Hardwood Tree Improvement and Regeneration Center
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Enrichment Planting of Oaks

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Introduction

Oaks (*Quercus* spp. L.) have been one of the dominant trees of the Central Hardwood Region of the United States for thousands of years (Davis 1981; Abrams and McCay 1996). These valuable species are now a vital part of the region's ecology (wildlife food and habitat; biodiversity), economy, and cultural heritage (Harlow et al. 1996). Since the 1960s, there has been an increasing concern that oaks are not regaining a dominant canopy position following regeneration of harvested stands (Carvell and Tryon 1961). Many current forest management strategies (clearcutting; single tree and group selection) tend to favor alternative dominant species, depending upon site conditions (Seifert et al. 2005). Uneven-aged management strategies, such as single tree selection, tend to favor shade tolerant species, such as sugar maple (*Acer saccharum* Marsh.), red maple *(A. rubrum* L.), and American beech (*Fagus grandifolia* Ehrh.), rather than the more shade-intolerant oak species (Johnson et al. 2002). Thus, it is often necessary to explore other management and regeneration techniques if a land manager intends to maintain oaks as a significant component of the next generation of forests.

Enrichment planting, an artificial regeneration technique designed to improve the proportion of a desired species (Johnson et al. 2002), is one way of increasing the successful regeneration of oaks on most sites. This method is most often used in conjunction with certain even-aged harvesting methods, such as shelterwood (Loftis 1990), or with an uneven-aged harvesting method called group selection (Jacobs et al. 2006).

Shelterwood and group selection harvests effectively alter environmental conditions at the forest floor by creating gaps in the canopy through selective harvesting, while leaving a certain percentage of trees standing on the site. Increased light in the understory will allow formerly suppressed advanced regeneration (existing seedlings and saplings in the forest understory) to increase growth rates and compete for a dominant position in the forest canopy. Enrichment planting in these openings can be used in forests where advance oak regeneration is sparse, or when naturally regenerating species are undesirable and likely to out-compete the preferred timber species.

Shelterwood Harvest

Enrichment planting under a shelterwood harvest is often less expensive and more aesthetically pleasing, at least until the final removal of overstory trees, than artificially regenerating a site following a clearcut harvest. Clearcuts open a harvested site to complete sunlight, allowing unhindered growth of fast-growing, shade-intolerant species, such as yellow-poplar (*Liriodendron tulipifera* L.). Oaks tend to exhibit slower above-ground growth than many competing species, as they invest more energy in their extensive root systems (Johnson et al. 2002). Therefore, clearcutting often results in the overtopping of oaks by competing species with faster shoot growth. Once these young oaks are overtopped, their chances of attaining dominant canopy positions are greatly diminished. In contrast, a properly implemented shelterwood harvest system may provide greater control and success for regenerating oaks.

A shelterwood harvest will remove competing understory and a certain proportion of overstory trees, thus reducing competition for light, nutrients, and moisture. In addition, shade from remaining canopy trees will serve to limit the growth of faster growing, shade-intolerant woody vegetation. An ideal harvest

Figure 1. *Regeneration below a shelterwood cut at Purdue University's Martell Forest, West Lafayette, IN. (Photo courtesy of George R. Parker)*

will allow just enough of an increase in forest floor light to give oak seedlings an advantage over slow growing, shade-tolerant species, yet not enough light to enable the growth of fast growing, shade-intolerant species. Shade from the remaining canopy trees will also lower soil and air temperatures, and reduce moisture loss from the soil and leaf surfaces. A shelterwood harvest may provide advantages over a clearcut by improving aesthetics and increasing mast for wildlife as well (Dey and Parker 1996).

Carefully planned shelterwood harvests have the potential to produce desirable results, even when not coupled with enrichment planting (Fig. 1). Shelterwood harvest strategies are most successful for regenerating oaks when there are already adequate numbers of well-established oak seedlings to fully re-stock the stand after harvest. These well-established seedlings, along with stump sprouts of desirable species, are referred to by foresters as "advance regeneration". Remaining shelterwood trees may also provide extra seed for continued seedling establishment over the next few years, once their canopies respond to the increase in light levels (Johnson et al. 2002).

