entry is now 45-years-old; age of trees in openings created from second entry is 30-years-old; and age of trees in openings from the third entry is 15-years-old. Entire 80-acre stand has been harvested in four entries.

Next entry in 15 years harvests trees that regenerated after the first entry that are 60 years old.

Benefits of progressively creating openings are that the stand is continually managed both within and between gaps at each entry to optimize stand growth of desired species. Frequent disturbances maintain open forest conditions in the stand that supply the partial sunlight to establish and develop oak advance reproduction during each entry in preparation for the harvest.

Harvest openings provide wide flexibility in regenerating oak. Smaller openings are more efficient for oak advance reproduction, but edges on larger openings can also regenerate oak with more intolerant species in the center. Larger openings may also retain some residual trees for acorns and shade similar to the shelterwood and two-age regeneration practices. Size and shape of opening can vary to capitalize on physical features of the land, ownership objectives, economics, as well as the presence of oak advance reproduction. Another concept not yet addressed by research is to retain groups or islands of trees rather than harvesting groups of trees, cutting between established groups.

Assorted options are available to apply different opening attributes to regenerate oak. However, each of these options is still a process that requires development of advance reproduction (advanced growth dependent) to successfully regenerate oak and partial light conditions through more open forests (disturbance dependent) to maintain development of shade-intermediate oaks.

BENEFITS

- Several opportunities to create partial light conditions advantageous to the development of oak advance reproduction in the small opening, on edge of larger opening, and in the intact exterior of the resident edge for 30+ feet (penetration of side light from the opening).
- The stand is disturbed frequently with different harvest entries. The area between harvested groups can be managed during each entry to benefit the growth of favored species (oaks) through thinnings and restricting undesired vegetation.
- Vegetation has greater diversity when applying openings with varied attributes.

WEAKNESSES

- Smaller harvest areas (many smaller groups) add more harvesting expense since each group will require a road or skid trail to the landing. Harvesting the same volume in many smaller openings is more expensive than in fewer and larger openings.
- Checkerboard impact of harvesting smaller groups in the stand causes non-continuous forest structures.

White oak advance reproduction in small gap opening. Photo Credit: *Wayne K. Clatterbuck*

FURTHER READING

LeDoux, C.B. 1999. An integrated approach for determining the size of hardwood group-selection openings. Forest Products Journal 49(3):34-37. (https://www.fs.usda.gov/research/treesearch/14450)

Lhotka, J.M. 2013. Effect of gap size on mid-rotation stand structure and species composition in a naturally regenerated mixed broadleaf forest. New Forests 44:311-325.

UTIA INSTITUTE OF AGRICULTURE THE UNIVERSITY OF TENNESSEE

TN WHITE OAK INITIATIVE

PB 1921 03/24 24-0091 Programs in agriculture and natural resources, 4-H youth development, family and consumer sciences, and resource development.
University of Tennessee Institute of Agriculture, U.S. Department of Agriculture and County governments cooperating. UT Extension provides equal opportunities in programs and employment.

PB 1921-G

OAK REGENERATION PRACTICES: TWO-AGE DEFERMENT SYSTEM

Wayne K. Clatterbuck, Professor, Silviculture and Forest Management, School of Natural Resources, University of Tennessee
Stephen E. Peairs, Professor, Silviculture and Forest Management, School of Natural Resources, University of Tennessee

The two-age deferment system maintains two age classes, usually a regenerating class that will grow and develop and an older, mature age class which is retained for another rotation. Pertaining to oak regeneration, if the present, mature oak stand does not contain advance oak reproduction and a harvest is imminent, then the forthcoming stand (rotation) will not be composed of oaks. However, by retaining a few mature oak reserve trees, acorn production continues. Even though oaks will not be a component in the development of the younger age class, oak advance reproduction can develop during the next rotation and build the number and size of seedlings during the 2nd (next) rotation. This oak advance reproduction would be available for regeneration for the 3rd rotation. Thus, if an oak seed source remains, oaks can flourish in successive stands. Otherwise, if all the overstory oaks are harvested now, future rotations will not be composed of oaks because of the absence of a seed source. Refer to the following table for the stepwise process.

White oak trees retained for another rotation in two-age deferment.
Photo Credit: *Wayne K. Clatterbuck*

Present (1st) Rotation	Next (2nd) Rotation[1]	Future Rotations[1]
Oak advance reproduction (AR) absent	Building AR from acorns of oak reserve trees during rotation	Stand is harvested releasing developed oak AR to regenerate the next stand
Next stand will not contain overstory oaks in regenerating age class w/o AR	Maintain open forests (partial light) with disturbances[2] during rotation for AR growth	No need to retain oak reserve trees unless for other purposes because oak AR is already present
Oak reserve trees retained to provide acorns to develop AR during 2nd rotation	Complete harvest of stand and reserve trees	

[1] Time between harvests ranges from 50 to 100+ years depending on objectives, site productivity, and stand growth

[2] Examples of disturbances include crop tree release, precommercial thinning, timber stand improvement such as cleanings, and careful burning

Dominant and codominant oaks with full vigorous crowns should be chosen as reserve trees. The best, highly-valued trees are harvested, not retained as the risk of stem degrade or damage in more open environments during the second rotation can lower their timber value. Instead, select reserve trees that have the potential to improve in value, size, and grade during the second rotation. These reserve trees will still produce acorns to build oak advance reproduction during the rotation.

