Guide to the Group Shelterwood Cutting Method for Regenerating Northern Red Oak
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by

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Cover Photo: A group of residual trees in an opening following a shelterwood cut in a red oak-sugar maple-white pine stand, 90 to 115 years old. If a denser stand border had been retained to the south and west (left part of photo) to exclude direct sunlight and wind, it could have provided ideal conditions in a small shelterwood nucleus for underplanting red oak nursery stock, and possibly sheltering some red oak natural reproduction. (Parry Sound District, Ontario, 1989. Photo by P. Secker)
ABSTRACT

Shelterwood cutting in the northern hardwood forests of North America is the silvicultural method recommended to regenerate heavy-seeded hardwood species such as northern red oak (*Quercus rubra* L.). The group shelterwood cutting method, applied on a small scale as opposed to using large-scale uniform shelterwood cutting, is particularly attractive because of the smaller risk of failure taken during the critical stages of establishment and early growth of red oak regeneration.

This report describes and illustrates a step-by-step field procedure for a three-phase group shelterwood cutting method that can be used to regenerate red oak naturally or artificially.

This report also includes practical appendices on soil-site requirements of red oak, tree-marking guidelines specific to the group shelterwood cutting method, regenerating red oak in the presence of deer browsing, nursery measures to maximize planting success, and the assessment of planting stock quality and seed tree and offspring characteristics.
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INTRODUCTION

Northern red oak (*Quercus rubra* L.) is a major species in the northern mixedwood and hardwood cover types of Ontario (Rowe 1972), and over much of the northern part of the eastern deciduous forest of the United States (Braun 1950). The once large supplies of high-quality hardwood timber, including red oak, have been severely reduced through repeated highgrading, which has left behind stands that are understocked and decadent (Arend and Scholz 1969). Good growth, high market value (principally for veneer and lumber), and the use of its acorns as food by many wildlife species make red oak a desirable species for regeneration and management. Jarvis (1956) pointed out that stand cultural treatments are needed to encourage the reproduction and growth of hardwood species for sawlog and veneer production in Ontario.

There are many reports that describe the regeneration of hardwoods, including red oak, by means of shelterwood cutting methods (Coder *et al.* 1987, Hannah 1988, Jacob and Wray 1992, Johnson *et al.* 1989, Johnson & Jacobs 1981, Johnson 1993, Leak *et al.* 1987, Loftis 1990, Marquis *et al.* 1984, Mills *et al.* 1987, Sander 1977, Sander 1979, Watt *et al.* 1973). Although these authors provided general recommendations, none described step-by-step field procedures to guide forest practitioners and woodlot owners through the various phases of the group shelterwood cutting method of regeneration. This report demonstrates a theory that the use of group shelterwoods, on a small scale, as opposed to large-scale uniform shelterwood cutting, may be a good way to learn about the requirements for the establishment and growth of red oak regeneration. The same principles modified to account for differences in silvics, could be used for other species with the intermediate shade-tolerance of red oak.

Appendix 1 provides some silvical characteristics and synecological requirements of red oak, and a comparison with those of some of its frequent associate species in mixedwood stands such as white pine (*Pinus strobus* L.), red pine (*Pinus resinosa* Ait.) and sugar maple (*Acer saccharum* Marsh.). Tree-marking guidelines specific to the group shelterwood cutting methods are described in Appendix 2.
BACKGROUND FOR THE GROUP SHELTERWOOD CUTTING METHOD

For species that regenerate under a shelterwood, release of the regeneration must occur for the young trees to attain dominance. Group shelterwood cutting may be used to meet this need. The concept of group shelterwood cutting (Gruppenschirrschlag), or "group shelterwood to create regeneration nuclei" (Koestler 1950), was credited to Gayer (1886) and introduced to the English forestry literature by Anderson's (1956) translation of Koestler's Waldbau (Silviculture). Gayer's concept stressed a regeneration process that does not spread uniformly and simultaneously over the whole stand, but which has all the regeneration phases existing beside one another in the stand. This process, extending over 20 to 40 years, includes:

(a) preparation of the stand through intensified stand tending to accelerate expansion of the crowns of potential seed bearers,

(b) seeding fellings during seed years to create regeneration nuclei,

(c) thinnings or final harvesting to release advanced reproduction or artificial regeneration and

(d) peripheral fellings to expand existing regeneration nuclei and initiate new ones. This slower regeneration process provides a smaller dependence on good seed years and thus a smaller risk of the treatments failing. It is the favorable conditions prevailing within the nuclei (initially, clusters of potential seed trees) and the stand size to be regenerated that will most often dictate the speed of progression of the regeneration. The concept of regeneration in phases was further elaborated by Mayer (1977), who emphasized long-term preparatory thinnings to maximize stand stability and minimize wind throw.

In North America, there has been a failure to recognize that:

(1) a species' regeneration requirements are the consequence of a long developmental "process" (e.g., basswood, *Tilia americana* L., mainly due to its infrequent seed years and difficulty in seed germination) and not of a single "act" such as cutting (e.g., sugar maple, mainly due to its frequent seed years and ease in seed germination); and,

(2) there are differences in a species' growth response from early youth to the attainment of dominance in the stand. This has made successful regeneration difficult for
secondary but commercially important species in mixture with more aggressive primary species (Stroemple 1983).

Since stands that have originated exclusively from natural reproduction following cutting are relatively rare, a combination of natural and artificial regeneration is therefore the rule. Mayer (1977) recommended planting of 2-to 3-year-old oak stock for faster establishment. In North America, Johnson (1985) independently developed a prescription for planting large red oak stock under a shelterwood to maximize establishment success.

