Red Pine Management Guide

A handbook to red pine management in the North Central Region

This guide is also available online at:

http://ncrs.fs.fed.us/fmg/nfgm/rp

A cooperative project of:

North Central Research Station

Northeastern Area State & Private Forestry

Department of Forest Resources, University of Minnesota

Silviculture

Silviculture

Silvicultural considerations for your red pine stand include:

1) assessments of site quality
2) regeneration needs and practices
3) treatments for established stands

We present these in some detail in this section. Moreover, we discuss how common silvicultural practices can be adapted to better meet ecological objectives including provision of wildlife habitat and sustainability of plant and animal biological diversity.

We also refer you to the Silvics of North America manual; specifically, the Red Pine section.

Site Assessment

Managers and landowners are interested in estimating potential growth before establishing a red pine stand. As such, the understanding of site quality and proper site selection is important in order to optimize tree growth and survival, and to minimize the risk of insect and disease infestations. Likewise, projecting growth and yield is often of interest in established stands.

Several approaches are currently used to assess site quality in the Lake States and Northeast. They include site index, soil-site approaches, and vegetative and biophysical approaches. Depending on the size of their land holdings, individual landowners may be limited in the range of site qualities available for red pine. In such instances, relative measures of site quality may be useful. For example, if a landowner's goals were inclusive of income, habitat, and recreation/aesthetics they may choose to select higher quality sites for timber production and lower quality sites where red pine occurs naturally for habitat management. In either case, an assessment of site quality would be important. On the other hand, they may wish to practice both timber management and reserve management on high quality sites and extensive management on the remainder of their land holdings. In either case, an assessment of site quality would be important.

The purpose of this section is to provide a summary of existing site quality work and how it may be used to select sites for income, habitat, or recreation/aesthetics management. References to the original publications are provided for the interested reader.

Site Index

Site index is the most commonly used method of assessing site quality in North America and is defined as the height of a tree at a base or index age, usually 50 years. Trees that are measured to determine site index should be over 30 years old and be in a dominant or codominant canopy position.

In Figure 1 are site index curves for red pine that have withstood the test of time (Benzie 1977).

Carmean et al. (1989) provided seven sets of site index curves for red pine using various index ages. Although an index age of 50 is commonly used, some of them use younger index ages. These curves are representative of height growth patterns for red pine based on total tree age, plantation age, and age measured at breast height (measured at 4.5 ft or 1.3 m above the ground) for specific regions across North America.

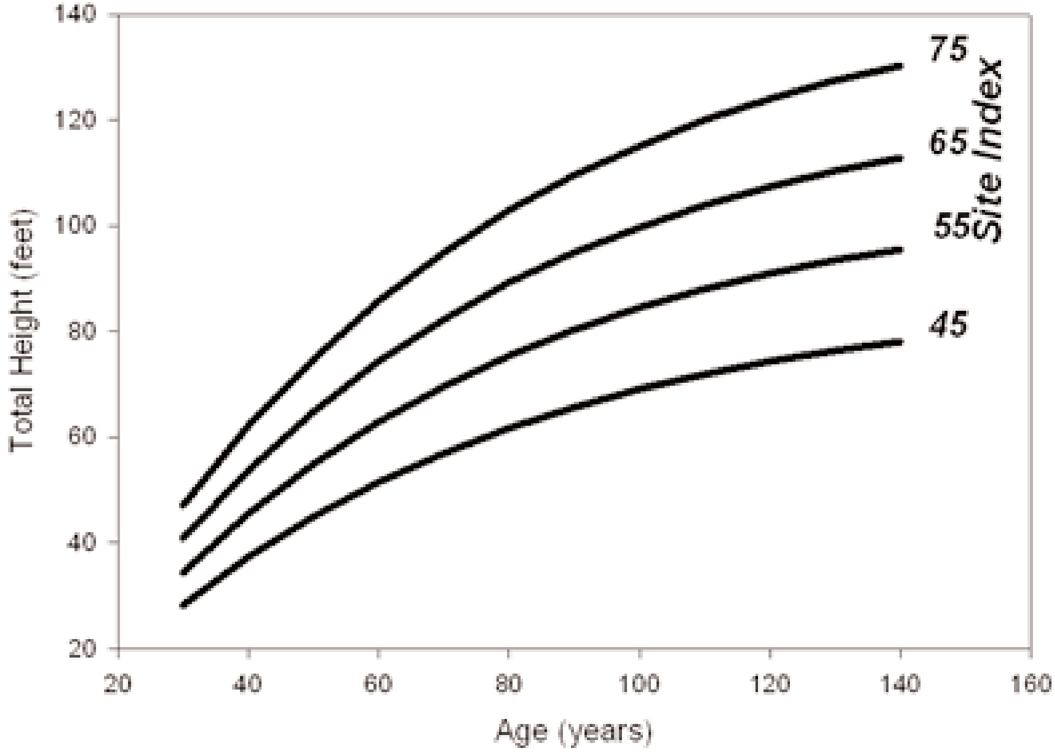


Figure 1. Site index curves for red pine from different regions of North America

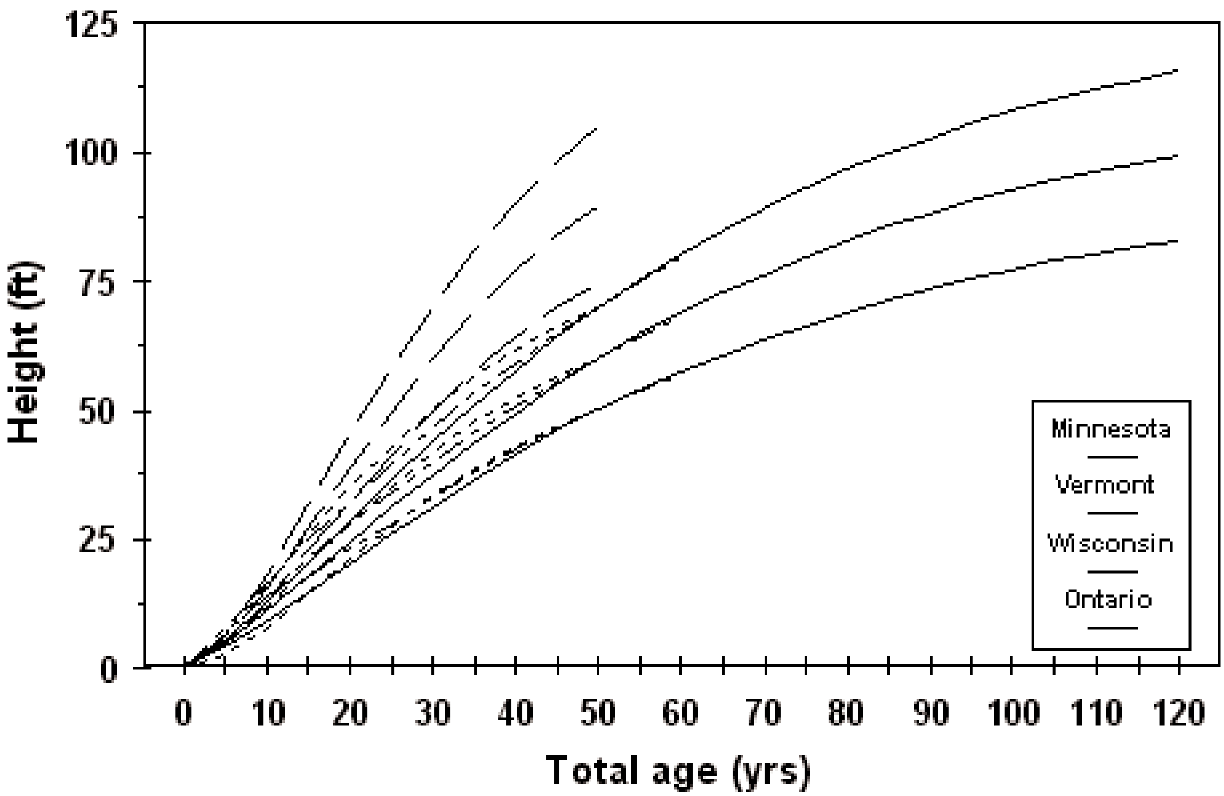


Figure 2. Comparison of site index curves based on total age from Minnesota, Vermont, Wisconsin, and Ontario. Site indices of 50, 60, and 70 are presented for each group of curves. Equation form: H = b 1S b2[1 - exp(b 3A)] b4 (S^b5), where H = total height in feet, S = site index, A = total age, and b i designates parameter estimates provided in Table 1.

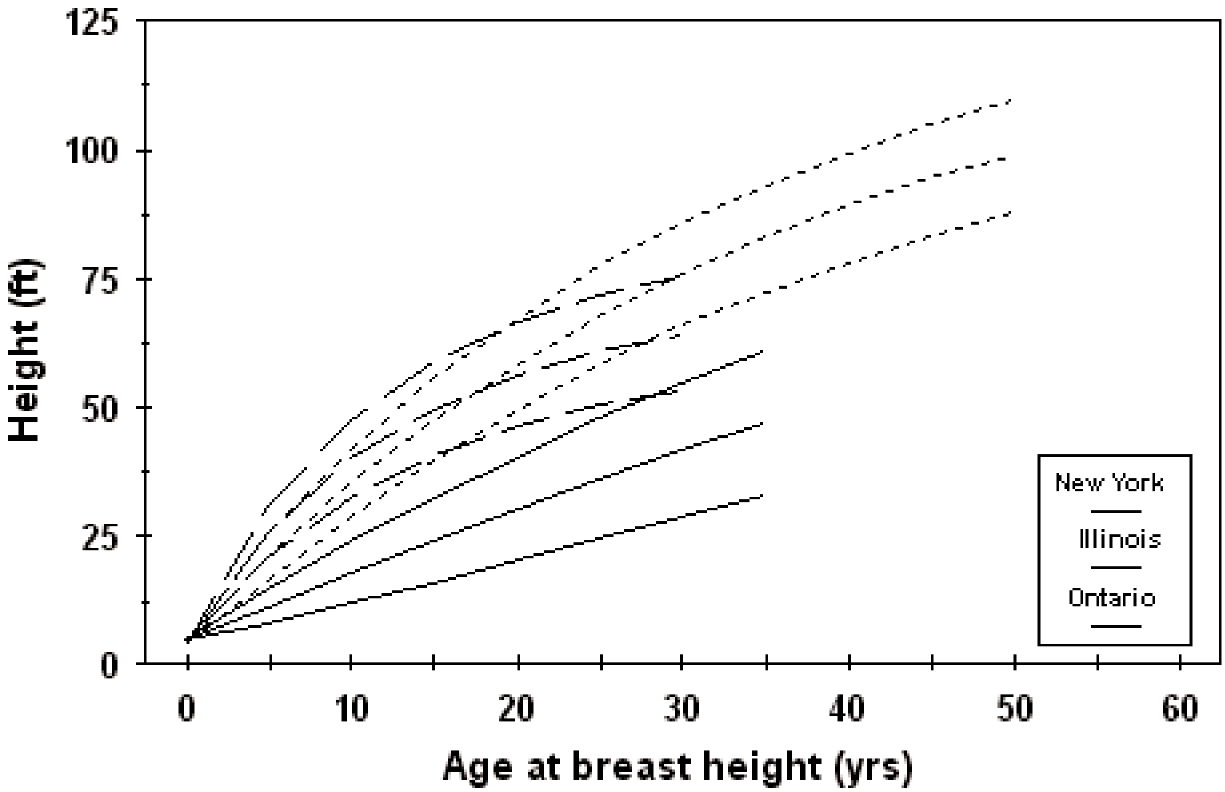


Figure 3. Comparison of site index curves based on breast height age from New York, Illinois, and Ontario. Site indices of 40, 50, and 60 are presented for each group of curves. Equation form: H = 4.5 + b 1S b2[1 - exp(b 3Abh)] b4 (S^b5), where H = total height in feet, S = site index, Abh = breast height age measured at 4.5 ft, and b i designates parameter estimates provided in Table 1.

Figures 2 and 3 are graphical comparisons of these published site index curves from distinctly different regions, grouping the curves according to a total or breast height index age. Below in Table 1 are the equations to reproduce these curves.