Selection of reserve trees is critical. The species should be long-lived and able to flourish through a second rotation. White oaks and hickories are examples of species with long life spans. Vigorous crowns without indication of decline should be chosen. Live crown ratios (length of crown : total height) should be at least 35%. Potential of stems to develop defect-free boles to improve tree grade should be included in the assessment. The topographic position of the tree also should be considered.

Trees on shallow soils such as noses of ridges are more susceptible to windthrow as well as areas in depressions, lower slopes, and stream valleys or bottoms when soils are saturated after excessive rainfall. Usually, 10 to 15 trees per acre should be retained as reserve trees, although a few will probably succumb during the second rotation in the more open, adverse environments.

Mast production by oak reserve trees will vary. Some trees rarely produce acorns; others are irregular with annual production; and some consistently produce acorns every year. If possible, potential reserve trees should be observed several years prior to the harvest for their acorn production, selecting those that are more dependable each year. Intermediate operations are necessary to maintain more open stand conditions to enhance the growth of oak into the overstory and discourage growth of competing species. Such operations would include crop tree release, thinnings, timber stand improvement such as cleanings, and careful burning.

Two-age deferment provides an array of seedlings of different species. Oaks will not be a component of the next generation, but oak advance reproduction will be present from the seed of the older trees in the future generation. Photo Credit: *Wayne K. Clatterbuck*

The two-age system is used to “lifeboat” oak in stands where adequate advance reproduction is not present at the time of harvest. A disadvantage of this system is that several rotations are involved often exceeding the tenure of ownership and managers. Unexpected large-scale disturbances (wind, fire, epidemics, climate) may alter or eliminate the management sequence. However, the two-age management option does keep oak reproduction capacity on the sites for the long-term. For more specific information on the two-age deferment system to regenerate oak, refer to the weblink below.

BENEFITS

- Sexual propagation for oaks is maintained for successive generations.
- Oak regeneration potential remains for future generations if seed sources are continually available even when oak advance reproduction is not present initially.

WEAKNESSES

- Long-lived species should be selected as reserve trees that will survive for 150+ years or two rotation lengths. White oaks are an example of this longevity, while red oaks are shorter-lived and should not be selected as reserve trees.
- Reserve trees, because of their advance age and size, are at risk and are more susceptible to physical damage from harvesting and weather associated with open environments such as ice storms, winds, and lightning as well as environmental influences such as droughts and pathogens. Damaged trees lower tree value.
- The growth of the reproduction located underneath and nearby the crowns of the few reserve trees will be reduced compared to growth of unaffected reproduction in more open areas.
- With the loss of successful oak reproduction in one generation, securing adequate oak advance reproduction in future generations may be problematic because of the longtime element and a changing environment.

FURTHER READING

Stringer, J. 2006. Two-age system and deferment harvests. Extension Publication SP679. Knoxville, TN: University of Tennessee Extension, Institute of Agriculture. 12 p. (https://utia.tennessee.edu/publications/wp-content/uploads/sites/269/2023/10/SP679.pdf)

UTIA INSTITUTE OF AGRICULTURE
THE UNIVERSITY OF TENNESSEE

TN WHITE OAK INITIATIVE

PB 1921-G 03/24 24-0091 Programs in agriculture and natural resources, 4-H youth development, family and consumer sciences, and resource development. University of Tennessee Institute of Agriculture, U.S. Department of Agriculture and County governments cooperating. UT Extension provides equal opportunities in programs and employment.

PB 1921-H

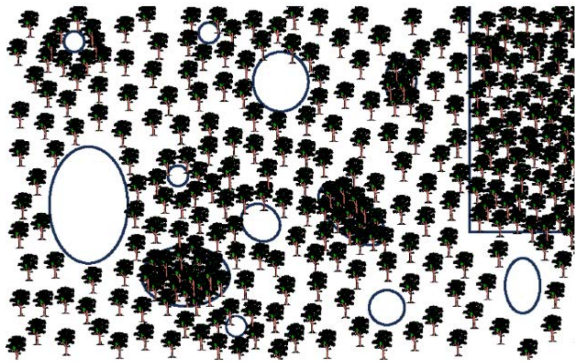
OAK REGENERATION PRACTICES: INTERMEDIATE PRACTICES TO MAINTAIN OPEN FORESTS

Wayne K. Clatterbuck, Professor, Silviculture and Forest Management, School of Natural Resources, University of Tennessee
Stephen E. Peairs, Professor, Silviculture and Forest Management, School of Natural Resources, University of Tennessee

Intermediate practices are management activities used to encourage the growth of existing trees in a forest. Examples include thinnings to reduce stand density and crop tree release. These practices also increase the light penetration into the forest, improving the growing condition for small oak seedlings and providing the growing space for these shade-intermediate oaks to ultimately ascend into the overstory. Often, a "bottleneck" occurs when there are too many trees, whether oaks or other species, which limit growing space and light penetration. These treatments are intermediate disturbances that maintain open forests that are necessary to ensure that oak seedlings continue to grow and develop. Intermediate practices improve the growth of residual trees by reducing stand density while promoting oak seedling development, but are not considered regeneration methods.