The term "group selection method", the one most often used in the North American forestry literature, is somewhat misleading. The phrase appears to describe the classical "group shelterwood" or "shelterwood cutting by groups", but does not emphasize the shelter provided by the residual trees as the main ingredient in a successful stand. The group shelterwood method relies on a group of trees optimally distributed so as to provide a uniform canopy shelter, or such a distribution created by thinning, and not a series of patches (clearcuts) that may not contain any planned or naturally occurring shelter. Exceptions are open patches resulting from blowdowns, firewood cuts from below (with or without residuals), uniform salvation cuts with occasional clear patches, and others, which may contain advanced natural reproduction or openings that are suitable for planting oak nursery stock. Large-scale uniform shelterwood cuts often leave behind many small clearcut patches, which quickly fill in with dense, competing vegetation (much of it unwanted), making natural or artificial regeneration problematic. Consequently, in "group selection" the emphasis is actually on the shelter provided by the method rather than on the selection process; it would be more appropriately called "group selection shelterwood", or simply "group shelterwood" (cutting method) as in Smith (1986), and Coder et al. (1987) who created a variant of what Johnson (1994) called a group selection method.

The Objective

The objective of the group shelterwood method is to open the tree canopy over small areas to increase the amount of diffuse light without increasing the amount of direct sunlight on the forest floor. The method thus encourages the establishment of advanced reproduction but discourages the growth of competing vegetation, which generally requires more intense light. The ideal result would be a mixture primarily composed of species with intermediate shade-tolerance, developing in a "staged mosaic of even-aged patches regenerated periodically in various cutting cycles" (Anderson et al. 1990).

The best locations to initiate stand openings (groups or patches) for red oak regeneration are in mature, dense stands with evenly distributed oaks or potential seed trees of other acceptable species. Within the openings and on the periphery of the openings, the crowns of residual seed
trees expand, encouraging seed production and volume growth. As these openings enlarge as a result of subsequent peripheral thinnings, they eventually merge into compact regeneration areas. If the thinnings follow a linear pattern, these areas often, conveniently, form long strips. The treatment that is applied to ultimately produce high-quality veneer will be single-tree selection. The forest manager is not predisposed to selling large tracts of timber, but rather veneer trees, auctioned individually.

This is not to say that large uniform shelterwood cuts cannot be successful over a good "ketch" of acorns. Success is particularly likely if planting of superior oak follows soon after thinning to assure uniform stocking, and neither animal browsing nor competition is a serious problem. However, the manager will more likely succeed in small-scale regeneration areas, spread over longer time periods, and this success will encourage other managers to adopt a similar approach.

In the next two sections we will present a three-phase technique for managing red oak under a group shelterwood method. The first section will discuss management where red oak regeneration already exists under the canopy (either naturally, or as a result of planting or seeding). Here, the procedure is to remove the overstory above and around the opening to admit light and thus favor the growth of the advanced oak reproduction. The second section will discuss management where there is little or no regeneration present. Here, the procedure is to reduce overstory density by creating one or more small openings under or near the partial shade of seed trees. If obtaining adequate natural regeneration is unlikely, burn the ground vegetation or suppress it with herbicides to facilitate planting of nursery stock or direct seeding of acorns.

**Burning**

Fire intensity, the duration of the exposure to heat, bark thickness and configuration, and the amount of slash and its flammability all have a strong effect on the survival of dormant buds under the bark. Thus, they affect the resprouting capacity of the hardwood species during the first and second season following a burn (Rouse 1986). A single burn can be expected to provide conditions favorable for light-seeded species (Little 1974), such as yellow birch (*Betula alleghaniensis* Britton), and for species that undergo multiple resprouting from burned stems (Arend and Scholz 1969, Godman and Tubbs 1973, Nyland et al. 1983, White 1986), such as basswood, black cherry (*Prunus serotina* Ehrh.), white ash (*Fraxinus americana* L.), red maple (*Acer rubrum* L.), red oak and others. Cutting of stems during the dormancy period also stimulates resprouting to produce dense clumps of sprouts (Stroemple 1983). Applying an appropriate herbicide to the cut stubs can thus be used to reduce competition as a result of resprouting (Johnson et al. 1984). A second burn 2 to 3 years later (Nyland et al. 1983) may be the key to promoting oak over its associates (Little 1974), because doing
so will kill unwanted root suckers or stem sprouts (Hannah 1988). As well, prescribed burning has the potential to reduce the amount of rodent habitat and control the acorn weevil (Balaninus glandium Marsh.) (Godman and Tubbs 1973). However, a burn that follows a thinning cut, with broken tops or downed trees near residual trees, will increase the incidence of scorching and killing (Godman and Tubbs 1973, Hannah 1988, White 1980).

**Planting**

Planting nursery stock may be the only option where pilferage of acorns by rodents is a problem, but where browsing by deer is likely to be tolerable (Marquis et al. 1976). Where oak stocking is inadequate or of poor form as a result of extreme deer browsing, tree shelters may be a good option to secure establishment (Appendix 3).

Measures to maximize plant-ability and the planting success of graded red oak nursery stock are described in Appendix 4. Criteria for assessing the stem quality of seedlings and saplings after planting are described in Appendix 5.