The curves using a total age for Minnesota, Wisconsin, and Ontario are based on site indices of 50, 60, and 70 at an index age of 50. Site indices from Vermont are based on site indices of 40, 50, and 60 at an index age of 30. Curves from Vermont indicate a more rapid early height. The Minnesota and Ontario curves have a similar form. The curves from Wisconsin suggest lower productivity, in terms of height growth, relative to other regions for red pine.

The site index curves based on a bh index age for Ontario are based on site indices of 50, 60, and 70 at an index age of 50 years at breast height. Site indices from Illinois are based on site indices of 30, 40, and 50 at 25 years at breast height. Site indices from New York are based on site indices of 20, 30, and 40 at an index age of 20 years at breast height. Curves from Vermont indicate a more rapid early height. The curves from Ontario indicate greater early height growth and greater productivity, in terms of height growth, than those from New York and Illinois. The curves from Illinois suggest similar productivity to the Ontario sites and younger ages but low productivity at older ages. The curves from New York indicate less productivity than those from Ontario but greater productivity than Illinois at older ages.

Table 1. Parameter estimates for the equations used to create Figures 2 and 3. See Carmean and others (1989) for details on the derivation of the parameters and citations for original references.

Region	*b 1*	*b 2*	*b 3*	*b 4*	*b 5*	Reference
Total age						
Minnesota Natural stands	1.8900	1.0000	-0.0198	1.3892	0.0000	Gevorkiantz 1957
Vermont Plantations (index age of 30 yrs)	2.0401	1.0003	-0.0361	1.7914	-0.0090	Hannah 1971
Wisconsin Plantations	2.6359	0.8259	-0.0389	21.5578	-0.6271	Wilde et al. 1965
Eastern Ontario Plantations	2.0434	0.9978	-0.0147	1.0937	-0.0035	Stiell and Berry 1973
Breast height age						
New York Natural stands (index age = 20 yrs bh)	19.0635	0.5885	-0.0111	3.3922	-0.3418	Richards et al. (1962)
Illinois Plantations (index age = 25 yrs bh)	0.7666	1.0909	-0.0733	3.2335	-0.2947	Gilmore (1957)
Central Ontario Natural stands	13.6713	0.5404	-0.0283	8.7720	-0.5308	Thrower (1986)

Growth Intercept

It is not always possible to determine site index directly. Records may not exist for a given stand prior to the establishment of a plantation. Or, the plantation may be considerably younger than the index age. Site index can be estimated using the growth intercept method that utilizes a designated period of early height growth as an indicator of site quality. Error in site quality estimates associated with slow and erratic height growth can be reduced or eliminated by measuring internode length above breast height. The primary disadvantage of the growth intercept method is that early height growth patterns may not be a reflection of later height growth patterns. Table 1 and 2 provide estimates of site quality for red pine based on annual internode growth above breast height.

Length of 5 internodes above 8 feet (feet)	Site index (feet)
4	38
5	46
6	52
7	56
8	61
9	65
10	68
11	72
12	76

Table 1. Estimates of site index for red pine trees greater than 15 years old. Based on the equation SI = 36.9 + 3.356GI – 192.474GI -2, where, SI = site index and GI = length of 5 internodes above 8 feet. Alban 1972a.

Red pine plantations are often established on sites occupied by other species. Or, a landowner would like to convert another type of forest type to red pine. Site index for red pine can be estimated from other trees growing on such sites provided their site index can be determined. Table 3 is the site index conversion for red pine from jack pine, white pine, white spruce, and aspen site indices.

Average annual height growth above bh (inches)	Site index (feet)
10	45
13	55
17	65
24	75

Table 2. Site index estimates based on average annual height growth above breast height.

Red pine	Jack pine	White pine	White spruce	Aspen
45	50	45	35	40
55	60	55	50	60
65	70	65	65	80
75	80	75	80	100

Table 3. Site index (in ft) conversions to red pine from jack pine, white pine, white spruce, and aspen site indices.

Soil-site Approaches

Soil-site studies are undertaken to determine a relationship between site index and edaphic (soil-related) and other variables describing a particular site (e.g., aspect, elevation). The results of soil-site studies have regional applicability only. However, they can be generalized across regions if soil-site studies from different regions have similar results. Results of eight soil-site studies (Hicock et al. 1931., Van Eck and Whiteside 1958, Wilde et al. 1965, Hannah 1971, Alban 1972, 1974, 1976, Brown and Duncan 1990) across the range of red pine are summarized in the following paragraph.

Site index is positively related to improved soil drainage, a sandy loam soil texture, rooting depth, and thickness of the A and B soil horizons. Site index is also positively correlated with the presence of finer textured soil bands or layers totaling a thickness of at least three to six inches within eight to fifteen feet of the soil surface.

Site index is negatively correlated to the percentage of gravel or rocks in the top 10 inches of the soil (see Table 1 below). The percentage of soil organic matter, or soil carbon has been found to affect site index both positively and negatively. Aspect and percent slope have relatively small impact on site index although higher site indices tend to be associated with lower slope positions. Higher concentrations of soil N and P are also related to higher site indices.

Table 1. Estimated site index for red pine plantations in the Lake States on well drained sand to sandy loam soils [1]

Gravel or rocks in top 10 inches	Depth of A plus B horizons (inches)					
	5	10	20	30	40	50
Percent by weight	---------------*Site Index (Feet)*---------------					
0	55	57	60	63	67	70
10	52	54	57	60	63	67
20	49	51	54	57	60	63
30	46	48	51	54	57	60
40	43	45	48	51	54	57
50	40	41	44	48	51	54

[1] Add 5 feet to site index on soils with bands or layers of finer textured material within 8 feet of the surface that improve water relations. Subtract 5 feet from site index for natural stands. (Adapted for the Lake States from Alban (1976).)

Ecological Classification Systems

Ecological site classifications and habitat typing are important, but less-well applied, approaches for understanding and predicting productivity of forest stands. These systems are well suited for determining appropriate species composition and potential successional development of forests. There is growing interest in using them to better define and ultimately manage the productive potential of forest landscapes.

Pest risk assessment

Grassy field. (S. Katovich)

Some potential red pine planting sites have inherent concerns from a pest risk standpoint. Managers should understand the risk involved in planting red pine on these sites. In some situations, planting red pine may not be appropriate.

Frost pockets
Landscape depressions and other locations that tend to collect and pool cold air can be very prone to late spring frost events. Frost can kill or injure new growth on red pine. Identifying frost pockets can be difficult. They tend to be most common in northern portions of Minnesota, Wisconsin and across the U.P. of Michigan. In some areas, frost damage can be almost an annual event.

Young tree dead in sweetfern.

Existing grass, turf or alfalfa
White grubs can exist in very high numbers in some grass dominated or old agricultural sites. Planting red pine seedlings in these areas can result in high seedling mortality. Grub surveys do exist and can be used to evaluate the local grub population. Grub populations as low as one larva per two cubic feet of soil can be enough to cause significant seedling mortality.

Sweet-fern on the site
Sweet-fern is a common plant in many sandy open areas in the northern parts of the Great Lakes region. It is the most important alternate host for a sapsucking insect, the Saratoga spittlebug. This spittlebug has a history of significant damage in young pine stands across the northern parts of Wisconsin, Minnesota and Michigan. Adult spittlebugs will not be a problem if sweet-fern and other alternate hosts are not abundant on the site. These plants provide feeding sites for the immature spittlebugs called nymphs. Managers can risk rate sites based on the abundance of alternate hosts.

In addition to sweet-fern, brambles (raspberry and blackberry), orange hawkweed, everlasting, aster, and willow sprouts can also serve as hosts for nymphs.

Planting red pine into a field dominated with sweet-fern is risky. Saratoga spittlebug populations can reach high levels under these conditions and cause a great deal of damage to young red and jack pine trees.

Well-stocked stands of pine more than 3 m (10 ft) tall and not yet showing visible spittlebug injury symptoms are safe and need not be risk-rated. Control and management suggestions are provided in the Forest Insect and Disease Leaflet titled, " Saratoga spittlebug."

Overstory red pine on the site - Growing young red pine under scattered large red pine can result in increased risk for the young trees to two major disease concerns. These are diplodia shoot blight and canker and Siroccocus shoot blight. Older red pine can harbor large amounts of these two fungal pathogens. Spores produced in the upper parts of the large trees can "rain" down onto smaller trees. If the environmental conditions are favorable for either pathogen, disease outbreaks can deform or kill many of the young red pines.

Both of these diseases are episodic, meaning that in many years conditions are not conducive to an outbreak and damage is very limited. But, eventually the appropriate conditions do occur, an epidemic outbreak occurs, and many young trees are infected and damaged.

Similar concerns can occur when growing young red pine along older red pine windbreaks or along the edges of older red pine stands.

Regenerating red pine

This section provides an overview of site preparation, planting, and release treatments for red pine. The practices have application for meeting a wide range of management objectives including income, habitat, and recreation/aesthetics focused management.

Artificial regeneration is emphasized because relatively little work has been conducted on the natural regeneration of red pine and few managers have experience with the practice. Indeed, managers often eschew the notion of natural regeneration and the practice of direct seeding of red pine in favor of plantation establishment. Limited information on red pine natural regeneration does suggest that:

1. Natural regeneration is best on shaded mineral soil,
2. Shading down to 25% of full light does not affect early survival or height growth,
3. Mechanical site preparation has greater efficacy in reducing competing vegetation than prescribed burning, and
4. Cone and seed feeding insects can destroy developing seed crops.
5. Insects and several diseases can kill or deform large numbers of red pine seedlings (link to Seedlings section within forest health) and saplings under certain conditions. In most situations, the conditions conducive to insect or disease problems can be identified and managed.

Site preparation

Effective site preparation helps improve the growing conditions for regeneration. Good site preparation should minimize competition for light, water, and nutrients without causing soil loss or damage. In the context of planting, the primary goals of site preparation are to reduce competing vegetation and create conditions conducive to planting. This may, at times, be achieved simply through full-tree harvesting. Spot site preparation practices (rather then whole stands) may also prove adequate, particularly in the context of fill planting. The more effective the site preparation, the less the need for release treatments to reduce competing vegetation around young seedlings / saplings. Generally, the higher the site quality the greater the need to control woody and non-woody vegetation to favor the establishment of red pine.

Red pine stand with open understory after several surface fires. Itasca County, MN (B. Palik)

Typical site preparation practices in the Lake States include disk trenching, the Brakee plow, roller chopping, brush raking, scalping, use of herbicides, and prescribed burning. A common site preparation practice is soil scarification, which expose patches of mineral soil to provide good conditions for natural regeneration.

Herbicides are effective tools for competition control and release of planted red pine seedlings. A variety of chemicals are available. What is best depends on site quality, soil conditions, and competing vegetation. All herbicides must be applied by a state certified or licensed applicator. The directions on the herbicide label must be followed for legal application. Requirements listed on the label include personal protective equipment, application site restrictions, crop species recommendations and weeds controlled.

Prescribed burning is often used as a cheap alternative to expensive site preparation techniques. Due to the risk and related liability issues involved with this practice, prescribed burning should only be done by certified professionals.

Prescribed burning is usually most effective for site preparation soon after harvesting when slash provides fuel. Conifer slash can be burned almost immediately after harvest, but adequate hardwood slash needs several weeks to cure. In mature red pine stands, one or more summer fires can be used to eliminate shrubs and reduce duff levels prior to harvesting. There may be concerns about charring standing timber. Burning plans should be approved and permits obtained as required.

Mechanical soil scarification using anchor chains (R. Klevorn)

Planting

Planting of bare root red pine or containerized seedlings should be done in the spring. Plant trees at the same depth as they grew in the nursery. On drier sites, planting slightly deeper may be beneficial, but planting too deep increases risk of injury by root collar weevils. Larger bare root seedlings or transplant stock should be used on more difficult sites, or when higher probability of establishment success (but greater cost) is desired.

Mechanical herbicide application (R. Klevorn)

The cost of producing containerized seedlings has been reduced in recent years and their usage has expanded. The use of containerized seedlings can extend the planting season into early summer. Containerized seedlings are also preferred on sites having shallow soils.

Spacing recommendations depend on many factors, including planting conditions, management objectives, and the desired final product. Planting 400 trees per acre (slightly more than a 10- by 10-foot spacing) will be less costly, crop trees will have rapid diameter growth, commercial thinnings can be made by the time trees need more growing space, and crown closure will not shade out ground vegetation for about 20 years. Planting 800 trees per acre (a little less than 8- by 8-foot spacing) will allow greater flexibility in selecting crop trees and controlling early stand development, crop trees will have less taper and smaller branches, and the stand will have more total volume in smaller diameter trees.