Enrichment planting beneath shelterwood harvests typically increases the probability of success on sites where the desired species may not have adequate advanced regeneration to fully re-stock the stand. Enrichment planting will ensure that some seedlings will be in a large enough size-class to out-compete surrounding vegetation. Enrichment planting may be done throughout the treated stand or just in areas where advance oak regeneration or potential stump sprouts are insufficient.

After the desired species have become adequately established in the sheltered understory, residual shelter trees are removed and the next generation of forest is released to grow in full sunlight. To decide on the timing of removal, one must evaluate the regenerating seedlings' ability to compete upon release, as well as the species the seedlings will have to compete with for growing space. It is important during this period to monitor the stand's development to ensure that competing species do not overtake the crop species. It may be necessary to implement further weed control methods if such a scenario arises.

Group Selection Harvest

Group selection harvests are often preferred to clearcutting or shelterwood harvests for aesthetic reasons. Group selection harvest openings range from 0.1 to 0.6 acres in size. They are used to favor reproduction of intolerant and mid-tolerant species. Opening size controls light within the opening, but aspect, slope gradient, and surrounding tree heights also influence the amount of solar radiation available to regenerating stems. The minimum distance across the middle of a group selection opening should be one to two tree heights, as a general rule (Johnson et al. 2002). Maximum opening size should entail consideration of light availability, aesthetic concerns, and resultant edge effects including development of epicormic branching on edge trees, seed dispersal distances, animal browse damage or predation from edge species, or effects on breeding birds (Johnson et al. 2002). Group selection harvesting is widely employed by foresters in the Central Hardwood Region to regenerate portions of stands. If properly applied, oak can be regenerated. However, in common practice, group selection harvests often do not result in oak-dominated stands.

Although oak seedlings established after harvest may contribute to future stand stocking (Loewenstein and Golden 1995), it is prudent to ensure adequate stocking from advance regeneration, stump sprouting, and tree planting before the harvest. Jacobs et al. (2006) indicated little variation in northern red oak seedling establishment success upon planting various stock types in 0.25 to 0.99 acre openings after two growing seasons, but they observed increased yellow-poplar regeneration in the openings; thus, indicating the importance of controlling competing vegetation in these openings.

The Process: Assessment → Harvest → Site Preparation → Planting → Maintenance

Several authors have investigated and given recommendations for enrichment planting of oaks in the Central Hardwood Region of the United States (Johnson et al. 1986; Weigel and Johnson 1998; Wishard et al. 1999; Spetich et al. 2004). These studies resulted in varying degrees of success depending upon site quality, natural regeneration potential, competing vegetation, and planting method. These results indicate that management prescriptions will vary by site and species, however, much of the literature is in agreement with the following general guidelines. The rigorous application of these steps will enhance the prospects for successful regeneration of oak stands: 1) assess site quality, existing and potential natural regeneration, competing vegetation, and deer damage potential; 2) correctly apply an appropriate silvicultural method through a well-marked and executed timber harvest; 3) prepare the site for the establishment and growth of the regeneration through the post-harvest timber stand improvement and vegetation control; 4) plant appropriate planting stock using correct planting methods and technique; 5) maintain the enrichment planting through vegetation and pest control.

Assessment

Site quality. Before prescribing any silvicultural operation, it is necessary to assess the quality of the site. Site quality may be evaluated by examining soil type, topographical factors (aspect, slope, and slope position), or more informal methods such as observing current vegetative composition and growth. Enrichment planted oaks will have a greater chance of success on sites with poor to good productivity rather than highly productive sites where competition will be heavy. Spetich et al. (2004) suggested a site index range of 60 to 79 feet (base age 50) when planting northern red oak. Planting sites of higher quality requires controlling competing vegetation. Competing species can grow much faster than oak seedlings on these sites. Very poor sites, however, may not provide sufficient resources (e.g. water and nutrients) to allow for adequate growth and survival of planted seedlings.

Figure 2. *Surveying potential for advanced oak regeneration below a mature oak stand before shelterwood harvest. (Photo courtesy of Amy L. Ross-Davis)*

Natural regeneration. The ability of an existing stand to naturally regenerate to oak should be evaluated prior to deciding to conduct an enrichment planting. Where feasible, foresters and land managers should plan timber harvests in conjunction with a good acorn crop year to encourage the establishment of oak seedlings. Natural regeneration potential may be assessed by surveying the amount, size, and distribution of advance regeneration and stump sprouting potential of crop species (Fig. 2). Foresters have developed methods for assessing regeneration potential.