**Direct Seeding**

There is very little information on direct seeding of red oak available that could be securely applied in practice. The success of seedling establishment by direct seeding often depends on the amount of pilferage of acorns by rodents (Marquis et al. 1976). Sowing acorns at a depth of 5 cm in the mineral soil and covering them with litter has been recommended for bottomland oaks in the southern United States (Johnson and Krinard 1985); under droughty conditions (e.g., following a burn under an open canopy), 10 cm may be safer. Johnson and Krinard sowed 3700 acorns/ha under forest conditions and obtained 1235 seedlings in the first year and 370 free-to-grow seedlings after 10 years.

Seed tree and offspring characteristics that can be used to guide acorn collections are described in Appendix 6.
A THREE-PHASE GROUP SHELTERWOOD CUTTING METHOD TO REGENERATE RED OAK

OAK REGENERATION PRESENT

PHASE ONE

Figure 1 illustrates the three steps required in the first of the three phases of the group shelterwood cutting method where natural reproduction is present in a stand opening:

(1) Remove the stand overstory in the opening;
(2) Remove the overstory around the opening; and
(3) Cut skid trails or stand exits.

**Step One**

Cut all residual overstory trees to increase the amount of light that reaches the understory and thus to help the reproduction already present in the opening achieve free-to-grow status. This understory sometimes includes reproduction in openings created naturally or artificially by the causes described on page 3.

**Step Two**

Enlarge the stand opening by removing all overstory trees in the surrounding stand to a distance of half the average height of the stand, thus allowing the reproduction to develop under uniform microclimatic conditions.

**Step Three**

Cut skid trails on the eastern edge of the stand to provide channels for cold air to blow out of the opening and thus minimize the frost pocket effect. If skid trails are not required, cut exits in the eastern edge of the stand; these should be wider on level terrain and narrower on slopes to channel out cold air readily.

Note: If skid trails are needed in the western or southern edges of the stand, keep them as narrow as possible to minimize wind and sunlight effects. (This assumes a prevailing west wind.)

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1. Frost pockets develop in small openings within stands because the openings allow cold air to pond and the surrounding stands and ground vegetation prevent it from leaving. In contrast, openings in coniferous plantations, especially when trees are pruned (naturally or artificially) to a considerable height, allow the cold air to exit relatively rapidly (Stroempfl 1987). See Geiger (1959) for additional information on this topic.
Leave trees in the exits only if they are widely spaced and free of obstructing branches near the ground; trees suspected of restricting the flow of air should be removed.

Break down high slash so it is nearer to the ground to improve air movement and aesthetics (Noyes 1970), to encourage decomposition, and to increase the area available if infill planting of red oak stock is required (Fig. 2).

Cut high stumps of desirable species closer to the ground to encourage vigorous sprouting at ground level (as opposed to high on the stump), which will lead to the development of additional high-quality reproduction (Stroemple 1983).
Figure 1. Phase one of the three-phase group shelterwood cutting method in a stand with pre-existing oak regeneration: The stand opening with natural reproduction (cross-hatched) and the surrounding periphery with no reproduction, with stand exits (arrows) to channel cold air out of the opening.
Figure 2. High slash, when broken down so that it lies nearer to the ground, should make additional area available for planting nursery stock. Cut high stumps (such as those in the foreground) of desirable species closer to the ground to encourage vigorous sprouting at ground level rather than high on the stump, which will encourage the development of additional high-quality reproduction (Stroempl 1983).
OAK REGENERATION PRESENT

PHASE TWO

Figure 3 illustrates the three required steps (6 to 15 years after Phase One, depending on site quality, stand structure, development of stems and stocking, and environmental influences) that comprise the second of the three phases of the group shelterwood cutting method where natural reproduction is present in the stand opening:

(1) Enlarge the opening that contains the reproduction;
(2) Thin the periphery that has little or no reproduction; and
(3) Extend the opening into the uncut stand and create exits.

**Step One**

Enlarge the diameter of the stand opening further by about half the average tree height to maintain the natural reproduction from Phase One, both free-to-grow saplings and developing seedlings.

**Step Two**

Thin the old stand to create a shelterwood (leaving 70 to 80% canopy cover) and increase the available light for existing reproduction, and/or in advance of anticipated natural reproduction. Conduct the thinning to a distance of twice the average tree height from the edge of the opening. The canopy cover could be potentially reduced to 60% or less depending on the size and amount of existing reproduction of oak and other acceptable species: the taller the reproduction, the less residual canopy is required. A visual depiction of three levels of residual crown canopy is illustrated in Figure 4. The crown area vs. basal area tables for the Lake States (Godman and Tubbs 1973) or for the northeastern United States (Leak and Tubbs 1983) are a useful aid. To produce a desired level of crown cover, use these tables to determine the required residual basal area after thinning. So long as forest conditions in your area resemble those in the tables, thinning on the basis of basal area will produce a close approximation of the desired crown cover.

**Step Three**

Regenerate the stand progressively by proceeding generally south-southeast.

**Note:** Extend the opening to the east and southwest only if stand density is high, good-quality residuals are evenly distributed, and the topography is downhill in the direction of the progression of the thinning. (The distance acorns fall from the seed tree to the ground downhill increases linearly with the steepness of the terrain.)

If the development of stems and stocking is not secured within the expected time period, in-fill planting of red oak must occur, following possible control of competing vegetation.

Extend the exits made in Phase One and create new ones through uncut stand boundaries in the direction of the cut’s progression.
Figure 3. Phase two of the three-phase group shelterwood cutting method in a stand with pre-existing oak regeneration: The stand opening now contains oak reproduction in the free-to-grow state (cross-hatched), with additional natural reproduction developing (single-hatched). The thinned old stand has had exits (arrows) created to channel cold air out of the opening.
80% of the canopy remains closed (70% on dry sites). Stand borders are closed on the western and southern edges.