THINNINGS

Traditional thinning is the removal of trees in immature stands to redistribute the growth among fewer, potentially more valuable, remaining trees by altering the light and space environment. The undesirable, poorer performing trees are thinned. The goal is to create uniform tree spacing for the remaining trees such that their growth rates are similar. In this manner, thinning is more systematic. This thinning practice occurs more frequently in plantations or single species, monotypic stands where spacing is more consistent, resulting in similar growth rates of like trees.



An example of variable density thinning with different thinning spacings and various skips, gaps, and patches of tree retentions (unthinned) and removals. Photo Credit: *Wayne K. Clatterbuck*

Variable density thinning is conducted frequently in natural, mixed species stands where spacing and growth rates of different species are heterogenous. The focus should be on which trees to retain (based on objectives) rather than trees to cut. Preferred trees remain through a more diverse system of dispersed retention, gap-level retention, and aggregated retention (patches) with the emphasis on establishing varied tree densities across the stand, within a range of individual removals, small group removals, to patches, groups, or islands that are not cut or thinned, respectively. Variable density thinning incorporates a series of skips, gaps, and patches of diverse sizes across the stand creating irregularity and diversity through individuals, clumps and small area harvested openings or uncut or unthinned retentions.

Both thinning strategies provide more dispersed sunlight and greater growing space that encourage growth and development of shade-intermediate oaks by removing adjacent trees. Traditional thinning results in uniform spacing where variable density thinning provides irregular spacing and structural stand complexity by retaining or cutting individual trees or groups of trees. The diverse light conditions caused by the irregular spacing of trees provide greater opportunities for oak to develop and flourish compared to closed canopy conditions.

CROP TREE RELEASE (CTR)

Another intermediate treatment to assure that oaks recruit into the overstory and that a bottleneck does not occur is crop tree release. The crop trees are relieved of horizontal competition from adjacent trees. The released trees become more free-to-grow to capture the additional growing space vacated by the removal of adjacent trees. Thus, the crop trees are more vigorous, healthier, and grow faster enhancing their crown position and stature in the stand. Removal of competing trees from crop trees maintains more open canopies that are favorable for shade-intermediate oaks.

Crop tree release is conducted primarily on trees in the co-dominant crown class and developing saplings and poles where growing space is limited as the stand approaches a closed canopy. Trees in a dominant crown position do not require a release and those that are in the intermediate crown position have already been left behind and do not recover even with a release. Removal of competing trees adjacent to crop trees in young stands is usually a precommercial operation and can be costly. However, some income may be derived with removal of co-dominant trees in older stands. Typically, 30 to 50 trees per acre are selected as crop trees and released for future growth and development. More released trees will increase costs for the operation.

Miller et al. (2007) provides a comprehensive synopsis of crop tree release (web address below) based on research and expresses much more information on application, benefits, economics, and risks than can be conveyed in this fact sheet. A few key aspects of crop tree release are outlined below:

Thinning provides growing space for remaining trees and partial sunlight to aid in the continued growth of oak advance reproduction. Photo Credit: *Wayne K. Clatterbuck*

- Release crop trees on 3 or 4 sides through a crown-touching release. Adjacent trees that are not affecting the crown of the crop trees should not be removed. Intermediate and suppressed trees below the crown level of the crop tree should not be treated or removed (extra cost). Trees exterior to the competitor tree removal will also grow into the released growing space. Additional crop tree removals may be necessary in the future as crop trees and other trees fill the available growing space.
- Trees being removed can be treated mechanically by cutting or girdling with a chain saw (keep safety in mind) or chemically with herbicides (glyphosate, triclopyr, imazapyr) through hack and squirt treatments where the trees die in place.
- Precommercial crop tree release is expensive, taking considerable time and effort. Costs incurred should be offset with potential benefits of the practice, primarily by selecting crop trees to improve the proportion of highly-valued species in the stand, greater diameter growth, better form, shorter rotations, or other management considerations. Selecting too many crop trees will increase implementation costs. Crop trees can be selected for timber, wildlife (habitat and mast), aesthetics, diversity, or other management purposes. For example, a rarely occurring species in the area should probably be retained rather than removed.

Crop tree release of a white oak tree.
Photo Credit: *Wayne K. Clatterbuck*

The purpose of crop tree management is to reduce adjacent competition allowing more space, sunlight, moisture, and nutrients for crop tree growth. Selected crop trees should respond to the release and remain competitive for many years. This intermediate practice enhances the development of slower-growing oaks by reducing competition, providing favorable environmental conditions (primarily more open canopies and dispersed sunlight), and allowing emergence of oaks into the overstory.

FURTHER READING

Miller, G.W., Stringer, J.W., Mercker, D.M. 2007. Technical guide to crop tree release in hardwood forests. Extension Publication PB1774. Knoxville, TN: University of Tennessee Extension, Institute of Agriculture. 24 p. (**https://utia.tennessee.edu/publications/wp-content/uploads/sites/269/2023/10/PB1774.pdf**).