Approximately 400 advance oak seedlings should be present at the time of overstory removal or final harvest. This number may decrease somewhat with the presence of potential stump sprouts. For oak seedlings to be considered “advance” regeneration, they must measure at least 3 to 4.5 feet tall or at least ¾ inch in root collar diameter. Oak seedlings of these dimensions have well-developed root systems making them more capable of competing with other fast-growing species in full sunlight. Stump sprouting potential is generally dependent upon the age, diameter, and species of the harvested tree. A stump’s probability of sprouting and the competitive ability of the sprouts decrease with tree age and diameter (Weigel and Peng 2002). Table 1 indicates the probability of stump sprouting of common oak species based on size class. Where adequate advance oak regeneration exists, enrichment planting may not be necessary to ensure that the new stand will be dominated by oak.

Table 1. *Probability of stump sprouting of harvested parent trees based on diameter at breast height (DBH).[1]*

DBH size class (inches)	Black Oak	Scarlet Oak	Northern Red Oak	White Oak	Chestnut Oak
2-5	85	100	100	80	100
6-11	65	85	60	50	90
12-16	20	50	45	15	75
17+	5	20	30	0	50

[1]Adapted from Sander et al. (1976).

Competing vegetation. The existing or potential understory competition within the planting area should be assessed. A general competition survey should consider size and species of any undesired vegetation currently in the stand’s understory. Sugar maple, red maple, American beech, flowering dogwood (*Cornus florida* L.), and white ash (*Fraxinus americana* L.) are common understory competitors in the Central Hardwood Region (Fig. 3). Foresters and landowners should also consider species currently in the forest canopy, as these trees likely contribute to the stored seed source within the forest floor, and may also produce strong

Figure 3. *Advanced regeneration of sugar maple will out-compete planted oak seedlings if not removed. (Photo courtesy of Douglass F. Jacobs)*

competition from stump sprouts if harvested. For example, 1,000 to 10,000 viable yellow-poplar seed per acre may blow up to 100 to 500 feet via the wind to colonize recent or future harvest areas. Many of these seeds remain viable in the soil for 4 to 7 years (Beck 1990). Since oak seedlings are slow growing, much of the competition in the understory will need to be controlled and prevented to help ensure success.

Deer damage potential. Oak buds and twigs are a preferred browse food for deer. Large deer herds effectively eliminate oak regeneration and damage regeneration of other desirable species. Deer damage potential should be assessed. The greater the deer browse pressure, the more well-established advance oak seedlings and saplings are required to successfully regenerate the stand to oak, or the greater the need to implement measures to protect the regeneration or reduce the deer herd.

Harvest

When possible, the initial harvest in a shelterwood should be conducted following a year of good acorn production to encourage the growth of naturally regenerating seedlings. This first harvest should reduce overstory density to 60 to 80 % stocking (Weigel and Johnson 2000; Johnson et al. 2002). This provides adequate light for oak seedling establishment, but sufficient shade to inhibit the establishment of yellow-poplar and the rapid re-establishment of the understory. The amount of overstory removal will be dependent upon site quality and the amount and type of competing vegetation in the understory. The stand should be thinned from below by removing understory and some intermediate crown class trees down to a diameter of 1.5 inches (Fig. 4). Trees should be selected for removal based upon form, species, and desirability of neighboring trees. Poorly formed, diseased, stressed trees, and less desirable species should first be selected for removal in the harvest. Better quality trees will also be marked for harvest to achieve the desired shelterwood light conditions and to make the lot of timber saleable. In a group selection harvest, all overstory trees will be removed in the harvest.

Site Preparation

All non-merchantable trees in the understory should be cut down or otherwise killed in the post-harvest timber stand improvement, down to less than 1.5 inches in diameter, but taller than 1 foot. Herbicide should be applied to the stump surface of undesirable species to prevent stump sprouting (Spetich et al. 2004). Herbicide should not be applied to oak stumps. Grapevines and noxious or invasive weeds should be controlled prior to

Figure 4. *Initial harvest of mature overstory and removal of competing understory. (Photo courtesy of Douglass F. Jacobs)*

harvest. If harvest timing coincides with a good acorn crop, scarifying the soil by light disking or raking immediately following acorn drop, but before the timber harvest, may improve oak seedling establishment (Lhotka and Zaczek 2003). Broadcast applications of foliar applied herbicides prior to planting will further reduce weed competition (Wright 1985). The use of broadcast herbicide applications, however, should be weighed against the potential damage to and need to conserve native plant communities. An alternative is to identify tree planting spots first and then make spot applications of herbicide in a 2 feet radius (circle) at each planting spot.