60% of the canopy remains closed (50% on dry sites). Stand borders are closed on the western and southern edges.

20% of the canopy remains closed (10% on dry sites). Stand borders are loosened.

Shelterwood canopy
- Closed
- Open

Figure 4. Overhead view of three main levels of residual crown canopy for the three-phase group shelterwood cutting method to regenerate red oak.
OAK REGENERATION PRESENT

PHASE THREE

Figure 5 illustrates the three required steps (16 to 25 years after Phase Two, depending on site quality, stand structure, development of stems and stocking, and environmental influences) that comprise the third of the three phases of the group shelterwood cutting method where natural reproduction and/or artificial regeneration is present in the stand opening created in the two earlier phases:

1. Weed out potential wolf trees within the free-to-grow reproduction;
2. Cut the adjoining overstory between two merging openings to create one compact regeneration area; and
3. Create new openings.

**Step One**

Weed out excessively branchy pole-size trees and large saplings within the free-to-grow reproduction because, if these are left, they will develop into wolf trees (Roach and Gingrich 1968) and their wood will be unsuitable for veneer or lumber.

**Step Two**

Depending on the stand density, topography, and the location and quality of the residuals, openings may be conveniently extended eastward to form a strip from the west to the east (Smith 1986).

If the remaining area between two openings with established reproduction is less than 40 x 80 m (the approximate size of an initial opening), cut all of the overstory between the openings to merge them into a single, compact regeneration area. Retain those residuals that are growing most vigorously, (check diameter of selected sample trees) usually at the stand edges between openings, until the first thinning of the new stand (i.e., the stand created at the end of phase 3).

**Step Three**

Create new openings and thin them as in Phase One and Phase Two to achieve the desired canopy cover and initiate the regeneration process.

Continue to maintain stand exits.

**Note:** Under favorable conditions of stand structure, site and environment, certain steps and phases may be combined. For example, if an underplanting operation follows thinning of a periphery that has little or no reproduction in Step 2, Phase Two, then you can combine Steps 1 and 2 into a single step in both Phase One and Phase Two.
Figure 5. Phase three of the three-phase group shelterwood cutting method in a stand with pre-existing oak regeneration: The stand opening with natural reproduction and/or artificial regeneration is complete with exits on the eastern side of the stand to channel cold air out of the opening.
OAK REGENERATION ABSENT

PHASE ONE

Figure 6 illustrates the three steps required in the first of the three phases of the group shelterwood cutting method where natural regeneration is initially absent in a stand opening:

(1) Select locations with oak seed trees or seed trees of other desirable species;
(2) Mark openings for subsequent cutting to suit regeneration requirements; and
(3) Cut stand exits.

**Step One**

Select locations with seed trees of high reproductive potential (based on age, crown size and form) and/or locations with a high stocking of reproduction of acceptable tree species. Here, the receptivity of the site (based on seedbed conditions, topography, exposure) should be high.

**Step Two**

Mark areas for cutting to establish openings under shelter of the seed trees. These openings should be generally elliptical to avoid the excessive shading that occurs at the corners of rectangular openings.

The size of an opening should be approximately twice the average height of the seed trees in width (e.g., 40 m) and double that in length. With a 40-m width and an 80-m length, an opening comprises 0.25 ha. The recommended size of an opening in various hardwood stands generally ranges from 0.2 to 0.4 ha (Barrett 1980, Carvell 1967, Coder et al. 1987, Sander 1971, Trimble 1973). Depending on the site’s aspect, slope, requirement for protection, and other factors, the size of an opening can range up to 0.8 ha (Daniel et al. 1979, Johnson 1985, Leak et al. 1987).

Retain a main canopy cover of approximately 70 to 80% on fresh sites and 50 to 60% on dry sites to delay the invasion of competing vegetation and thus to help the natural reproduction develop; if the reproduction fails to appear the canopy will continue to keep competing vegetation in check and thus allow planted stock to develop. The planting operation should then be carried out in the same year as the thinning of the old stand or in the year following the thinning in Phase Two.

**Step Three**

Cut eastward exits through the stand boundaries to channel cold air out and thus minimize the effect of potential frost pockets.
Figure 6. Phase one of the three-phase group shelterwood cutting method in a stand without pre-existing regeneration: The initial shelterwood cut is 40 x 80 m in size (not to scale), and oriented in a south-southeast direction. Note exits on the eastern side of the stand (arrows) to channel cold air out of the opening. The 40- and 80- m distances represent twice and four times the average stand height, respectively.
OAK REGENERATION ABSENT

PHASE TWO

Figure 7 illustrates the three steps required in the second of the three phases of the group shelterwood cutting method where natural reproduction may appear, or planting of red oak stock or sowing of acorns is anticipated in the stand opening. Phase Two follows 3 to 5 years after Phase One (depending on site quality, stand structure, development of stems and stocking, and environmental influences) if natural reproduction has appeared. Phase Two could also follow Phase One in the same or the following year if natural reproduction has failed to appear and planting will be carried out. The three steps are:

1. Remove the overstory from above the reproduction and/or thin the old stand for planting.
2. Apply herbicide to competing vegetation or burn it, if necessary, before planting or sowing; and
3. Cut stand exits.