Mechanical herbicide application (R. Klevorn)

The time to reach pole size (5 inches diameter) will vary from 15 to 30 or more years depending on spacing and to a lesser extent on site quality. Closer spacings will require precommercial thinning during the sapling stage (2-5 inches average diameter) to provide a recommended 50 square feet of growing space for each crop tree, and the wider spacings may need an extra release or two to control grass, shrub, and hardwood competition.

Planting stock

Trees should be planted at spacings of up to 10- by 10-feet if all or most of the planted trees have a good chance of surviving, precommercial thinnings are not likely, and favoring ground layer plant communities is an objective. Most production-oriented plantations are established at spacings of 6- by 8-feet and 6- by 10 feet. Machine planting costs can be reduced by using wider rows and closer spacing of trees in a row, but plans for access and future management operations must also be considered at the time of stand establishment.

Patterns other than typical uniformly spaced, row plantings should be considered for some extensive management and restoration applications. While planting remains a cost effective way of ensuring adequate red pine regeneration, some objectives require planted stands to look less like plantations and more like stands of natural origin. Variable row widths and spacings, or spiral planting schemes can be considered. Planting schemes can also be designed to accommodate future thinnings and harvest. For example, a rectangular 8 ft by 12 ft spacing would facilitate the use of modern harvesting equipment.

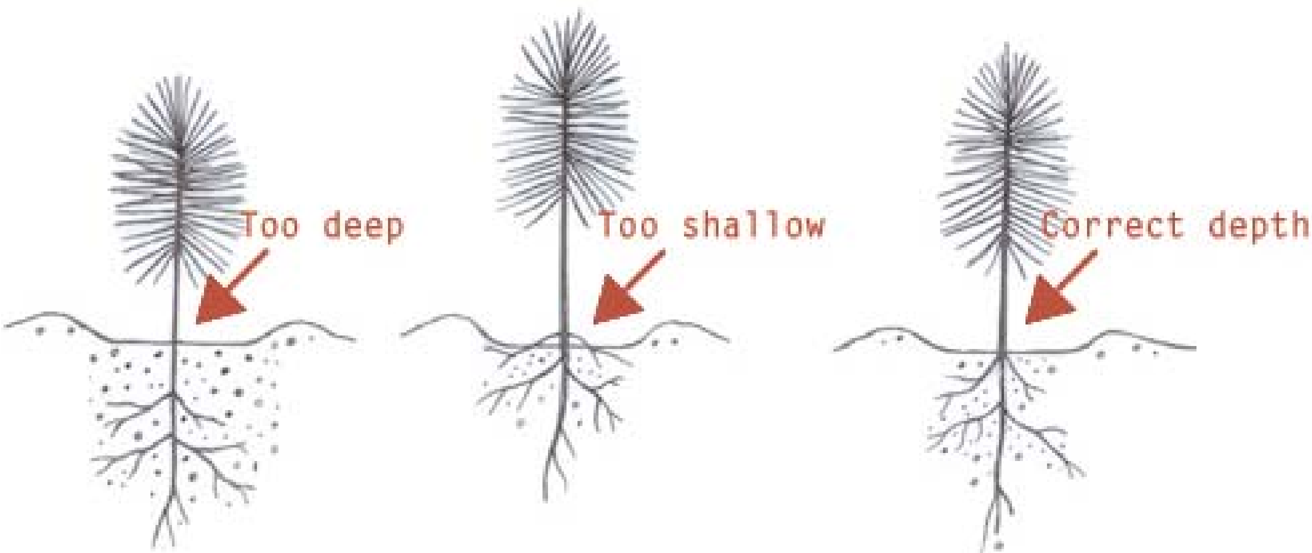


Figure 1. Proper planting depth.

Planting and Pests - Poorly planted seedlings often develop deformed root systems known as J-roots. These root systems can sustain trees during normal or wet years but they often fail during drought years or under heavy competition. Drought and competition stress makes trees susceptible to pests such as root collar weevil, diplodia and armillaria. Proper planting is a key initial step in minimizing pest impact.

J-root. (S. Katovich)

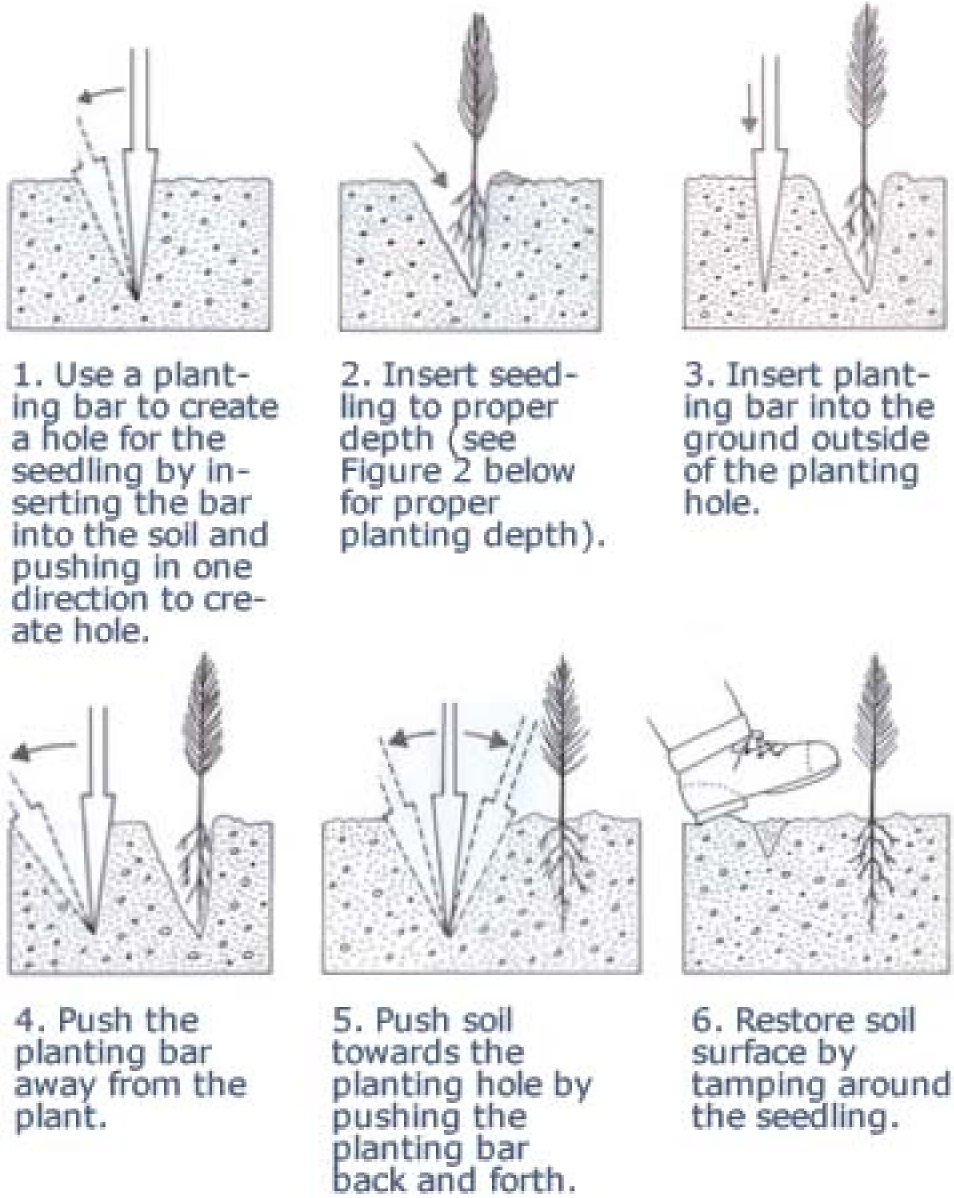


Figure 2. How to plant a seedling.

Seeding

Natural seeding during good seed years can successfully establish seedlings on prepared seedbeds, such as those prepared by summer prescribed burning under a mature stand. Scarifying the soil may also be successful if shrubs are not present.

Mature red pine stand with natural regeneration after shelterwood cut. (A. Ek)

Direct seeding is not widely employed, but has been used successfully on well-prepared sites provided adequate soil moisture is present during the first several months after germination. Seed should be coated with bird and rodent repellants and sown at approximately 15,000 viable seeds per acre (about 5 ounces) early in the spring to take advantage of moist soil conditions. Using improved red pine seed from a seed orchard may increase the likelihood of seedling germination and improve tree growth rates .

Somewhat better results have been experienced by covering red pine seed with 0.25 inches of soil but it may be more expedient to broadcast more seed on the surface than to use less seed and cover it. It is easier to cover the seed when sowing 5 to 10 seeds in prepared spots. Direct seeding in general has not been successful because of inadequate site preparation, inadequate moisture, or loss of seeds to birds or rodents. There is also less control of stocking following direct seeding.

Mechanical release of red pine seedlings from competing shrub vegetation Itasca County, MN (C. Kern)

Releasing regeneration

Release of red pine seedlings from shrubs and other low competitors may be needed after the third growing season. The most practical tool for release is chemical control with broadcast foliar herbicides. Spraying should occur after pine leader growth is complete and the terminal bud is set, around mid-July, and be completed before the end of the growing season to avoid damage to the seedling and to achieve the best control of competing vegetation.

At the time of this writing, herbicide use is restricted on National Forests in the Lake States and Northeast to non-forestry applications. Moreover, their use is not acceptable for a variety of landowners for non-regulatory reasons. In these cases, competition control must be conducted through hand release. Hand release is labor intensive and, as with any mechanical means, results in the re-sprouting of undesired vegetation because the root systems remain intact. Application must be reapplied at two- to three-year intervals. Additionally, mechanical release does little to provide adequate growing space for newly planted trees in sites with high levels of herbaceous competition.

Red pine stand with hazel understory. Cass County, MN (B. Palik)

A decision key specific to red pine regeneration

The following key to planting and vegetation management is based on over 30 years of combined field experience in Itasca, St Louis, and Cook Counties in northern Minnesota. Consequently, its usage should be tempered with field experience from other regions but, nonetheless, it serves as a useful basis for decision making in managing red pine for a variety of objectives.

Consider the following when using this key:

- Stockability refers to the stocking potential of a site in terms of planting area. That is, the site conditions that affect planting chance. Some examples are shallow soils and soils with exposed bedrock, or sites with small wetlands, all of which are common in the northern Lake States and preclude the possibility of high levels of stocking.

- It is assumed that planting levels determine a management intensity or goal, and the guidelines listed are intended to maximize survival of planted stock. High intensity management implies a primary goal of maximum fiber and wood product production in a plantation setting. Low intensity implies habitat or recreation management goals, including mixed-species management.

- Definitions are:
  - Delay – delay treatment in the next growing season
  - Reassess – reevaluate during the next growing season
  - Release – removal of undesirable species
  - Weed – thorough removal of competition of all sizes
  - Liberate – remove individuals overtopping desirable species
  - Fill plant - add to existing stocking by inter-planting
  - Re-plant - ignore existing seedlings and begin stand over

- To use the Decision Support Key, start with the first pair of numbered statements (start with statement pair number 1) and choose the statement that best describes your goal or situation. Follow this statement to a number, to a recommendation, or to a number and a recommendation. If a number is given, find the corresponding pair of statements and continue the process until a final recommendation is reached.