Emmingham, W.H., Elwood, N.E. 1983. Thinning: An important timber management tool. Oregon State University Extension Service Publication PNW 184. Corvallis, OR. 8 p. (**https://extension.oregonstate.edu/sites/default/files/documents/pnw184.pdf**).

UTIA INSTITUTE OF AGRICULTURE THE UNIVERSITY OF TENNESSEE

TN WHITE OAK INITIATIVE

PB 1921-H03/2424-0091Programs in agriculture and natural resources, 4-H youth development, family and consumer sciences, and resource development. University of Tennessee Institute of Agriculture, U.S. Department of Agriculture and County governments cooperating. UT Extension provides equal opportunities in programs and employment.

PB 1921-I

OAK REGENERATION PRACTICES: OAK ENRICHMENT OR SUPPLEMENTAL PLANTINGS

Wayne K. Clatterbuck, Professor, Silviculture and Forest Management, School of Natural Resources, University of Tennessee
Stephen E. Peairs, Professor, Silviculture and Forest Management, School of Natural Resources, University of Tennessee

If natural advance oak reproduction is not present, a logical supposition is to plant oak seedlings to supplement or enrich the existing reproduction and culture those planted seedlings to a larger size. Unfortunately, planting oaks in existing natural stands has been mostly unsuccessful with poor survival. Few plantings exist today. Clark and Dey (weblink below) present a series of thorough protocols concerning seedling care, selection, and planting as possible explanations for poor seedling survival once planted. However, the planting environment and the maintenance of that environment for the growth and culture of shade-intermediate oaks are often disregarded. Dispersed, partial sunlight (20 to 35% full sunlight) that favors oaks and discourages intolerant and more tolerant species must be maintained for development of oaks. Effective site preparation is essential and control of competing vegetation several times is necessary to ensure that oak emerges into the overstory. Often, owners and practitioners set up the correct environment to plant oak initially but fail to maintain those environments afterward. The inherent slower growth of oaks necessitates that management actions for competition control continue and partial light conditions be maintained after planting to be successful.

Scraggly and weak white oak seedling in the deep shade of a closed canopy. This 8-year-old seedling is barely maintaining itself and will eventually die because of limited sunlight.
Photo Credit: *Wayne K. Clatterbuck*

Prominent shade-tolerant midstories should be removed to provide the partial light environments for shade-intermediate oaks to prosper and succeed in enrichment or supplemental plantings.
Photo Credit: *Wayne K. Clatterbuck*

Growth of seedlings (and trees) is balanced between the aboveground stems and leaves and the root system. Seedlings grow well in the nursery where growth components (water and nutrients) are generously provided, and competition is controlled. However, once a seedling is lifted from the nursery bed, usually more than half of the seedling's root system is not retained which stresses the seedling. With the diminutive root system, the aboveground portion is also affected. The outplanted seedling either is stimulated to regenerate more roots quickly to sustain the top, or the top dies back, or both, so that the shoots and the roots re-establish equilibrium. After planting in more adverse environments compared to nurseries, height growth is minimal during the first growing season, allowing competitor species to have a growth advantage adversely impacting the planted oak seedling. The growth strategy of oak seedlings is to put its energy in root system development first, then top growth afterward as compared to many competitors where top growth is the priority rather than growth of roots.

The slower top growth strategy of oak seedlings, especially in the first year after planting, allows competitors to surpass the oak seedling growth.

The barrier to planting oak seedlings for most landowners is the cost. Estimated costs of supplemental/enrichment planting vary greatly depending on the number of oak seedlings planted per acre and the amount of vegetation to be controlled that influence planted oaks as well as providing the partial sunlight under which oak respond. The estimates below are based on planting 300 oak seedlings per acre at a 12’ by 12’ spacing and average site preparation and vegetation control/release treatments using a combination of mechanical and chemical treatments. Readers should realize that costs will increase with greater number of seedlings planted or decrease with a fewer number of seedlings. Vegetation control costs will also fluctuate on the amount and size of vegetation controlled. Cost estimates are within the average of costs reported by several universities in the mid-South United States and as referenced in the Clark and Dey publication.

Cost Item		Average Cost per Acre
Purchasing White Oak or Other Oak Seedligs	$1.00/seedling x 200 seedlings/acre of large, better-quality seedlings without culled, inferior seedlings as referenced by Clark & Dey	$200/acre
Cost of Planting Large, Better-Quality Seedlings Compared to Smaller Seedllings	$0.80/seedling x 200 seedlings/acre	$160/acre
Site Preparation, Vegetation Control, and Adjust Light Levels before Planting		$100.00/acre
Release, Vegetation Control, 2 or 3 years after Planting		$100.00/acre
Release, Vegetation Control, 6 to 10 years after Planting to Address Density Bottlenecks		$100/acre
Estimated Total		**$660/acre**

These reforestation costs can be offset somewhat by cost-share programs as well as reserving a proportion of timber sale revenues for reforestation. Even with these financial adjustments, initial costs of planting, as well as investment for long-term revenue, may be cost prohibitive for many landowners. Failure to create environments to culture oak seedlings after planting and allowing seedlings to fend for themselves often leads to other species supplanting the growth of oaks. Although developing advance oak reproduction is time consuming before the overstory harvest, many opportunities and options are available to naturally regenerate oak at less cost as suggested in this collection of fact sheets. Planting oak seedlings should be considered if less time is a priority in regeneration efforts and increased costs are acceptable.