Planting

The future stocking and density (trees per acre) of the stand is dependent on the number of oak seedlings planted, the amount of natural advance oak regeneration already present, and the number of oak seedlings that become established from seed. Stocking level recommendations will vary depending upon individual landowner objectives and future management objectives. Spacing between planted seedlings will depend upon final stocking goals, and abundance and distribution of established oak regeneration. Ultimately, it will be up to the landowner or forester to decide what stocking level will meet the future goals of the stand, but it is recommended that 150 to 385 oak stems of at least 4.5 feet in height be established per acre at the time of overstory removal (Desmarais 1998). Alternatively, enrichment planting can be targeted to those areas lacking advance oak regeneration or sprout potential, thus reducing planting costs.

It will be critical to choose the right seedling stock. Seedlings should be obtained from a local nursery that uses a native seed source (Jacobs 2003). Because of intense competition, seedlings planted in a shelterwood, clearcut, or group selection opening need to be larger than what might normally be planted in other settings. Bare-root hardwood seedlings should have at least a shoot height of 18 inches, a root collar (the part of the root just below ground level) of at least ¼-inch thick, preferably ½ inch or larger (Johnson et al. 2002). Seedling shoots should be balanced with their roots

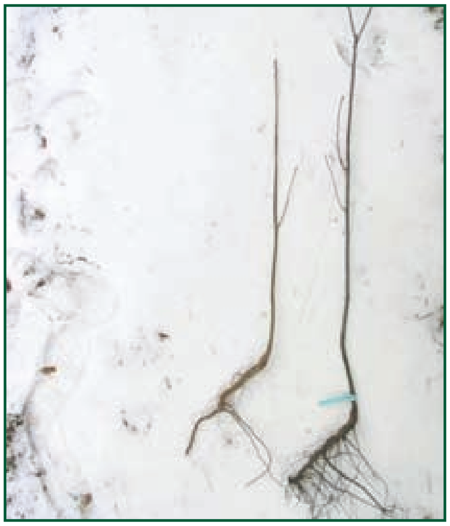

Figure 5. *Bareroot northern red oak seedlings. (Photo courtesy of Douglass F. Jacobs)*

(Fig. 5). Larger seedlings with greater size root collars are needed when no site preparation or weed control will be used or where site quality is high and yellow-poplar competition is present (Fig. 6). Smaller seedlings should be culled and not planted. Seedling and planting costs are also important considerations. It is better to pay more for high quality seedlings rather than risk planting failure with less expensive, poor quality seedlings. Seedling quality will have a large bearing on the success of the enrichment planting operation and future timber quality (Pijut 2003).

Follow best management practices when transporting, storing, and handling seedlings (Pijut 2003). Removing seedling tops 6 to 8 inches above the root collar before planting tends to improve seedling performance when planted under shelterwoods (Johnson et al. 2002).

Seedlings should be planted in late winter to early spring when seedlings are still dormant. The hand planting of large planting stock can be challenging work, so it is vital to use a competent planting crew. Mechanized planting options for large planting stock include a hand auger with a 2-cycle engine power

Figure 6. *Large container oak seedlings can be expensive, but should provide better survival and growth after planting. (Photo courtesy of Douglass F. Jacobs)*

head and tracked skid steer or tractor with an auger attachment. All of the proper tree planting protocols must be followed by the crews, and supervisors must ensure prevention of desiccation and mechanical damage to the roots during the planting operation (Pijut 2003).