Managing established red pine stands

Table 1.—Management action keys for red pine management

Start		Condition or Goal	Go to or do
1.		Site is typical for red pine in the locale See Ecological and Silvical Highlights of Red Pine, p. 3	2.
1.		Site is not typical for red pine	4.
	2.	Reserve management objectives dominate See Managing Stands in the Context of Ownership Goals, p. 2	*Go to Key A*
	2.	Reserve management objectives do not dominate See Managing Stands in the Context of Ownership Goals, p. 2	3.
3.		Production management is the primary objective See Managing Stands in the Context of Ownership Goals, p. 2	*Go to Key B*
3.		Extensive management is the primary objective See Managing Stands in the Context of Ownership Goals, p. 2	*Go to Key C*
	4.	Site is less productive (drier or wetter) than typical red pine site See Ecological and Silvical Highlights of Red Pine, p. 3	*Consider establishing or converting to site-appropriate species*
	4.	Site is more productive than typical red pine site See Ecological and Silvical Highlights of Red Pine, p. 3; Site Quality Assessment, p. 9.	*Consider establishing or converting to site-appropriate species or intensive red pine production (Key B)*

Start		Condition or Goal	Go to or do
Key A: Reserve Management			
1.		Red pine stand already established on site	2.
1.		No red pine stand currently on site	5.
	2.	Stand is seedling size	3.
	2.	Stand is not seedling size	7.
3.		Stand currently meets expectations for composition and structure Consider protection needs; see Damaging Agents, p. 29	*Reassess at later date*
3.		Restoration needs exist in terms of structure or composition See Managing Red Pine Stands for Ecological Complexity, p. 23	4.
	4.	Stocking of red pine is unacceptably low	5. *Regenerate all or portions of site*
	4.	Stocking of red pine is variable or stocking of other desirable species is inadequate or competition levels are undesirably high See Regenerating Red Pine, p. 13	*Fill plant and/or control competition; reassess at later date*
5.		No established stand on area	6. *Consider all regeneration options in light of Reserve Management goals*
5.		Established stand on area Consider conversion and legacy retention prescriptions; see Managing Red Pine Stands for Ecological Complexity, p. 23	6. *Harvest in light of Reserve Management goals*
	6.	Good establishment conditions exist, free of undesirable competition Consider regenerating multiple species; see Regenerating Red Pine, p. 13 and Managing Red Pine Stands for Ecological Complexity, p. 23	*Plant or seed; reassess at later date*
	6.	Inadequate establishment conditions exist Consider regenerating multiple species; see Regenerating Red Pine, p. 13 and Managing Red Pine Stands for Ecological Complexity, p. 23	*Prepare site; plant or seed; reassess at later date*
7.		Stand requires structural or compositional treatment in light of Reserve Management objectives Consider variable density thinning, releasing co-occurring species; underplanting additional species; see Stand Density, p. 19; Managing Red Pine Stands for Ecological Complexity, p. 23; consider protection and maintenance needs (e.g., prescribed understory fire); see Damaging Agents, p. 29	*Thin, release, or underplant; reassess at later date*
7.		Stand condition (structure and composition) meets expectations Consider protection and maintenance needs (e.g., prescribed understory fire); see Damaging Agents, p. 29	*Reassess at later date*

Start		Condition or Goal	Go to or do
Key B: Production Management			
1.		Red pine stand already established on site	2.
1.		No red pine stand currently on site	5.
	2.	Stand is seedling size	3.
	2.	Stand is not seedling size	9.
3.		Stocking and competition levels are acceptable for production management See Regenerating Red Pine, p. 13	*Reassess at later date*
3.		Stocking and or competition levels are unacceptable	4.
	4.	Stocking is unacceptable See Regenerating Red Pine, p. 13	8. *Replant*
	4.	Stocking is variable and/or competition levels are high See Regenerating Red Pine, p. 13	*Fill plant or control competition; reassess at later date*
5.		No merchantable stand on area	6.
5.		Merchantable stand on area See Regenerating Red Pine, p. 13.	8. *Harvest and consider all regeneration options in light of Production Management goals*
	6.	Will have merchantable stand in 20 years or less	7.
	6.	Will not have merchantable stand in 20 years	8.
7.		Consider waiting until merchantable size	*Reassess at later date*
7.		Prepare site now according to Production Management goals	8.
8.		Good establishment conditions exist, free of excessive slash and competition See Regenerating Red Pine, p. 13	*Plant; reassess at later date*
8.		Inadequate establishment conditions exist in the form of excessive slash, herbaceous or shrub competition See Regenerating Red Pine, p. 13	*Prepare site; plant; reassess at later date*
	9.	Stand is at rotation age for production management See Rotation Age, p. 22	*Harvest;* go to 8.
	9.	Stand is not at rotation age for production management	10.
10.		Stand requires thinning, crop trees require pruning, or competition control is needed See Stand Density, p. 19; Pruning, p. 21; Growth and Yield, p. 22; Damaging Agents, p. 29	*Thin, prune, or release; reassess at later date*
10.		None of the above are required	*Reassess at later date*

Start		Condition or Goal	Go to or do
Key C: Extensive Management			
1.		Red pine stand already established on site	2.
1.		No red pine stand currently on site	5.
	2.	Stand is seedling size	3.
	2.	Stand is not seedling size	9.
3.		Red pine stocking, competition levels, and species composition are acceptable for extensive management See Regenerating Red Pine, p. 13; Managing Red Pine Stands for Ecological Complexity, p. 23	*Reassess at later date*
3.		Red pine stocking, competition levels, or species composition are unacceptable for extensive management	4.
	4.	Stocking of red pine is unacceptable See Regenerating Red Pine, p. 13	8. *Regenerate site*
	4.	Stocking of red pine is variable or stocking of other desirable species is inadequate or competition levels are undesirably high See Regenerating Red Pine, p. 13	*Spot-plant red pine or other species; control competition; reassess at later date*
5.		No merchantable stand on area	6.
5.		Merchantable stand on area Consider restoration opportunities; consider legacy retention prescriptions; see Managing Red Pine Stands for Ecological Complexity, p. 23	8. *Harvest in light of Extensive Management goals*
6.		Will have merchantable stand in 20 years or less	7.
	6.	Will not have merchantable stand in 20 years or less	8.
7.		Consider waiting until merchantable size before action to regenerate red pine	*Reassess at later date*
7.		Prepare site now according to Extensive Management goals; consider restoration opportunities and legacy retention prescriptions; see Managing Red Pine Stands for Ecological Complexity, p. 23	8.
	8.	Good establishment conditions exist, free of undesirable competition Consider regenerating multiple species; see Regenerating Red Pine, p. 13; Managing Red Pine Stands for Ecological Complexity, p. 23	*Plant or seed; reassess at later date*
	8.	Inadequate establishment conditions exist Consider regenerating multiple species; see Regenerating Red Pine, p. 13; Managing Red Pine Stands for Ecological Complexity, p. 23	*Prepare site; plant or seed; reassess at later date*

9.		Stand is at rotation age for extensive management objectives Consider legacy retention prescriptions; see Rotation Age, p. 22; Managing Red Pine Stands for Ecological Complexity, p. 23; Damaging Agents, p. 29	*Harvest, regenerate;* go to 8
9.		Stand is not at rotation age for extensive management	10.
	10.	Consider standard or variable density thinning, pruning, release of co-occurring species, decadence creation, underplanting tolerant species; see Stand Density, p. 19; Pruning, p. 21; Managing Red Pine Stands for Ecological Complexity, p. 23.	*Thin, prune, release; reassess at later date*
	10.	None of the above are required or desired	*Reassess at later date*

Source: A revised managers handbook for red pine in the North Central Region. Gilmore, Daniel W.; Palik, Brian J. 2006. Gen. Tech. Rep. NC-264. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. 55 p.

There are a wide array of silvicultural activities that can be used in established red pine stands. These activities may be aimed at controlling stand density, increasing growth, improving tree form and quality, or controlling competing vegetation. We discuss these activities separately from those focused on regeneration because they are generally aimed at achieving objectives other than establishing a new cohort of trees. This is not to say that establishing new seedlings of red pine, or other tree species, would never be an objective in established stands. In fact, this may be an objective (see Managing for ecological objectives), in which case certain stand tending activities, for example thinning, might be combined with regeneration practices (see Regenerating red pine) to establish new trees in the understory.

Ground spraying to remove competing vegetation prior to planting (MNDNR)

In this section, we highlight the primary silvicultural tools you might use in established stands, with specific reference to application in red pine forests.

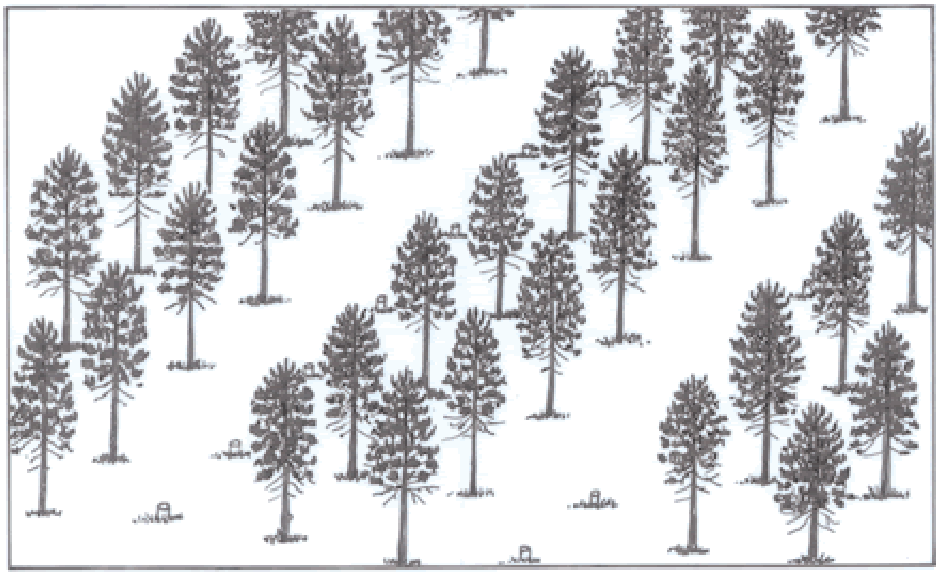
You should also refer back to applicable, but more general topics in Forest Management 101, for example control of competing vegetation (Weeding and Cleaning).

Thinning and stand density

Foresters manage stands to meet a variety of landowner objectives. In cases where timber production is the primary objective, management often focuses on maximizing financial return. This usually involves encouraging growth on some collection of desirable trees, while capturing mortality from the less vigorous ones. Density control is the primary means by which this is accomplished.

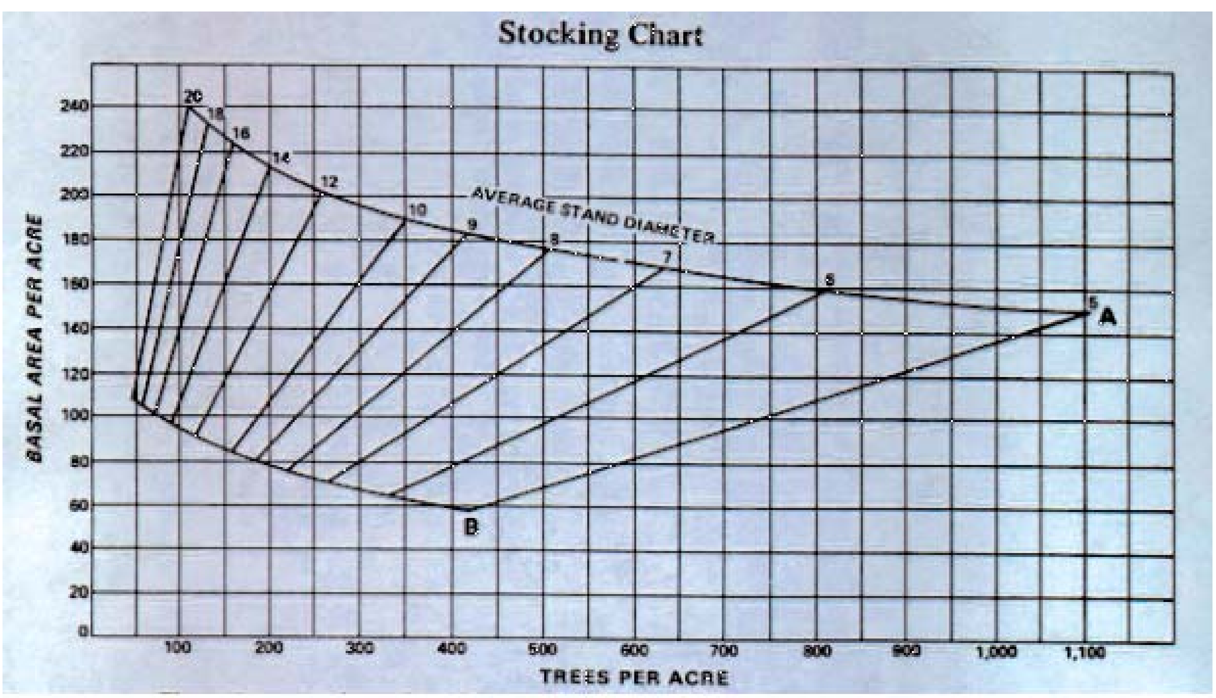
Mechanical thinning treatment. (E. Sagor)

There are a number of thinning methods which can be used over the life of a stand. A few of the methods often used in even-aged red pine management include mechanical thinning and thinning from below. Mechanical thinning is the removal of trees in rows or strips at fixed spacing intervals throughout the stand. This method is commonly applied as the first thinning in red pine stands that are densely crowded and have a relatively uniform crown class. Typically every second or third row is removed until the stand matures and most of the remaining trees are large, high quality growing stock. At this point, row thinning becomes less suitable and thinning from below becomes the more appropriate thinning method. Thinning from below is the removal of intermediate and codominant trees to favor the large, high quality trees in the upper crown classes. Depending on the users objectives the trees removed during low thinnings are typically high risk trees, trees that are crowding potential crop trees, undesirable species and trees of poor quality and low vigor. As a general rule, high quality leave trees which will be used as a seed source should be disease free, with straight stems, medium to thin branches that meet the trunk at a 90 degree angle, are good self-pruners, and possess a crown balanced in height and width. For timber purposes, avoid leaving trees with large diameter branches that may not be able to support snow loads and those with forked stems and irregular or misshapen crowns.