FURTHER READING

Clark, S.L., Dey, D.C. 2022. Enhancement planting of upland oaks. FOR-161. Lexington, KY: Cooperative Extension Service, University of Kentucky, Department of Forestry and Natural Resources. 12 p. (https://www.fs.usda.gov/research/treesearch/66238).

Morrissey, R.C., Seifert, J., King, N. Selig, M. 2007. Enrichment planting of oaks. FNR-225. Purdue Cooperative Extension Service, Purdue University, Department of Forestry and Natural Resources. West Lafayette, IN. 8 p. (https://www.extension.purdue.edu/extmedia/fnr/fnr-225.pdf).

INSTITUTE OF AGRICULTURE
THE UNIVERSITY OF TENNESSEE

TN WHITE OAK INITIATIVE

PB 1921-103/2424-0091 Programs in agriculture and natural resources, 4-H youth development, family and consumer sciences, and resource development.
University of Tennessee Institute of Agriculture, U.S. Department of Agriculture and County governments cooperating. UT Extension provides equal opportunities in programs and employment.

PB 1921-J

OAK REGENERATION PRACTICES: PLANTING OAKS FOR AFFORESTATION

Wayne K. Clatterbuck, Professor, Silviculture and Forest Management, School of Natural Resources, University of Tennessee
Stephen E. Peairs, Professor, Silviculture and Forest Management, School of Natural Resources, University of Tennessee

Millions of oak seedlings have been produced by tree nurseries and planted in the eastern United States each year since the 1980s. Most of these oak plantings have been unsuccessful, as they are not apparent on the landscape. Possible causes include inadequate site preparation, failure to control competing vegetation, not matching the species to a favorable site, and poor planting stock.

Most oak plantings occur on former agricultural or pasture lands where seed sources or sprouting are not present. Afforestation is plantings which changes land use from non-forested areas to growing trees. Planting hardwood trees is a long-term, costly proposition (refer to the fact sheet on oak enrichment planting) involving site preparation, control of competing vegetation (probably several times), cost of seedlings, and cost of planting. Great strides have been made for nurseries to produce higher quality seedlings and in proper planting procedures. This fact sheet focuses on tree density (spacing) decisions, use of ground covers, and control of unwanted competing vegetation before and after planting.

Afforestation planting of oak on an old field site. Even though the field was site prepared and herbicide vegetation control is evident between planted rows and seedlings, volunteer yellow-poplar and sweetgum (right and left of the oak seedling, respectively) will outgrow and overwhelm the planted oak seedling. Photo Credit: *Wayne K. Clatterbuck*

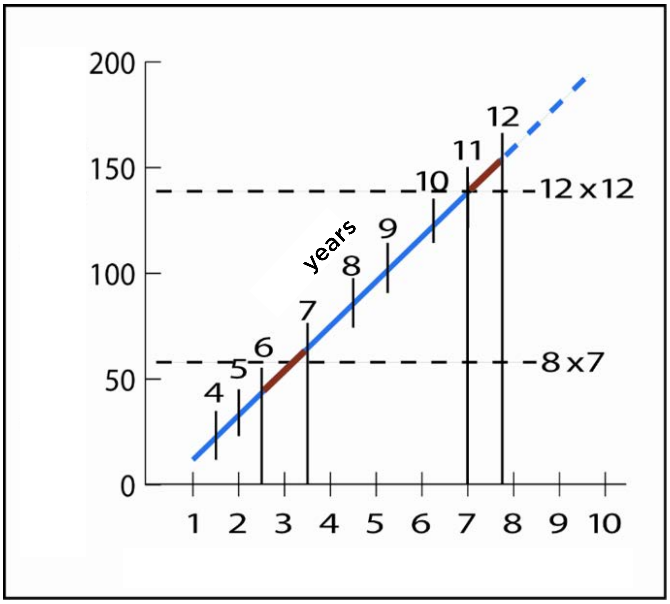
SPACING

The first decision is to determine the spacing to plant seedlings. The spacing will depend on several factors: objectives for the trees in the planting, expense of seedlings and planting, and cost and effective control of competing or unwanted vegetation. Narrow spacings encourages tall, skinny trees with slender crowns and small diameters. A greater number of trees are planted, increasing initial costs. Trees will consume the available growing space quickly such that costly precommercial thinning operations are required. With wider spacings, fewer number of trees are planted, resulting in shorter-bodied stems with crowns that are more horizontal than vertical. At the wider spacings, growing space is available for a longer time period before the trees occupy all the growing space (canopy closure) resulting in larger diameters. Thinnings at these wider spacings may produce some revenue, but tree form and clear bole length may be compromised.