Maintenance

Monitoring. Once the seedlings have been planted, it is recommended that periodic survival checks are conducted to ensure seedling survival and evaluate other maintenance needs to ensure their success (Fig. 7). Seedlings should be monitored following the first two growing seasons (WDNR 2006). The presence of insects, disease, or animal damage, and occurrence of competing vegetation should also be noted. The 2nd or 3rd year following timber harvest in a group selection

Figure 7. *Seedlings should be periodically checked for growth, survival, and overall health. (Photo courtesy of Anthony S. Davis)*

opening and in shelterwoods with low residual overstory stocking, the vegetation becomes too thick to continue monitoring. The window of opportunity to correct problems also quickly closes after the 3rd growing season.

Animal browse. Animal browse from rabbits, voles, moles, and most especially deer in the Midwest can damage or destroy newly planted seedlings. Many methods of prevention are available though they differ greatly in terms of their cost and effectiveness. Various designs of tree protectors, shelters, and fencing schemes, plus a variety of repellents have been developed and tried with varying degrees of success. The most efficient way to control deer damage is through adequate hunting pressure. McKenna and Woeste (2004) discuss animal damage control in greater detail.

Weed control. Even with careful planning and proper implementation, it is still possible that competing vegetation may overtake planted and naturally regenerating seedlings. Yellow-poplar can be a very aggressive competitor on good sites upon

Figure 8. *Yellow-poplar regeneration after initial harvest may be extensive and grow quickly. (Photo courtesy of Douglass F. Jacobs)*

the release cutting (Fig. 8). In these situations, it will be necessary to apply weed control to the competing vegetation. Because of limited access and irregular spacing of desirable species, competing vegetation is commonly treated with directed foliar applications of post-emergent herbicides. This is most effectively accomplished with a backpack sprayer and hand-wand. When applying herbicides it will be necessary to shield desired seedlings from overspray.

Where herbicides are not an acceptable method for competition control, alternatives include mechanical vegetation control and prescribed burning. Mechanical vegetation control includes mowing, scarification of the forest floor, and clearing understory vegetation with a small bulldozer or tractor prior to planting seedlings, or cutting stems of competing vegetation. Alternatively, prescribed fire conducted under low-risk conditions may prove to be a cost-effective form of weed control. Well-timed burns kill and weaken competing regeneration (Fig. 9). While oak seedling tops are killed by fire, the roots and buds at the root collar survive and re-sprout vigorously. Because it is beneficial to oak regeneration only under very specific conditions and because of the inherent risks associated with its use and the need to comply with local air quality standards, controlled burning should

Figure 9. *Low intensity prescribed burn should only be conducted with professional supervision. (Terry Price, Georgia Forestry Commission. Reproduced with permission, www.forestryimages.org)*

only be done under the supervision of qualified personnel.

Release. Once an adequate number of desired trees have become well established, the overstory should be removed to release the seedlings. One more herbicide application made prior to overstory removal helps reduce the competition for the planted seedlings upon release. The final removal is dependent upon the status of the regeneration in the understory, and may be done some time between 3 and 10 years after the initial harvest (Sander and Graney 1993; Spetich et al. 2004). This time frame should allow for planted seedlings to overcome planting shock and obtain a competitive advantage over controlled vegetation (Fig. 10). Once the overstory removal is complete, any leftover stumps or cut stems from undesirable species should be sprayed with an herbicide to prevent re-sprouting.

Summary

Many factors contribute to the success or failure of an enrichment planting operation, but several studies have shown good seedling survival rates using the basic methods described above. For example, after 2 years Dey and Parker (1997) showed a 99 % survival rate among planted northern red oaks in a shelterwood enrichment planting study, where 50 % of the overstory crown density was removed. Weigel and Johnson (1998) found a 98 % survival rate in planted northern red oaks following the first growing season after

Figure 10. *Release of oak sapling after removal of overstory. (Photo courtesy of Douglass F. Jacobs)*

reducing overstory density by 60 % stocking. Thirteen growing seasons after planting, survival rates ranged between 50 and 77 % depending upon the specific treatment.

There are many costs and benefits that must be weighed before deciding whether to do enrichment planting; how much to plant and what seedlings to use. Controlling competition from other species is a necessary associated cost. Alternative regeneration methods, such as clearcutting, are cheaper and easier to plan and execute, but the probability of regenerating an oak dominated stand on medium to good productivity sites is low. By controlling the regeneration of the future stand, a landowner may better realize his or her objectives. Although enrichment planting can be costly, when properly implemented it helps ensure that oak will be a prominent component of the new stand.

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