Two important aspects of stand density in even-aged stands are stocking level and uniformity. As the stocking level decreases towards a minimum, uniformity of distribution of trees increases in importance. The minimum stocking level for uniform stands of different (average) stand diameters was calculated using the maximum amount of growing space required by trees of different diameters (stocking chart). Minimum stocking for stands averaging 5 inches in diameter is about 400 trees and 60 squre feet per acre. In stands averaging 15 inches in diameter, minimum stocking is about 80 trees and 100 square feet per acre.

The stocking chart suggests the recommended upper limit of stocking for managed stands averaging 5 inches in diameter is about 1100 trees and 150 square feet per acre of basal area. For stands averaging 15 inches in diameter, the recommended upper limit of stocking is 175 trees and 215 square feet per acre of basal area. Contemporary management entails lower planting densities, plant equipment considerations, and access for pre-commercial thinnings.



Seedling and sapling stands (less than 5 inches average diameter) should have between 400 and 900 trees per acre. Fewer than 400 trees will not provide minimum recommended stocking by the time the stand reaches pole-timber size and more than 900 trees will exceed the upper limit of recommended stocking before the trees reach pole-timber size and can be thinned commercially.

Stand density guides for uneven-aged red pine stands have not been formalized but in general, seedling density needs to be higher than sapling density, which in turn needs to be higher than pole density, which should outnumber sawtimber density. Losses in the smaller size classes are expected and considerable effort will be needed to assure survival and growth of enough trees in each class to replace those harvested, lost, or which have recruited into the next size class. The regeneration in uneven-aged red pine stands must be monitored for Sphaeropisis and Sirococcus shoot blights.

Precommercial Thinning: Precommercial thinning may be needed in young stands to meet management objectives. For example, in a naturally-regenerated stand of seedlings (less than 2 inches average diameter) having more than 2000 trees per acre, a minimum of 100 potential crop trees per acre should be given a minimum growing space of 25 square feet per tree. Densely stocked saplings stands (2 to 5 inches average diameter) with a basal area of 160 square feet per acre or more should be precommercially thinned. Crop trees in sapling stands should be given about 50 square feet of growing space per tree to maintain good diameter growth.

Commercial Thinning: One of the most important ways stand composition and development can be controlled is by periodic commercial thinnings. Stands should be thinned before they exceed the recommended upper limit of stocking for managed stands (see below). For production management, a uniform distribution of high quality trees with at least the minimum recommended stocking for the average stand diameter should be left, but not over half – and preferably less – of the basal area should be removed in any one thinning. Stands managed near the minimum recommended stocking will have the most rapid diameter growth. As a more general guide, pole stands (5 to 9 inches average diameter) should be considered for thinning when the basal area is 140 square feet or more per acre and they should be thinned to leave about 90-110 square feet per acre.

Stocking charts and Density Management Diagrams (DMDs) are popular tools for developing thinning prescriptions for even-aged stands. Their popularity stems from their ability to easily incorporate the ecological principle of self-thinning, or competition induced mortality, which provides the stimulus for thinning. The focus of management in the context of density control is to prevent stands from reaching the zone where self-thinning can occur. On the stocking chart self-thinning would occur when stands reach the A-line. Basal area is represented by the “Y” axis and trees per acre are represented by the “X” axis. Average stand diameter at breast height is represented by the lines radiating out from the origin of the two axes. Red pine stands are over-stocked above the A line – too high of a basal area, too many trees per acre, and too big. The stand is under-stocked below the B line – too few trees of any size.

Stocking charts and DMDs are similar management tools; their primary difference being the scale of measurement. DMDs use a logarithmic scale. A density management diagram for red pine and instruction for its usage.

Thinning will not usually result in an increase in stand volume at the end of the rotation. Rather, thinning will allow individual trees to grow larger and increase the relative rate of stand growth. Thinned volume plus volume at the end of the rotation (total yield) may or may not be higher than the total volume of an unthinned stand. Thinning, however, serves to capture volume otherwise lost to mortality. Thus, total volume removed over the life of a stand may be greater if a thinning program is implemented. Site quality, thinning intensity, and stand age at thinning are factors that affect volume removed during thinning and stand volume at the end of a rotation. Residual trees should have a live crown ratio of 30% or greater in order to receive the maximum potential growth response from thinning. Many organizations are emphasizing a 40% live crown ratio. Depending on stand age, trees with shorter live crown ratios may have a minimal growth response from thinning. Red pine crowns develop upward and outward. Thus, if a stand is near its maximum potential height and has a 10% live crown ratio, very little growth response to thinning would be observed. For red pine, post-thinning stand density has a greater impact on post-thinning stand growth (Gilmore et al. 2005) than the thinning method used (Smith 2003).

For income focused management, sawtimber trees should be thinned periodically to maintain uniform growth rates on the crop trees. For habitat focused management in mixed-species stands, red pine might be favored as crop trees at each thinning. However, other species should be left to achieve biodiversity goals, provide habitat requirements, and expand the species and type of timber products.

Insect and disease Warning: From a pest management standpoint, thinning is viewed as very beneficial. It generally maintains or increases individual tree health and vigor. Vigorous pine trees can better defend themselves from most insect and disease problems. However, the presence of many freshly cut stumps and logs can, on occasion, attract or provide conditions suitable for some significant pests.

- Annosum root disease can be introduced into stands through fresh stumps. This disease causes expanding pockets of dead and dying pine. Annosum is present in lower Michigan and it has been expanding in Wisconsin. It is likely to be found relatively soon in Minnesota red pine. The link above provides detailed management recommendations that can reduce the likelihood of introducing or spreading Annosum.

- Freshly cut logs left in a stand in the spring and early summer can provide breeding material that produces large Ips bark beetle populations. Population increases of 10-fold can occur in one growing season, with three generations of Ips pini possible. Thus, a local population of 1,000 can increase to 1,000,000 individuals in one season. Management suggestions revolve around prompt removal of freshly cut logs in spring and summer. This includes removal in the early spring of logs cut during the winter months.

Prescribed under burning

Periodic fire was a naturally occurring disturbance in red pine dominated forests prior to effective fire suppression. Infrequent, high intensity fires that killed overstory trees were important for opening the canopy, exposing mineral seedbeds, facilitating regeneration of new red pine cohorts, and creating complex structural condition (see Managing for ecological objectives). More frequent, low intensity surfaces fires helped to thin dense stands of trees and prevented proliferation of dense woody shrub populations.

Prescribed underburn. (B. Palik)

Prescribed surface fire in mature red pine stands can be an effective management tool for eliminating shrub competition, reducing thick duff layers, and preparing mineral seedbeds. Growing season fires, conducted repeatedly over several (2-4 years) growing seasons, have been shown to be effective at controlling dense shrub (hazel) competition and exposing mineral soil. The reduction in hazel abundance in stands receiving several growing season burns can last many decades. This burning may be done prior to harvesting to prepare seedbeds, however concerns over charred bark on harvested trees should be considered. As with burning after harvest, burning plans should be approved and permits obtained as required.

Pruning

Pruning, as part of a red pine production management system, is used to increase the value of red pine sawtimber by promoting growth of clear, knot-free wood in the first log of the tree. Those who implement pruning must generally balance the cost of producing high value red pine logs containing clear wood with maximizing the return on investment.

The simplest and least expensive way to prune red pine in plantations is to plant at high densities (~ 800 trees per acre) and allow trees to self-prune. The natural process of pruning usually occurs as crowns close and lower branches are shaded, fall off, and the wound is closed. Artificial pruning accelerates this process. Increased use of flitch technology whereby veneer is acquired from slicing very thin boards has dramatically increased the importance of pruning. It generally takes about 60 years (depending on site quality, timing of pruning and adequate thinning) to recoup the cost of pruning.

Red pine after pruning (1. lift) up to 9 feet (A. Ek)

The use of proper technique is critical when pruning. Done improperly pruning is a waste of resources and can injure trees. There are a number of things to consider when pruning red pine. Season of pruning is important; red pine pruning should be done in the late-fall to early-spring, otherwise the bark is loose and can strip away easily from no more than the weight of a saw, damaging the stem. Always retain an adequate live crown ratio by not pruning more than the lower one-third of the live crown and try to keep live branches in the upper half of the tree. Dead branches should always be removed. Prune the branches flush with the end of the branch collar and do not leave stubs. Stubs can be entry sites for insect and disease infestations. Prune only the largest diameter (dominant and co-dominant) trees with the best form because these trees have the greatest potential for return on investment. Avoid pruning trees with numerous branches greater than 2 inches in diameter. Begin pruning when trees reach a dbh of 4 to 6 inches in diameter.

Minimizing pruning costs using natural pruning can be achieved by planting red pine seedlings at high densities (~ 800 trees per acre). The number and size of knots in a sawlog or utility pole is a major factor in determining the value of a tree. Higher plantation densities also encourage straight boles with a minimum of taper. Pruning is typically applied in concert with thinnings in anticipation of stimulated diameter growth.

Pruning may be an important consideration even outside of a production management model. Extensive management objectives may well include production of large quantities of trees with high quality, knot-free timber. Moreover, pruning may be used to promote development of clear boles, which can be characteristic of old-growth conditions. Because spacing in stands managed for something other than intensive production is typically wider than uniform plantations managed for production management, pruning may be required to remove lower branches on potentially high value trees.

Pruning is recommended in stands dominated by the desired species (>60% of trees). However, in mixed-species stands, look for the possibility of exchange of dominance whereby unpruned trees overtake and reduce the growth of pruned trees in the 1-2 years immediately following pruning. A good guideline is to prune all stems in a stand if a change of dominance may occur between pruned and unpruned trees.