As illustrated in the following graph, narrow spacings close the available growing space in the canopy faster (more trees per acre) than wider spacing where the canopy takes longer to close. The consequences of these spacings are that at narrow spacings, less competition control is required before canopy closure, but trees are smaller in diameter. At wider spacings, canopies take longer to close, resulting in a greater length of time for competition control. For most plantings, depending on objectives and cost, a compromise of 400 to 500 planted seedlings per acre (combinations of 9- to 12-foot spacing between and within rows) would strike a balance between number of competing vegetation control treatments before the canopy closes and desirable tree growth and form.

For example, if the management objective is to produce as much mast as possible, wider spacings with large tree crowns would be optimum. If longer tree boles for timber production are desired, then narrower spacings would be preferred. Even at the spacings suggested, additional thinnings will be required after each canopy closure to increase the growing space per tree as the trees mature in the plantation. Ultimately, at 40 to 60 oak trees per acre are desired at maturity.

Thorough site preparation prior to planting is essential to control unwanted vegetation. The better the site preparation at this time without the seedlings, less vegetation control will be necessary following the planting, allowing seedlings more growth resources. One option is to pre-plant compatible ground covers such as small grains (winter wheat, grain ryes, oats) to discourage colonization of unwanted broadleaf weed seed. Seedlings should be planted directly into the ground cover. Typically, fields that were in row crops the season before seedling planting have little residual vegetation to control. Fields that are fallow for several years will require greater vegetation control efforts. Perhaps the most difficult afforestation conversion is from fescue pastures to planted trees. Fescue, with its thick, fibrous, surface root system, intercepts most precipitation, preventing moisture from reaching the roots of the planted seedlings. Thus, the fescue should be eliminated. Often fescue is controlled in strips within a fescue field to minimize herbicide costs. A row of seedlings is then planted in the strips. Efforts to control the encroachment of fescue and other vegetation into the strips after planting have proved to be troublesome, affecting seedling growth and requiring further vegetational control with escalated costs. Refer to the weblink below for various options and guidelines for successfully establishing ground covers.



Crown closure interval for northern red oak. Blue line represents groundline diameter/crown surface area for plantations on a temporal scale. At 8- by 7-foot spacing (800 trees per acre) the planting will close canopy during the 6th growing season. At the 12- by 12-foot spacing (302 trees per acre), the canopy will close during the 11th growing season. From Stringer, Clatterbuck & Seifert (2009).

Grass with its thick, fibrous root system is a serious moisture competitor to growth of planted seedlings and should be controlled.
Photo Credit: *Wayne K. Clatterbuck*

A broad-spectrum herbicide is applied for site preparation prior to planting to influence a wide array of residual, competing vegetation. Mowing or bushhogging may be necessary to reduce vegetation height so herbicides can be more easily applied. Once seedlings are planted, mowing or disking is not effective for vegetation control since the method would be conducted several times a year, increasing time and expense. Mowing does not control rootstocks which continue to resprout. The frequency of mowing also increases the probably of damage to seedlings by the equipment. A benefit of mowing competing vegetation late during the growing season is to avoid seed dispersal and spread of the unwanted plants. Herbicidal weed control is a better choice. The herbicide is translocated to the roots of the vegetation, disrupting plant processes which causes the plant to die, be stunted, or diminished.

Several herbicides can be applied depending on the weed complex to be controlled. The specifics or scenarios for each herbicide are discussed in the further reading references cited below and are beyond the scope of this fact sheet. Two aspects to be considered is whether to apply a pre-emerge or post-emerge herbicide or a broadleaf or grass herbicide based on the weed complex. **Remember that broadleaf trees are impacted by broadleaf herbicides**.

If controlling broadleaf weeds after planting, directed spray broadleaf herbicides are necessary such that the spray is not directly applied to or drifts onto the tree seedlings. Once tree crowns grow above the weed complex such that they are receiving full sunlight, weed control is no longer required. Eventually, the tree crowns will shade out the ground vegetation.

To Avoid Herbicide Injury and Weed Competition of Planted Seedling

- Control of annual and perennial weeds is much easier before seedling planting. Adequate planning and site preparation before planting is essential for success.
- Use herbicides to control unwanted vegetation that is present after planting. If only grasses are present, spray grass herbicides over the top of seedlings (refer to weblink below for specific herbicides). These grass specific herbi cides will not affect the broadleaf seedlings. If broadleaf competition is present, use directed spray of a broadleaf herbicide making sure the spray does not get on the planted seedling. Retreatment of broadleaf herbicides will be necessary until the seedling grows above the weed complex.
- Mechanical cultivation (disking and hoeing) can be used but should be repeated several times during the growing season. Mechanical cultivation usually results in damage to the seedlings. Mowing or bushhogging are not feasible because it favors the grass, the greatest moisture competitor of tree seedlings.