**Step One**

Remove the overstory from above developing natural reproduction. If regeneration has failed to appear, retain the overstory in the opening and, instead, thin the old stand. Move mainly south-southeast, to create a shelterwood as in Step Two of Phase One (p. 15), and to prepare the site for planting of stock.

**Step Two**

Apply herbicide or conduct a prescribed burn to control competing vegetation before planting nursery stock (Fig. 8) if ground vegetation has become too abundant under the shelterwood (i.e., competing vegetation is as tall as or taller than the average height of the seedlings to be planted, bare planting spots are difficult to recognize, and other features are present that may have contributed to planting failures at similar locations). It may also be feasible to underplant red oak without the use of herbicides if anticipated losses as a result of suppression by vegetative competition can be compensated for by modest increases in the number of planted trees (Johnson 1989, 1992). Johnson provided a table of the number of planted trees required with and without weed control to obtain one future dominant or codominant tree. The number of trees decreases rapidly with increasing initial stem diameter (from 6.5 mm to 16 mm), whether or not stands are treated with herbicides. The bigger the seedling (both in height and diameter), the greater the success rate (Johnson 1992).

If acorns are available and pilferage by rodents and loss due to competing vegetation are expected to be tolerable, sow three or more times as many acorns as the conventional number of planted nursery stock, i.e., 3330 or more per ha.

**Step Three**

Continue to maintain stand exits. Establish new stand openings in suitable areas and proceed as in Phase One (see p. 15).
Figure 7. Phase two of the three-phase group shelterwood cutting method in a stand without pre-existing regeneration: A stand opening with developing natural reproduction or artificial regeneration (hatched) has been created, surrounded by a shelterwood cut without regeneration and including exits mainly on the eastern side of the stand (arrows) to channel cold air out of the opening.
Figure 8. Red oak 56 cm tall by mid-growing season of the first year in part of a shelterwood underplanting operation, following the use of herbicide to control competition. The seedling is a vigorous candidate to compete with the surrounding vegetation if it remains unbrowsed. (Photo by P.W. Secker, Parry Sound District, 1989.)
OAK REGENERATION ABSENT

PHASE THREE

There are two situations that may face the manager in the third phase of the group shelterwood cutting method where oak regeneration is absent:

(a) Natural reproduction has appeared in Phase One and the overstory above it has been removed in Phase Two; or

(b) Planting has been carried out in the same year or the following year after thinning of the old stand in Phase Two. In either case, wait 6 to 15 years (depending on site quality, stand structure, development of stems and stocking, and environmental influences) before applying the same three steps as in Phase Three with oak regeneration present. That is:

(1) Weeding out wolf trees within the free-to-grow regeneration;
(2) Cutting the adjoining overstory between two merging openings to create one compact regeneration area; and
(3) Treating newly located openings as in Phase One and Phase Two to achieve the desired canopy cover and start the regeneration process anew.
APPENDIX 1

SOIL-SITE RELATIONSHIPS AND SYNECOLOGICAL CHARACTERISTICS

OF RED OAK

There are great similarities between the northern red oak in North America and the same species naturalized in Europe, and red oak is also similar to two native European species, pedunculate oak (Quercus pedunculata Ehrh. = robur L.) and sessile oak (Q. sessiliflora Salisb. = petrea [Matt.]). These species are called "soil-daring" because they thrive on alkaline or acidic soils, light or heavy soils, and loose or compacted soils (Krahl-Urban 1959, Leibundgut et al. 1963). Broadfoot et al. (1971) found red oak most frequently on soils with a surface soil pH of 5.0 to 6.5, with associated species such as basswood, birches (Betula spp.), black cherry (Prunus serotina Ehrh.) and sugar maple.

Generally, good oak soils are medium to coarse in texture, have a high water permeability and are relatively low in calcium content. There are three soil groups favorable for oaks:

(1) loamy sands, pH 7;
(2) loamy clays, pH 6-7; and
(3) clay loams, pH 4-5. The lowest calcium content usually occurs in the clay loams.

Generally, the roots of oaks are known as "soil-adaptable", i.e., the tap root often disappears as soil compaction increases, and is replaced by dense laterals that form a wide "root plate". In Parry Sound District and throughout the Muskoka region of Ontario, red oak with heights of 25 m or more and with spreading lateral root plates close to the surface usually grow on shallow-soil sites (30 to 90 cm to bedrock) with a fresh to dry moisture regime; these are usually fine to medium sands with pockets of fresh silt or clay (Secker 1986). These sites may be seasonally waterlogged and poorly drained, or very dry. Some lateral roots develop "sinker" roots for stability. In light soils, the tap root of oaks can generally be long, but it stops as soon as it reaches a nutrient-rich, moisture-holding layer; alternatively, it changes into heart roots with numerous laterals that extend vertically as well as horizontally. Older oaks generally do not have a pronounced tap root regardless of the soil conditions (Koestler et al. 1968).