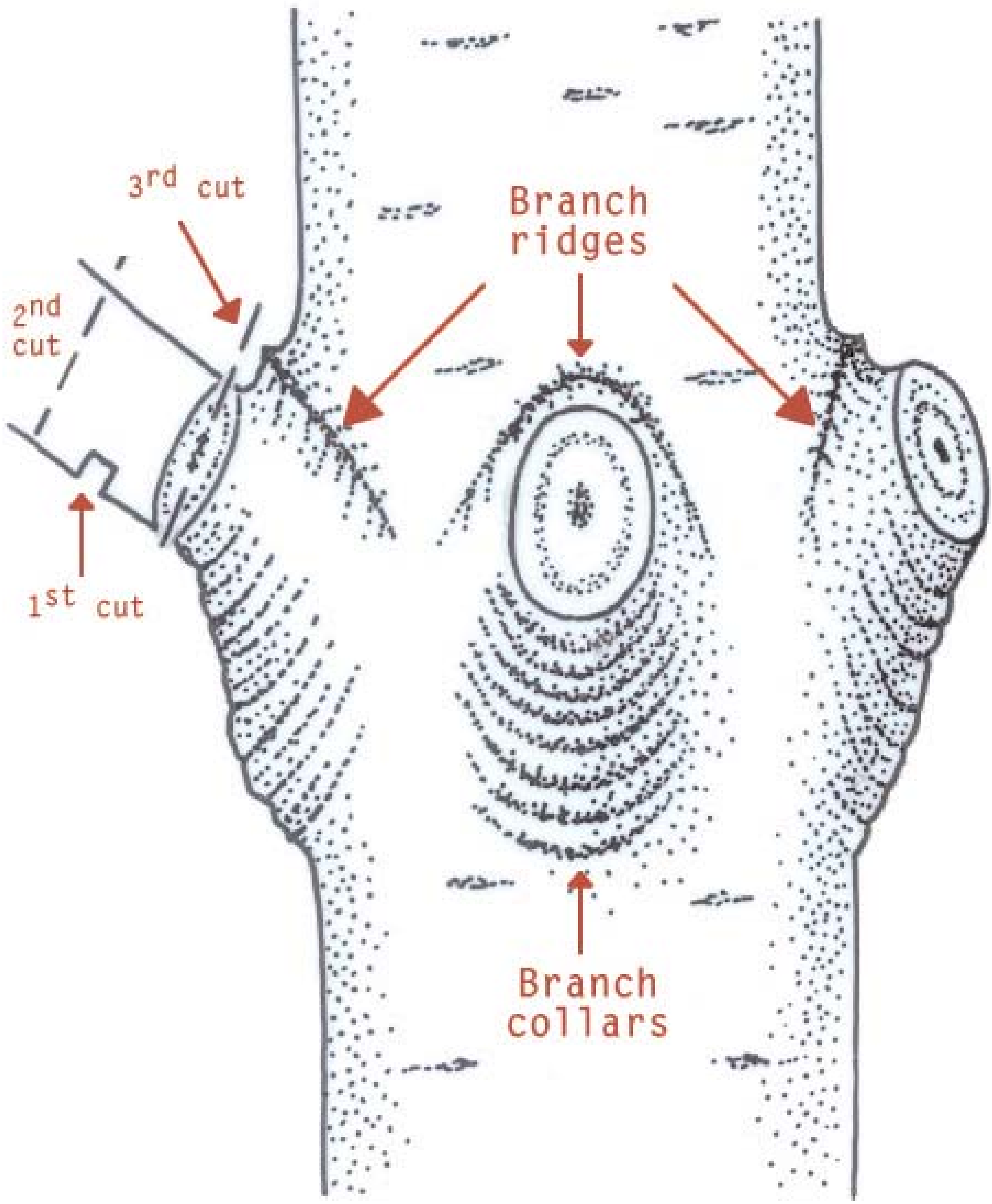


Figure 3. The key to proper pruning is to protect the tree stem and trunk. To avoid tearing the bark and stem wood and to facilitate healing, make a small cut just (known as the wedge or notch) beyond the branch collar. Then make your second cut just beyond the notch from top to bottom. Once the branch has broken free at the notch, make a third cut parallel to and just beyond the branch collar to reduce the length of the stub.

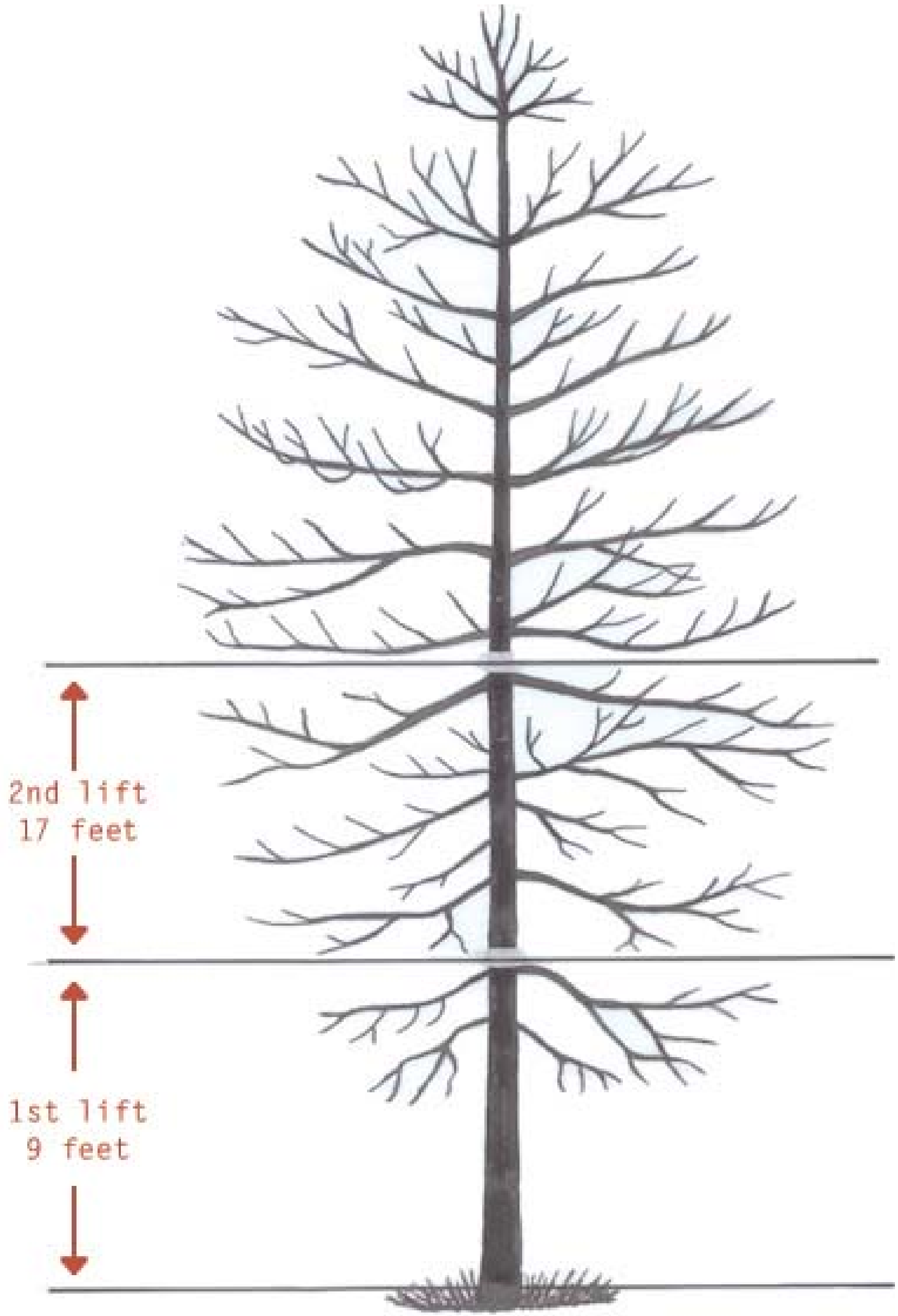


Figure 4. Pole size trees (hardwoods 5 to 11 inches and conifers 5 to 9 inches dbh) can be pruned one or two lifts (9 to 17 feet) which results in one or two logs of knot free sawtimber or veneer.

Growth and Yield

Growth and yield equations have been refined over the years but for the most part “modern” equations do not differ greatly from volume tables published in the early-1900s.

Below in Table 1 are the stand volume and individual tree prediction equations.

Table 1. Tabulation of volume and dbh prediction equations for red pine.

Stand volume prediction equations V = 0.4085 BAH, where V = total volume (ft 3 ac -1), BA = basal area (in.), H = tree height (ft) (Buckman 1962) V = 1.1606 BA 1.0762H 0.6228, where V = total volume (ft 3 ac -1), BA = basal area (in.), H = tree height (ft) (Walters and Ek 1993) V m = V exp(-0.9979(t/D) 3.0445 + -2.2294N -0.2621(d/D) 6.7081), where V m = merchantable volume (ft 3 ac -1), V = total volume (ft 3 ac -1), D = quadratic mean dbh (in.), N = number of trees per acre, t = minimum merchantable top diameter inside bark (in.), d = minimum merchantable dbh (in.) (Mack and Burk 2004)
Individual tree volume prediction equations V = 0.002979 D 1.7143H 1.1287, where V = total volume (ft 3), D = dbh (in.), and H = total tree height (ft) (Fowler 1997) V = 0.0046 D 1.8598H 0.9299, where V = total volume (ft 3), D = dbh (in.), and H = total tree height (ft) (Gilmore et al. 2005) V = 0.1202 D 2.0565, where V = total volume (ft 3), and D = dbh (in.) (Gilmore et al. 2005)
Individual tree dbh prediction from stump diameter D = 0.3462 + 0.7963D stmp, where D = dbh (in.), D stmp= stump diameter (in.) measured at 6 in. above ground (Gilmore et al. 2005)
Individual tree volume prediction from stump diameter V = -8.417 + 1.8201 D stmp, where V = volume (ft 3), D stmp= stump diameter (in.) measured at 6 in. above ground (Gilmore et al. 2005)

Following are basal area growth and yield tables derived from Buckman (1962). You can use these tables to estimate several different measures of growth and yield based on site quality, age, and stand density.

Current annual basal area growth per acre 1 for even-aged red pine stands by site, age, and stand density.

Total Age	Total Height	Stand density – basal area per acre					
		30	60	90	120	150	180
Years	*Feet*	---------------*Square Feet per acre*---------------					
SITE INDEX 75							
20	30	6.2	6.9	7.4	7.6	7.6	7.2
40	61	4.9	5.7	6.2	6.4	6.3	5.9
60	86	3.8	4.6	5.1	5.3	5.2	4.8
80	103	2.9	3.7	4.2	4.4	4.3	3.9
100	115	2.2	3.0	3.5	3.7	3.6	3.2
120	124	1.6	2.4	2.9	3.1	3.0	2.7
140	130	1.3	2.1	2.6	2.8	2.7	2.3
160	134	1.1	1.9	2.4	2.6	2.5	2.1
SITE INDEX 65							
20	26	5.5	6.3	6.8	7.0	6.9	6.5
40	53	4.2	5.0	5.5	5.7	5.6	5.3
60	74	3.2	4.0	4.4	4.6	4.6	4.2
80	89	2.3	3.1	3.5	3.8	3.7	3.3
100	100	1.5	2.3	2.8	3.0	2.9	2.6
120	107	1.0	1.8	2.3	2.5	2.4	2.0
140	112	.6	1.4	1.9	2.1	2.0	1.7
160	116	.5	1.3	1.8	2.0	1.9	1.5
SITE INDEX 55							
20	22	4.9	5.7	6.2	6.4	6.3	5.9
40	45	3.6	4.4	4.9	5.1	5.0	4.6
60	63	2.5	3.3	3.8	4.0	3.9	3.5
80	76	1.6	2.4	2.9	3.1	3.0	2.6
100	85	.9	1.7	2.2	2.4	2.3	1.9
120	91	.4	1.1	1.6	1.9	1.8	1.4
140	95	--	.8	1.3	1.5	1.4	1.0
160	98	--	.6	1.1	1.3	1.2	.8
SITE INDEX 45							
20	18	4.2	5.0	5.5	5.7	5.6	5.2
40	37	3.0	3.7	4.2	4.5	4.4	4.0
60	51	1.9	2.7	3.2	3.4	3.3	2.9
80	62	1.0	1.8	2.3	2.5	2.4	2.0

100	69	.2	1.0	1.5	1.7	1.6	1.3
120	74	--	.5	1.0	1.2	1.1	.7
140	78	--	.1	.6	.8	.8	.4
160	80	--	--	.5	.7	.6	.2

[1]BA growth = 1.6889 + .041066 (BA) - .00016303 $(BA)^2$ - .076958 (Age) + .00022741 $(Age)^2$ + .06441 (Site Index) (Buckman 1962).

Volume[1] in cunits (100 cubic feet) per acre for even-aged red pine stands by site, age, and stand density.