Mixed species plantings are recommended for afforestation plantings. Unlike monocultures, advantages of mixed species plantings include increased diversity and resiliency of vegetation and wildlife, better stand resistance from insects and disease, greater vertical and horizontal complexity, and synergism between and among species that could lead to improved tree form, grade, and growth. Choosing species to plant in mixtures involves evaluating species that occur and are compatible on similar sites, their light tolerances, and differential growth rates. Most natural stands dominated by oak did not originate as pure oak stands, but developed in the midst of other species. The primary disadvantage of mixed species plantings is that results are uncertain. Knowledge about the development of mixed species plantings is in its infancy. The ecology of the species involved, the various site attributes, and differential species growth rates should be thoroughly assessed for planning prescriptions, spacings, and silvicultural treatments.

FURTHER READING

Clatterbuck, W.K., Coakley C. 2023. Minimizing erosion on harvest sites by revegetating logging roads, skid trails and landing. Extension Publication PB 1916. Knoxville, TN: University of Tennessee Extension, Institute of Agriculture. 9 p. (**https://utia.tennessee.edu/publications/wp-content/uploads/sites/269/2023/10/PB1916.pdf**).

Robinson, D.K., Clatterbuck, W.K. 2006. Unwanted vegetation. Forest Landowner 65(1): 1-4.

Stringer, J.W., Clatterbuck, W., Seifert, J. 2009. Site preparation and competition control guidelines for hardwood tree plantings. Extension Publication PB 1783. Knoxville, TN: University of Tennessee Extension, Institute of Agriculture. 36 p. (**https://utia.tennessee.edu/publications/wp-content/uploads/sites/269/2023/10/PB1783.pdf**).

UTIA INSTITUTE OF AGRICULTURE
THE UNIVERSITY OF TENNESSEE

TN WHITE OAK INITIATIVE

PB 1921-J03/24 24-0091 Programs in agriculture and natural resources, 4-H youth development, family and consumer sciences, and resource development.
University of Tennessee Institute of Agriculture, U.S. Department of Agriculture and County governments cooperating. UT Extension provides equal opportunities in programs and employment.



Conclusion/Summary

Unfortunately, many oak-dominated stands suitable for harvest have not been disturbed or managed for many years, resulting in closed canopies and dense midstories and understories of shade-tolerant species. These environmental conditions inhibit establishment and development of advance oak reproduction which has intermediate light tolerance. The harvest of these stands without adequate oak advance reproduction usually shifts composition to non-oak species.

The major obstacle in regenerating oak is the failure to create environmental conditions that will favor oak advance reproduction before the harvest. Creating and maintaining those conditions requires that the property owner understands that measures should be taken to initiate and develop advance reproduction prior to the harvest and assume the cost, effort and time required to do so. Otherwise, oaks will be scarce, if present at all, as an overstory component of the next stand. Oak seedlings are established after a bumper acorn crop that occurs every 3 to 5 years. This delayed time period for establishment of oaks often discourages property owners from regenerating oak if they wish to harvest their timber now. Additional time is required to develop advance reproduction of sufficient size for oaks to flourish when released with the harvest. Because of the slow, initial growth of oak seedlings and their shade-intermediate light tolerance, faster-growing vegetation must be controlled (additional cost) before they exceed oak seedling growth. Natural oak regeneration is a process rather than an event that should be planned accordingly. Without oaks of competitive sizes and sufficient numbers, property owners accept whatever regenerates after a harvest (event). Oak will not be an appreciable component of the next stand. Oak is advanced growth dependent requiring a head-start growth advantage over other regeneration establishing after the harvest.

The key to establishing and developing advance oak reproduction for natural regeneration is in the regulation of sunlight reaching the forest floor and maintaining that level of sunlight through frequent disturbances. Too much or too little light promoting intolerant and shade-tolerant vegetation respectively can deter shade-intermediate oak advance reproduction allowing species other than oak to prosper. Partial sunlight defined as 20 to 35% of full sunlight is necessary for developing competitive oak seedlings. These light levels can be attained through several practices: shelterwood, midstory removal, thinning, and small opening sizes. Oaks also are disturbance dependent. Frequent targeted disturbances, such as judicious burning, thinning, and controlling unwanted vegetation promote more open-canopied stands, providing the partial light conditions not only to initiate oak advance reproduction during the rotation but to maintain those light conditions to enhance growth of the oak advance reproduction.

Often oak advance reproduction is not evenly distributed throughout the stand, with reproduction being more abundant in some areas and perhaps absent in others. In those situations, advance oak reproduction should be cultured in small areas, groups, or islands where partial light conditions can be managed. Where advance oak reproduction is not present in similar areas, there is little probability of oak occurring, thus measures to promote oak are not necessary, saving costs and efforts.

If stands are to be cut without adequate oak advance reproduction present, supplemental oak plantings or two-age deferments are methods that could be used to keep oaks in future stands (refer to fact sheets). These methods require more time, effort, and expense in site preparation, repeated control of resident, unwanted vegetation, and maintaining partial light conditions that enhance oak growth.

Planted oak seedlings do not have the head start growth advantage over other competing vegetation. Thus, the success rate of planted oak seedlings is often poor without continual care. Oak reserve trees in deferment cuts allow establishment of oak advance reproduction from seed in the next rotation for release during the succeeding second rotation.