Although relatively drought-hardy, juvenile oaks generally require a ready supply of moisture and therefore develop a strong tap root. However, the genetically pre-disposed juvenile tap root will not redevelop once it has been severed, e.g., after undercutting in the nursery. Instead, numerous adventitious roots form horizontally rather than vertically (Carpenter and Guard 1954, Leontovyc and Capek 1987, Woessner 1972).
Due to red oak's rapid root-regenerating capacity (Farmer 1975), planting of nursery stock should be scheduled to allow root growth-promoting substances in buds to be translocated to the roots before the trees begin to develop the moisture stress that is associated with oak's rapid leaf development (Johnson et al. 1984). Therefore, fall underplanting in forest stands may be advantageous to promote new root growth before frost penetrates the soil and/or to achieve the benefit of early root activity soon after soil thawing in the spring. Since northern red oak is rated as only moderately sensitive to heavy top- and root-pruning (compared with other hardwoods), pruning of nursery stock is recommended to facilitate handling (Larson 1975, Lindstrom 1963). Johnson et al. (1986) and Johnson (1988) recommended 1 + 1 or undercut 2 + 0 stock of at least 10 mm in basal diameter that is top-pruned 15 to 20 cm above the root collar within two weeks of planting. The practice of using red oak stock larger than 1 + 0 for planting in forest stands is also supported by Labrecque and Popovich (1988).

Figure 9 shows the daily shoot and root growth of pedunculate oak compared with grey alder (Alnus incana Willd.), Norway spruce (Picea abies L. [Karst.]) and silver fir (Abies alba Mill.). The root growth of this oak occurs over 73% of the total growth period and is most active in March, April and May and again in August (or later, depending on the location and environmental influences). Similar data for northern red oak are not available, but this species is similar to pedunculate oak in many ways.

**Points to Consider:**

* Identify red oak sites on the basis of existing species associations, stand history, and the form and position of oak trees in the stand.

* The moisture-seeking tap root of juvenile oaks is a forceful, genetically predisposed feature, but one that is lost when the root is severed.

* Root initiation precedes shoot elongation and continues after shoot dormancy occurs. Fall planting of nursery stock will likely initiate early root growth.

* The tap root will be deep in less-dense soils but not where a nutrient-rich, moisture-holding layer occurs near the soil-surface. The tap root is replaced by numerous lateral roots in shallow and/or compacted clayey soils, which are often rich in nutrients and moisture near the surface. Older oaks eventually have their tap root replaced by a network of lateral roots.
Figure 9. Daily shoot and root growth increment of juvenile trees of four species from March to October (Leibundgut et al. 1963).
* The absence of a tap root may influence oak's physical stability thus, shorter rotations are recommended on shallow soils.

Table 1 shows red oak's moisture, nutrient, light and heat requirements in relation to those of red pine, white pine and sugar maple.

Table 1. Synecological requirements of red oak compared with those of red pine, white pine and sugar maple. Values range from 1 (lowest) to 5 (highest). Data from Bakuzis and Hansen (1959).

<table>
<thead>
<tr>
<th>Species</th>
<th>Moisture</th>
<th>Nutrient</th>
<th>Light</th>
<th>Heat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red oak</td>
<td>1.5</td>
<td>4.2</td>
<td>2.8</td>
<td>3.5</td>
</tr>
<tr>
<td>Red pine</td>
<td>1.1</td>
<td>1.6</td>
<td>4.5</td>
<td>2.1</td>
</tr>
<tr>
<td>White pine</td>
<td>1.7</td>
<td>2.1</td>
<td>2.8</td>
<td>2.0</td>
</tr>
<tr>
<td>Sugar maple</td>
<td>3.2</td>
<td>5.0</td>
<td>1.0</td>
<td>3.5</td>
</tr>
</tbody>
</table>

Points to Consider:

* Red oak vs. red pine: Red oak needs almost three times as much nutrients as red pine, almost twice the amount of heat and just over half the light. The moisture requirements of both species are quite similar.

* Red oak vs. white pine: Red oak needs twice as much nutrients as white pine, and almost twice the amount of heat, but the light requirements of both species are equal. The moisture requirements of both species are also quite similar.

* Red oak vs. sugar maple: Red oak needs less than half as much moisture as sugar maple, but almost three times as much light. The other requirements of both species are quite similar.
APPENDIX 2

TREE-MARKING GUIDELINES FOR PREPARATORY CUTS

Regardless of the number of preparatory cuts (thinnings) before the regeneration cut, the following tree-marking guidelines specific to the group shelterwood cutting method are recommended beginning with a pole-size stand and thereafter:

* Mark according to the overstory’s canopy density and the light requirements of the species selected rather than according to a predetermined overstory basal area. However, basal area versus crown cover tables such as those in Godman and Tubbs (1973) or Leak and Tubbs (1983) can help you to predict crown areas on the basis of more easily measured stem basal areas.

* Mark competitors for cutting where they obstruct the maximum growth potential of good-quality trees in the dominant canopy.

* Mark trees for cutting in the lower canopy using the same guidelines as for the dominant canopy.

* Mark unwanted trees on the basis of visible infections (e.g., cankers) rather than based on physical deformities (e.g., excessive branchiness).

* Do not mark all the "unwanted" intermediate and suppressed trees, as these may be all there is to offset excessive gaps in the main canopy. As well as discouraging rapid invasion and growth of undesirable competition, they are particularly important when underplanting is necessary to supplement natural stocking. This is often the case when insufficient numbers of potential acorn producers are present, or when seed crops fail.

* Locate log-landing areas in the northern or eastern part of the stand, where the exposure of stand edges to direct sunlight and consequent invasion of ground vegetation will be reduced compared with landings in the southern and western stand edges.
Refrain from disturbing the southern and western stand edges so as to preclude excessive sunlight and wind from entering the stand.

Retain about 10 to 20% of the most vigorous residuals at desirable locations to provide crown cover after a harvest cut. These trees will most likely be found in areas such as stand edges, providing continued shelter and increased log value until the first thinning of a newly regenerated stand.

Rehabilitate log-landing areas by seeding of legumes and cereal species and/or planting of nursery stock.