Total Age	Total Height	Stand density – basal area per acre					
		30	60	90	120	150	180
Years	*Feet*	*-----------Cunits per acre-----------*					
SITE INDEX 75							
20	30	3.7	7.3	11.0	14.7	18.4	22.0
40	61	7.5	14.9	22.4	29.9	37.3	44.8
60	86	10.5	21.0	31.6	42.1	52.6	63.2
80	103	12.6	25.2	37.8	50.4	63.0	75.6
100	115	14.1	28.2	42.2	56.3	70.4	84.5
120	124	15.2	30.4	45.4	60.7	75.9	91.1
140	130	15.9	31.8	47.7	63.6	79.6	95.5
160	134	16.4	32.8	49.2	65.6	82.0	98.4
SITE INDEX 65							
20	26	3.2	6.4	9.5	12.7	15.9	19.1
40	53	6.5	13.0	19.5	25.9	32.4	38.9
60	74	9.0	18.1	27.2	36.2	45.3	54.3
80	89	10.9	21.8	32.7	43.6	54.5	65.4
100	100	12.2	24.5	36.7	49.0	61.2	73.4
120	107	13.1	26.2	39.3	52.4	65.5	78.6
140	112	13.7	27.4	41.1	54.8	68.5	82.2
160	116	14.2	28.4	42.6	56.8	71.0	85.2
SITE INDEX 55							
20	22	2.7	5.4	8.1	10.8	13.5	16.2
40	45	5.5	11.0	16.5	22.0	27.5	33.0
60	63	7.7	15.4	23.1	30.8	38.6	46.3
80	76	9.3	18.6	27.9	37.2	46.5	55.8
100	85	10.4	20.8	31.2	41.6	52.0	62.4
120	91	11.1	22.3	33.4	44.6	55.7	66.8
140	95	11.6	23.2	34.9	46.5	58.1	69.8
160	98	12.0	24.0	36.0	48.0	60.0	72.0

SITE INDEX 45							
20	18	2.2	4.4	6.6	8.8	11.0	13.2
40	37	4.5	9.1	13.6	18.1	22.6	27.2
60	51	6.2	12.5	18.7	25.0	31.2	37.4
80	62	7.6	15.2	22.8	30.4	37.9	45.5
100	69	8.4	16.9	25.3	33.8	42.2	50.7
120	74	9.1	18.1	27.2	36.2	45.3	54.3
140	78	9.5	19.1	28.6	38.2	47.7	57.3
160	80	9.8	19.6	29.4	39.2	49.0	58.8

[1]Cubic feet = 0.4085 (Basal area x Height) (Buckman 1962).

[2]Total main stem volume in cunits from 6-inch stump to tip of tree. Estimated cunits to a 4-inch top d.i.b. can be obtained by subtracting 1.067 (Basal area per acre in sq. ft. / ave. tree diameter in inches squared).

Current annual cubic foot growth 1 per acre for even-aged red pine stands by site, age, and stand density.

Total Age	Total Height	Stand density – basal area per acre					
		30	60	90	120	150	180
Years	*Feet*	*---------------Cubic Feet per acre---------------*					
SITE INDEX 75							
20	30	101	131	158	182	203	218
40	61	142	180	210	232	246	253
60	86	147	188	218	237	246	244
80	103	131	174	204	221	225	217
100	115	110	154	184	199	200	188
120	124	85	129	158	172	171	159
140	130	72	117	146	159	156	137
160	134	63	109	139	152	149	130
SITE INDEX 65							
20	26	80	108	132	152	169	183
40	53	108	140	166	185	198	206
60	74	109	144	168	185	196	195
80	89	92	128	150	168	172	165
100	100	66	104	130	143	143	136
120	107	48	86	112	124	124	110
140	112	30	69	94	106	104	93
160	116	25	64	89	100	96	78

SITE INDEX 55							
20	22	61	83	103	119	133	144
40	45	80	107	129	145	155	160
60	63	75	106	128	143	151	150
80	76	56	87	109	121	124	118
100	85	36	69	91	103	105	96
120	91	19	48	71	86	86	74
140	95	--	36	58	68	67	54
160	98	--	26	48	57	54	39
SITE INDEX 45							
20	18	45	63	79	93	105	114
40	37	56	77	94	109	117	121
60	51	47	72	90	101	106	105
80	62	30	56	73	83	86	80
100	69	9	36	53	63	64	59
120	74	--	20	38	46	46	36
140	78	--	6	23	30	32	20
160	80	--	--	20	28	26	14

[1]Cubic feet growth = 0.4085 (basal area growth x height + height growth x basal area + basal area growth x height growth) (Buckman 1962).

Volume in cords per acre 1 for even-aged red pine stands by site, age, and stand density.

Total Age	Total Height	Stand density – basal area per acre					
		30	60	90	120	150	180
Years	*Feet*	---------------*cords per acre*---------------					
SITE INDEX 75							
40	61	7.2	14.5	21.7	29.0	36.2	43.5
60	86	10.2	20.4	30.6	40.8	51.0	61.3
80	103	12.2	24.5	36.7	48.9	61.2	73.4
100	115	13.6	27.3	41.0	54.6	68.3	81.9
120	124	14.7	29.4	44.2	58.9	73.6	88.3
140	130	15.4	30.9	46.3	61.7	77.2	92.6
160	134	15.9	31.8	47.7	63.6	79.6	95.5

SITE INDEX 65							
40	53	6.3	12.6	18.9	25.2	31.5	37.8
60	74	8.8	17.6	26.4	35.1	43.9	52.7
80	89	10.6	21.1	31.7	42.3	52.8	63.4
100	100	11.9	23.7	35.6	47.5	59.4	71.2
120	107	12.7	25.4	38.1	50.8	63.5	76.2
140	112	13.3	26.6	39.9	53.2	66.5	79.8
160	116	13.8	27.5	41.3	55.1	68.9	82.6
SITE INDEX 55							
40	45	5.3	10.7	16.0	21.4	26.7	32.0
60	63	7.5	15.0	22.4	29.9	37.4	44.9
80	76	9.0	18.0	27.1	36.1	45.1	54.1
100	85	10.1	20.2	30.3	40.4	50.5	60.5
120	91	10.8	21.6	32.4	43.2	54.0	64.8
140	95	11.3	22.6	33.8	45.1	56.4	67.7
160	98	11.6	23.3	34.9	46.5	58.2	69.8
SITE INDEX 45							
40	37	4.4	8.8	13.2	17.6	22.0	26.4
60	51	6.1	12.1	18.2	24.2	30.3	36.3
80	62	7.4	14.7	22.1	29.4	36.8	44.2
100	69	8.2	16.4	24.6	32.8	41.0	49.2
120	74	8.8	17.6	26.4	35.1	43.9	52.7
140	78	9.3	18.5	27.8	37.0	46.3	55.6
160	80	9.5	19.0	28.5	38.0	47.5	57.0

[1]Cords = 0.003958 (Basal area x Height). Rough cords for trees 3.6 inches DBH and larger to a 3-inch top d.i.b. (Buckman 1962).

[2]Must be in trees 3.6 inches DBH and larger.

Current annual cordwood growth per acre 1 for even-aged red pine stands by site, age, and stand density.

Total Age	Total Height	Stand density – basal area per acre					
		30	60	90	120	150	180
Years	*Feet*	----------cords per acre----------					
SITE INDEX 75							
40	61	1.3	1.7	2.0	2.2	2.4	2.4
60	86	1.4	1.8	2.1	2.3	2.4	2.4
80	103	1.3	1.7	2.0	2.1	2.2	2.1
100	115	1.1	1.5	1.8	1.9	1.9	1.8
120	124	.8	1.2	1.5	1.7	1.6	1.5
140	130	.7	1.1	1.4	1.5	1.5	1.3
160	134	.6	1.0	1.3	1.5	1.4	1.3

SITE INDEX 65							
40	53	1.0	1.4	1.6	1.8	1.9	2.0
60	74	1.1	1.4	1.6	1.8	1.9	1.9
80	89	.9	1.2	1.5	1.6	1.7	1.6
100	100	.6	1.0	1.3	1.4	1.4	1.3
120	107	.5	.8	1.1	1.2	1.2	1.1
140	112	.3	.7	.9	1.0	1.0	.9
160	116	.2	.6	.9	1.0	.9	.8
SITE INDEX 55							
40	45	.8	1.0	1.2	1.4	1.5	1.5
60	63	.7	1.0	1.2	1.4	1.5	1.5
80	76	.5	.8	1.1	1.2	1.2	1.1
100	85	.4	.7	.9	1.0	1.0	.9
120	91	.2	.5	.7	.8	.8	.7
140	95	--	.3	.6	.7	.6	.5
160	98	--	.3	.5	.6	.5	.4
SITE INDEX 45							
40	37	.5	.7	.9	1.0	1.1	1.2
60	51	.5	.7	.9	1.0	1.0	1.0
80	62	.3	.5	.7	.8	.8	.8
100	69	.1	.3	.5	.6	.6	.6
120	74	--	.2	.4	.4	.4	.3
140	78	--	.1	.2	.3	.3	.2
160	80	--	--	.2	.3	.2	.1

[1]Cordwood growth = .003958 (basal area growth x height + height growth x basal area + basal area growth x height growth) (Buckman 1962).

[2]Must be in trees 3.6 inches DBH and larger.

Volume in M board feet per acre 1 for even aged red pine stands by site, age, and stand density.

Total Age	Total Height	Stand density – basal area per acre					
		30	60	90	120	150	180
Years	*Feet*	---------------*M Board Feet per acre*---------------					
SITE INDEX 75							
60	86	5.4	10.8	16.1	21.5	26.9	32.3
80	103	6.4	12.9	19.3	25.8	32.2	38.6
100	115	7.2	14.4	21.6	28.8	35.9	43.1
120	124	7.8	15.5	23.3	31.0	38.8	46.5
140	130	8.1	16.3	24.4	32.5	40.6	48.8
160	134	8.4	16.8	25.1	33.5	41.9	50.3
SITE INDEX 65							
60	74	4.6	9.2	13.9	18.5	23.1	27.8
80	89	5.6	11.1	16.7	22.3	27.8	33.4
100	100	6.3	12.5	18.8	25.0	31.3	37.5
120	107	6.7	13.4	20.1	26.8	33.4	40.1
140	112	7.0	14.0	21.0	28.0	35.0	42.0
160	116	7.2	14.5	21.8	29.0	36.3	43.5
SITE INDEX 55							
60	63	3.9	7.9	11.8	15.8	19.7	23.6
80	76	4.7	9.5	14.2	19.0	23.8	28.5
100	85	5.3	10.6	15.9	21.3	26.6	31.9
120	91	5.7	11.4	17.1	22.8	28.4	34.1
140	95	5.9	11.9	17.8	23.8	29.7	35.6
160	98	6.1	12.2	18.4	24.5	30.6	36.8
SITE INDEX 45							
60	51	3.2	6.4	9.6	12.8	15.9	19.1
80	62	3.9	7.8	11.6	15.5	19.4	23.3
100	69	4.4	8.6	12.9	17.3	21.6	25.9
120	74	4.6	9.2	13.9	18.5	23.1	27.8
140	78	4.9	9.8	14.6	19.5	24.4	29.3
160	80	5.0	10.0	15.0	20.0	25.0	30.0

[1]Board fee = 2.084 (Basal area x Height). Board-foot volume by Scribner Dec. C. log rule for trees 7.6 inches DBH to a 6-inch top d.i.b. (Buckman 1962).

[2]Must be in trees 7.6 inches DBH and larger.

Current annual board foot growth per acre 1 for even-aged red pine stands by site, age, and stand density.

Total Age	Total Height	Stand density – basal area per acre					
		30	60	90	120	150	180
Years	Feet	---------------Board Feet per acre---------------					
SITE INDEX 75							
60	86	751	959	1112	1211	1255	1245
80	103	670	887	1039	1126	1148	1105
100	115	560	785	936	1016	1023	958
120	124	433	659	807	878	871	812
140	130	365	595	743	810	795	699
160	134	320	556	709	777	762	662
SITE INDEX 65							
60	74	556	737	856	943	999	993
80	89	467	654	766	860	878	841
100	100	339	531	661	728	732	694
120	107	242	440	571	634	630	560
140	112	153	352	482	541	530	472
160	116	127	327	454	509	491	400
SITE INDEX 55							
60	63	382	539	655	732	769	765
80	76	286	445	556	619	635	602
100	85	185	352	466	527	534	488
120	91	95	247	361	436	436	379
140	95	--	184	295	348	340	273
160	98	--	135	244	291	276	201
SITE INDEX 45							
60	51	242	365	457	516	542	537
80	62	155	284	374	425	437	410
100	69	48	182	273	320	325	300
120	74	--	102	192	236	233	183
140	78	--	29	116	155	161	103
160	80	--	--	102	142	131	71

[1]Board foot growth = 2.084 (basal area growth x height + height growth x basal area + basal area growth x height growth) (Buckman 1962).

[2]Must be in trees 7.6 inches DBH and larger.

Rotation age

Rotation age is affected by many factors including site quality, desired product, stocking, and intensity of forest management activity. Generally, for production management purposes, the rotation age for red pine is between 60 to 90 years, as defined by culmination of mean annual volume growth increment. However, red pine is a long-lived species, providing opportunities to grow and manage stands for up to 200 years and individual trees to even greater ages. In fact, longer rotations, exceeding 100 to 150 years, have become more common on public lands and when managing for large diameter sawtimber.