The options and guidelines to successfully regenerate oak is presented in the accompanying flowchart. Treatments and responses are highly dependent on site conditions and resident vegetation. If the stand is managed throughout the rotation with open forest conditions (<75 square feet of basal area), actions to recruit and culture advance oak reproduction are not necessary. Frequent disturbances promote and maintain a partial light environment for enhancement of advanced growth dependent oaks. Maintaining oak using a single forest harvest is predicated on the existence of sufficient densities of large advance oak reproduction. Hodges (1989) states the following:

"the answer to the question of how to ensure adequate oak regeneration ... is not the development of some radically new method of cutting, but recognition that all cutting operations in the stand, from the very first, should have as some of their objectives creation of an environment, largely light conditions, favorable for oak regeneration ... and furthermore ... ensure that cuttings occur frequently enough to maintain the growth of oak regeneration." This statement emphasizes that regenerating oak is

- A process and not an event,
- That oaks are disturbance dependent because of their shade-intermediate light tolerance, and
- That oaks are advanced growth dependent due to their slow, initial seedling growth.

The fact sheets present methods to promote advance oak reproduction when not present before the harvest or options after the harvest to maintain oak through planting or deferment. All options take considerable time, effort, and expense to be successful, often inhibiting oak regeneration from occurring. However, if stands are actively managed during the rotation with more open canopies, the advance oak reproduction process becomes part of that management regime, avoiding the need for subsequent actions to develop oak advance reproduction before the harvest.

REFERENCES

Hodges, J.D. 1989. Regeneration of bottomland oaks. Forest Farmer 49(1): 10-11.

OAK REGENERATION GUIDELINES

Minimum of 200 oak seedlings per acre to eventually yield 40 to 60 dominant and codominant oak trees per acre

EVENT	GUIDELINES		
Oak advance reproduction absent	Delay harvest until bumper acorn crop	**Site preparation** before and **soil scarification** after acorn dispersal	Provide intermediate light conditions to increase oak seedling height and discourage growth of other species. Methods: **midstory removal, shelter-wood, small opening sizes (gaps), or thinnings**. Once oak advanced reproduction is >4-feet tall, release seedlings by removing the overstory
Oak advance reproduction present, but diminutive (<18") in height	→		
Oak advance reproduction absent, but must harvest now	**Planting** this year or **2-age deferment** to develop oak reproduction during the rotation	**Site preparation and prescribed burning** prior to planting or natural oak reproduction to control residual vegetation.	Control undesirable competing vegetation as needed.
Oak advance reproduction present >4-feet tall	→		Remove overstory to release seedlings. Some control of unde-sirable species may be periodically necessary

Intermediate operations (*crop tree release and thinnings*) to maintain partial light conditions and provide additional growing space for development of shade-intermediate oaks.

<u>Encouraging the Regeneration of Oaks</u>

- Oaks are a keystone species on the landscape for forestry and wildlife purposes

- The amount of oak in Tennessee is slowly diminishing because the environmental conditions to regenerate the species are not present, primarily light conditions and advance reproduction.

- Oaks are a shade-intermediate species. If the canopy is too open, excessive sunlight will favor more sun-loving (shade-intolerant) and faster-growing species such as yellow-poplar and black cherry rather than oak. If the canopy is closed, shady conditions are created that favor more shade-tolerant species such as maple and beech rather than oak.

- Full sunlight in the 20 to 35 percent range tends to favor growth of shade-intermediate oaks rather than competing shade-tolerant or shade-intolerant species. Published research from many sources (Dey et al. 2012, Phares 1971, Dillaway & Stringer 2006, Gardiner & Hodges 1998; Lorimer et al. 1994, Gottschalk 1987 & 1994, Lhotka and Lowenstein 2009) have verified these light levels that benefit oak growth.

- The issue is establishing and maintaining the open forest conditions that create these light levels. Several methods are available such as shelterwood, midstory control, planting, small gap sizes, and intermediate practices such as thinnings.

- Oaks are **advance growth dependent**. The slow initial growth of oak reproduction necessitates that they gain a head start in growth before the harvest to be able to compete with faster-growing species after the harvest.

- Oaks are **disturbance dependent.** Their shade-intermediate light tolerance requires more <u>open forests</u> with frequent disturbances rather than closed canopies.

- Regeneration of oak is a **process** rather than an event after a harvest. Advance reproduction gives white oak a growth advantage (head start) to compete with faster-growing species.

Primary Obstacle

- Willingness of forest owners to secure adequate advance reproduction and favorable light conditions before the harvest to regenerate oak for the future forest.

NOTES

NOTES

This peer-reviewed University of Tennessee Extension publication was funded in part by the Tennessee White Oak Initiative administered by the Tennessee Forestry Association through an educational grant from the Tennessee Department of Agriculture, Forestry Division. The authors gratefully acknowledge the cooperativeness of these organizations in supporting this project.

UTIA.TENNESSEE.EDU

Real. Life. Solutions.™

PB 1921 03/24 24-0091 Programs in agriculture and natural resources, 4-H youth development, family and consumer sciences, and resource development. University of Tennessee Institute of Agriculture, U.S. Department of Agriculture and County governments cooperating. UT Extension provides equal opportunities in programs and employment.