Note: Tree marking guidelines beyond the scope of the present report are discussed by Anderson and Rice (1993).
APPENDIX 3

REGENERATING RED OAK UNDER DEER COMPETITION

Forest managers strive to secure red oak seed to help reproduce oak stands. Wildlife managers strive to improve red oak seed production as an important source of food for deer and other animals. However, the consumption of large quantities of young oak leaves and shoots by deer imposes another obstacle to the success of regenerating oaks.

In the Horse Lake tract near Dorset, Ontario, where red oak reproduction is adequate but of very poor form due to extreme deer browsing, saplings 2 m in height vary between 12 and 31 years of age (with an average of 18). The saplings would normally reach 2 m at age 13 without browsing, or perhaps a greater height in as little as 7 years with release of the stand canopy and protection from browsing. Figure 10 shows the predicted increase in height growth of oak in this tract with the exclusion of deer browsing combined with early canopy release to improve light conditions and subsequent growth of the trees (Stroempl and Zakrzewski 1988).
Figure 10. Predicted growth of red oak reproduction without deer browsing and with canopy release at age 5 years, in the Horse Lake tract near Dorset, Ontario.
The value of timber production lost as a result of browsing during a regeneration period was estimated to average $2,656 U.S./ha in northwestern Pennsylvania (Marquis and Brenneman 1981). Regeneration is more likely to be successful if effective measures are introduced to divert deer from browsing on the oak. One effective measure is to ignore the deer population and plant a maximum of 125 superior quality red oak nursery stock per hectare under 60% or less canopy cover and protect each with a Tubex (St. George Co. Ltd., St. George, Ont.) tree shelter 1.5 or 1.8 m tall to minimize or exclude possible browsing; tree shelters will also keep away the tall vegetative competition that often overtops the usually smaller transplants without tree shelters. Another option is to decapitate young oak already present in the stand and to protect the stubs with tree shelters to promote vigorous growth of the resprouts. Tree shelters have improved the survival and early height growth of planted red oak (Lantagne and Ramm 1990). Figure 11 shows a Tubex tree shelter around a red oak sapling in the fourth growing season after planting under a shelterwood.

Oliver (1978) reported that the best board-foot volume of red oak in mixed New England stands was obtained with not more than 111 upper-canopy stems per ha (45/acre) at age 60, provided that this component had remained at this density since age 30, in stands containing 3672 stems/ha (1500/acre) of other species and subordinate to the oaks. Furthermore, Oliver noted that a large number of oaks close together may not only be unnecessary, but also undesirable if one wishes to avoid the need for thinning among competing oaks.
Figure 11. Red oak 1+0 nursery stock in a shelterwood underplanting operation. A 1.5-m-tall Tubex tree shelter was placed over the oak at planting to prevent early browsing by rodents and deer. Note that the oak’s crown is 25 cm above the shelter in August of the fourth growing season. (Photo by Bruce Fleck, management forester, Bancroft District, 1992.)
Environmental Conditions

1. To prevent winter drying, water heeled-in stock during the warm, dry snow-free months of October/November and March/April.

2. Cover heeled-in stock to exclude light, heat and wind, but maintain constant air circulation.

3. Bundle heeled-in stock for shipping as well as short-term storage before shipping so as to exclude light, heat and wind. (Do not sacrifice biologically favorable conditions for the sake of easier handling.)

4. Water bundled stock during short-term storage, and also prior to shipping, to ensure that the roots are fresh at the destination.

5. Transport bundled stock in a manner that excludes light, heat and wind.

6. Red oak stock in kraft bags or burlap sacks with their tops exposed are sometimes transported in a refrigerated van where air circulation contributes to desiccation. These conditions are favorable for spruce and pine stock in kraft bags totally sealed.

Morphological Quality and Grading

The following are characteristics of high-quality stock:

1. **Buds**: A cluster of conspicuous buds at the apex (ensure stock dormancy to prevent flushing of buds before planting).

2. **Stem length and form**: The main shoot is sturdy, well defined and straight, and branches are usually absent.

3. **Root-collar diameter**: A minimum diameter of 6 to 8 mm at about 2 cm above the root collar.
4. **Root length and volume**: Several strong primary lateral roots (not just fibrous roots) extend from the main (central) root. Roots are pruned to about 20 to 25 cm in 2+0 stock and 10 to 15 cm in 1+0 stock to facilitate "deep" planting and to ensure that dormant buds will resprout if the main stem is severely damaged. For more information on deep planting, see Stroeml (1990).

**Physiological Conditions**

1. Use stock that originates from sources based on a phenotypic selection; e.g., late-flushing oak (from northern locations) is less likely to be damaged by late frosts, and caterpillars that hatch from eggs deposited on late-flushing oak may die of starvation before leaves are produced.

2. Consider the use of nursery stock for fall planting under forest conditions. Using stock under open-field conditions, where frost heaving can be a serious problem, may be unsuccessful. Some nursery practices, such as late (Aug/September) fertilization prior to lifting can seriously jeopardize the suitability of the stock for fall planting by delaying hardening off in the fall.

**In the Field**

1. **Long-term storage** (3 days and longer): Every district should have a storehouse with a mound of snow and a fan to provide conditions similar to an ice house and thus delay flushing of stock, which has usually begun in the nursery prior to field delivery.

2. **Mid-term storage** (3 days and shorter): Use "silver cool tree tarps", so as to exclude light, heat and wind, but provide constant air circulation. Water the bundled stock before storage, as necessary. Alternatively, store bundled stock under shelter in a running stream or body of water stirred occasionally by wind or rain to provide aeration and minimize exposure to light, heat and drying wind, and to keep roots moist.

3. **Short-term storage** (a few hours): Store bundled stock in a pool at the planting site during or shortly after a rain, which mixes air with water. Alternatively, store the stock in buckets of fresh water. Avoid exposing roots to light, heat and wind during short-term storage before and during planting.

For more information on stock grading, with illustrations, see Stroeml (1985).
# APPENDIX 5

## RED OAK QUALITY CLASSES AND FIELD ASSESSMENT OF PLANTED STOCK

### Seedling Stage

<table>
<thead>
<tr>
<th>Quality Class</th>
<th>Quality Description</th>
</tr>
</thead>
</table>
| Excellent     | * Terminal shoot (leader) present, with a cluster of prominent buds at its apex  
* Terminal shoot unobstructed and free to grow  
* Browse damage absent |
| Good          | * Terminal shoot present, with a cluster of prominent buds at its apex  
* Terminal shoots may be unevenly forked or somewhat obstructed  
* Browse damage only on previous year’s growth or minor at stem base |
| Fair          | * Top may be bushy or forked, but the tree remains competitive with surrounding vegetation  
* Browse damage conspicuous  
* Recovery possible |
| Poor          | * Terminal shoot (leader) absent  
* Top bushy or severely forked  
* Recovery questionable |

*Note: A "poor" seedling may also be healthy and free of the above damage but irrecoverably overtopped by vegetation (unless release and/or corrective treatment follows).*
### Sapling Stage

<table>
<thead>
<tr>
<th>Quality Class</th>
<th>Quality Description</th>
</tr>
</thead>
</table>
| Excellent     | * Terminal shoot (leader) above the reach of deer browsing  
|               | * Cluster of prominent buds at the apex  
|               | * Dominant, narrow crown; leader unobstructed and free to grow |
| Good          | * Terminal shoot above the reach of deer browsing  
|               | * Cluster of prominent buds at the apex  
|               | * Dominant or codominant narrow crown; may be unevenly forked or somewhat obstructed |
| Fair          | * Apical dominance not established  
|               | * Browsing damage evident  
|               | * Intermediate crown may be bushy or forked; competes with the surrounding vegetation  
|               | * Recovery possible |
| Poor          | * Terminal shoot (leader) absent  
|               | * Crown development bushy  
|               | * Browsing damage severe  
|               | * Recovery questionable |

**Note:** A similar description for red oak quality classes can be found in Table 2 in Stroemple (1987).
APPENDIX 6

SEED TREE AND OFFSPRING CHARACTERISTICS

Seed Tree

The accompanying photographs (Fig. 12, 13, 14, 15, 16) illustrate the quality characteristics of seed trees deemed suitable for acorn collection. The basic factors to consider are:

* branch arrangement
* crown form
* stem form
* if in doubt as to the source of acorns on the ground, mix acorns collected from around several trees that are close together

late-flushing oaks are less susceptible to late frosts; conversely, those from milder climates are less hardy when transferred to colder climates

most offspring will carry the characteristics of the parent seed tree (Table 2)

<table>
<thead>
<tr>
<th>Form of Seed Trees</th>
<th>Proportion of Offspring (%) that Share the Seed Tree's Form</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Same</td>
</tr>
<tr>
<td>Broomlike (test area 1)</td>
<td>100</td>
</tr>
<tr>
<td>Broomlike (test area 2)</td>
<td>74</td>
</tr>
<tr>
<td>Forked</td>
<td>73</td>
</tr>
<tr>
<td>Straight stem</td>
<td>85</td>
</tr>
</tbody>
</table>

Table 2. Comparison of the characteristics of seed trees and their offspring (Krahl-Urban 1959).
Figure 12. Open-grown red oak of stocky form with widespread, repeatedly forking branches should not be accepted because they are unlikely to be producers of high-quality offspring. (Photo by the authors, Huronia District, 1989.)

Figure 13. Red oaks in a mixed hardwood/pine stand, near the stand in Fig. 12, are of high quality. (Photo by the authors, Huronia District, 1989.)
Figure 14. Red oaks with low forks are acceptable as long as the stem form and crown structure are of high quality. Such forking is usually a result of apical damage to young oaks. (Photo by the authors, Huronia District, 1989.)

Figure 15. An open-grown oak that developed with two main stems, both repeatedly forking (left). The offspring (right) also developed stems with repeated forking, similar to the mother tree at the left (Krahl-Urban 1959).
Figure 16. The most common forms of oak transplants. From left to right: straight, forked and broomlike (Krahl-Urban 1959).
Offspring

Note whether the stem form of the offspring is straight, forked or broomlike.

Straight

The most important feature for good quality nursery grown stock, besides stem form and crown structure, is the presence of a prominent bud or cluster of buds on the leading shoot; without this, oak tends to develop long, horizontal branches, sometimes even under dense vegetative cover.

Forked Stem

Forked stems are very common. However, genetically induced forking must be distinguished from a forked stem of other origin, such as one due to frost, insect, browsing damage or breakage.

Broomlike

Look for multiple forking and/or dense, irregular branching, which results from a cluster of three or more terminal buds of equal size on the leading shoot.

Flat-topped Stem (not illustrated)

Do not eliminate a flat-topped seedling if it has a single stem that may gradually re-establish a leader and resume an upright position. This will depend on the amount of light upon release and the amount of competing woody vegetation present.
LITERATURE CITED