Periodic thinning serves to extend economic rotation age by delaying culmination of mean annual increment. Table 1 below displays rotation ages based on maximum mean annual board foot growth at different levels of basal area (after periodic thinning). For wildlife habitat and recreation/aesthetics management purposes, declining growth rates in extended rotation stands are not a primary concern. Rather, it is the ecological contributions of old trees and stands that are of primary interest. Consequently, the shape of the mean annual increment curve and the influence of thinning on growth may be of limited concern to landowners interested in wildlife habitat and recreation/aesthetic goals.

Table 1. Rotation ages calculated at various site indices and densities for red pine.

Planted trees/Acre	Basal area density after periodic thinning											
	30	60	90	120	150	180	30	60	90	120	150	180
	SITE INDEX 75											
	Rotation age – years						*Board feet per acre per year*					
400	63	93	103	113	118	103	331	614	831	980	1013	841
800	83	103	103	113	143	123	302	561	775	894	867	654
	SITE INDEX 65											
	Rotation age – years						*Board feet per acre per year*					
400	93	83	103	103	123	98	247	471	654	774	732	618
800	83	103	103	133	148	118	237	447	605	676	583	415
	SITE INDEX 55											
	Rotation age – years						*Board feet per acre per year*					
400	93	93	103	118	113	78	189	367	496	555	492	394
800	93	103	123	143	138	143	184	336	451	448	340	161
	SITE INDEX 45											
	Rotation age – years						*Board feet per acre per year*					
400	98	108	123	118	88	88	124	245	336	329	263	263
800	103	123	128	138	--	--	113	217	259	226	--	--

Source: Unpublished red pine yield tables for managed plantations and natural stands in the Lake States. Computer program developed by A.L. Lundgren (1971), from growth and yield studies at the Northern Conifers Laboratory.

[1] International ¼ inch board boot volumes in trees 9 inches d.b.h. and larger to a 6 inch top d.i.b.

[2] Mean annual growth did not culminate prior to 153 years of age in these high density stands.

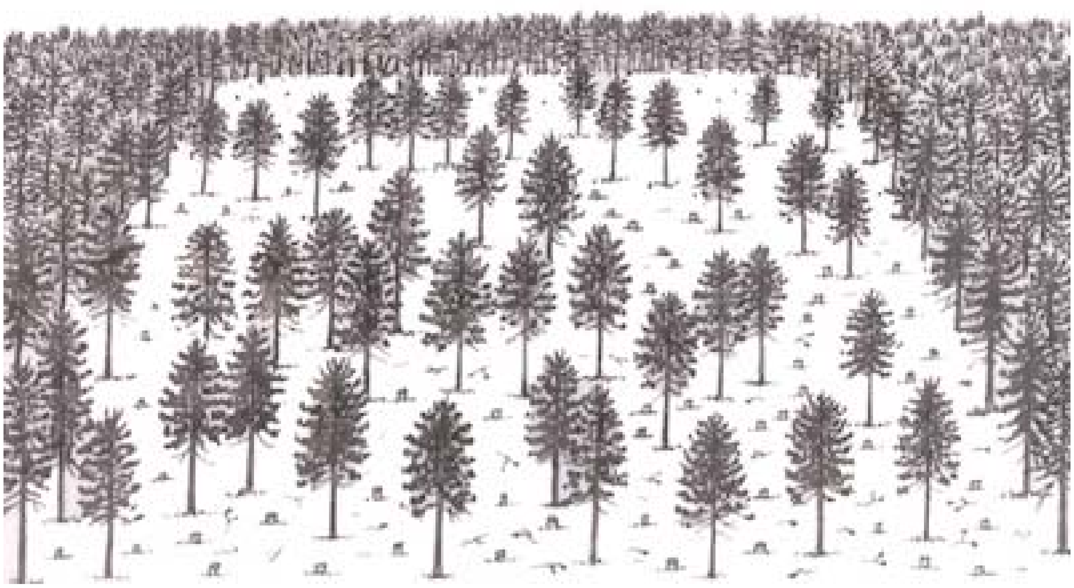
Older stands and trees can have an increasing risk to insect and disease concerns. These are discussed in the Forest Heath section.

Harvesting

Common regeneration harvest approach for red pine stands include:

- Clearcutting: the most common final harvest approach for red pine in the Lake States Region.

- Shelterwood: used on sites where it is important to establish sufficient seedlings, before the mature stands will be harvested (e.g. to modify severe microclimate conditions, or to protect erosion on steep slopes).



- Retention harvesting: involves leaving mature red pines during harvest for one or more rotations. While not widely practiced with red pine, may be applicable for meeting certain ecological objectives (visit Managing for Ecological Objectives).

Harvesting systems

Pulpwood is commonly harvested using a feller buncher or a harvester. If harvested with a feller buncher, whole trees are skidded out of a stand and then delimbed with a delimber and cut to length at the landing site. If the trees are cut with a harvester, they are normally cut as shortwood and taken out of the stand with a forwarder.

Small and medium size sawtimber, poles, and cabin logs can be harvested with a harvester, but bigger trees have to be cut manually with a chainsaw.

Feller buncher (R. Klevorn)

Skidder (C. Blinn)

Forwarder (C. Blinn)

Delimber (C. Blinn)

Managing for ecological objectives

Forest management focused heavily on enhancing ecological complexity is an evolving area of interest. It can be a major objective or be incorporated into management for objectives such as income, wildlife habitat, or recreation. It involves consideration of three basic principles:

- Incorporation of biological legacies (features of pre-disturbance forests) into regeneration harvest prescriptions
- Incorporation of natural stand development processes into intermediate treatments
- Allowing appropriate recovery periods between regeneration harvests

For more information on these topics see the separate sub pages.

Biological legacies

Modifying traditional regeneration harvests: Traditional clear-cutting harvest and regeneration prescriptions for red pine may be modified to incorporate biological legacies by including retention of large (healthy) red pine trees (and other species if they are present), decadent trees, snags, and downed boles. The sizes of retained live trees, snags, and logs on the ground should span a range of diameters including very large (in a relative sense) red pine. Give special consideration to actual or potential habitat trees, including cavity trees, mast trees, nest trees, etc. Protect natural regeneration whenever possible.

Red pine shoot blight: With concerns about red pine shoot blight (see Forest Health section), consider regenerating primarily white and jack pine after an initial regeneration harvest that retains mostly overstory red pine. Reducing losses from shoot blight when retaining overstory red pine may require adopting a long-term silvicultural plan that emphasizes alteration of pine dominance. With this approach, you will retain overstory red pine during an initial regeneration harvest, followed by planting or seeding of species other than red pine, e.g., primarily white and or jack pine. At the end of the next rotation, you might retain primarily white and jack pine, followed by planting or seeding of red pine.

Red pine dispersed retention after harvest. Itasca County, MN (B. Palik)

Amount of retention: The number or amount of structures such as live trees, snags, CWD, etc. retained during harvest is typically dependent on management objectives and desired future conditions. For instance, by retaining a low stand density, say a basal area of residual red pine of 20 square feet per acre, followed by regeneration, you will have a largely single-aged stand containing scattered older trees. In contrast, if you retain higher basal area (e.g., 40-60 square feet per acre) of residual red pine at harvest, you will have a two-aged stand. Keep in mind that there will be growth reductions when regenerating red pine or other intolerant species under even modest levels of a residual overstory. However, maximizing regeneration growth throughout the stand may not be your primary concern when managing for ecological complexity. Moreover, the continued growth of the residual trees may compensate for growth loss in the younger portion of the stand.

Red pine stand with aggregate retention. Itasca County, MN (E. Zenner)

Spatial pattern of retention: Consider the spatial pattern of retention within the harvested area. Some ecological objectives are best sustained by dispersing retained trees, snags, and CWD over the harvested area while other objectives are best served by aggregating such structures. Within a single harvest area, you can vary the retention pattern from dispersed to aggregate by alternating between patch and dispersed cutting across the stand. Consider adjusting regenerating species to residual overstory condition, for example, favoring white pine under dispersed retention and red or jack pine in openings.

Sphaeropsis shoot blight in red pine stand. (S. Katovich)

Natural stand development processes

Variable density thinning: In contrast to a uniform thinning across a stand, consider variable density thinning to increase structural heterogeneity within the stand. First select a target residual basal area and trees per acre, using thinning guides. Then vary the density of thinning from heavily thinned patches (i.e. gaps) to unthinned patches, with moderate thinning between these endpoints. The result is greater horizontal variability in stand densities, thus providing for greater heterogeneity in structural conditions across a stand.

Residual red pine trees will create a two-age class stand. (A. Ek)

A common approach for implementing variable density thinning on the ground is to subdivide your stand using a ¼ ac grid pattern. The thinning application will vary on the scale of ¼ ac patches. For example, alternative ¼ ac gaps, with ¼ ac skips (no thinning) and ¼ ac thinned patches. Consider tying patch type locations to existing features in the stand. For example, orient a skip patch on a desirable ecological feature, such as a large remnant tree or snag or a unique tree species. Some gaps might be place where there is already a natural opening in the stand. Avoid over aggregating patch types within the stand.

Red pine stand after variable density thinning. Itasca County, MN (B. Palik)

Creating Decadence: Consider deliberate felling of a few live trees to increase the abundance and types of dead trees on the ground (course woody debris). Also, consider girdling (or killing in some other way) living trees to create snags. Consider a range of tree sizes, including large diameter red pine individuals. A small blowdown can also provide course woody debris without any costly forest operations.

Introduction and conservation of compositional diversity: If you create larger canopy gaps in a stand, using variable density thinning, you may facilitate the establishment of mid- and intolerant tree, shrub, and herbaceous species. Moreover, during the course of stand development, more shade tolerant species (e. g., eastern white pine) may become established in the understory. Encourage or under plant these species, if your objective is enhancement of ecological complexity and native plant diversity. Moreover, do not preferentially remove non-target tree species (that is, species other than red pine) during thinning.

Under burning: Periodic surface fires were a natural occurrence in red pine dominated forests, particularly on drier sites. Periodic use of prescribed surface fire will help maintain (or restore) understory conditions that are reflective of conditions occurring prior to effective fire suppression. Natural fires often burned heterogeneously across stands. To emulate this, make no special effort to insure that the entire stand burns evenly. Surface fires may also be an effective means to induce decadence creation, through fire scaring and small-scale canopy disturbance if individual trees are killed. Take care not to induce excessive injury or mortality, which may occur if thick duff layers surround most trees or if the fire occurs during excessively dry periods.

Blowdown of large red pine. Itasca County, MN (B. Palik)

Red pine stand with hardwood and eastern white pine mid-story. Itasca County, MN (B. Palik)

Red pine snag created using blasting cord to remove the live crown. Chippewa National Forest, Itasca County, MN (H. Tjader)

Red pine stand with open under-story after several surface fires. Itasca County, MN (B. Palik)

Recovery periods

Recovery periods between regeneration harvests are needed for development of significant structural and compositional complexity in red pine stands. Today red pine stands are often harvested before significant levels and types of complexity have developed. In general, economic rotation ages, typically 50-90 years, are shorter than those required to develop complex stand structures. If the primary management objective is enhancement of older forest habitat features and associated species diversity and development of ecological complexity, then longer than economic rotation ages are appropriate. Thus the primary determinant of intermediate harvest or rotation age in such cases would be the development of desired or acceptable levels of structural complexity, compositional diversity, and within-stand heterogeneity.

Forest Health

Forest health

Past management guides have viewed red pine as a species with fewer insect and disease related concerns than other Lake States conifers. It does not have a major defoliator such as the jack pine budworm that damages older jack pine stands on a regular basis. Nor does it have a major pathogen such as blister rust in white pine that can kill large numbers of trees. Its more common disease problems tend to be subtle, such as periodic outbreaks of shoot blights that kill and deform seedlings and small trees. These epidemics occur infrequently and are often forgotten during the intervening non-epidemic years. Though red pine does not have what many would regard as a single major pest problem, it does have an array of insects and diseases that can, on occasion, cause significant damage.

Mammal caused damage is generally minimal in red pine. Pocket gophers can eat the roots of seedlings and young trees causing extensive damage in isolated plantations in some locations in the Lakes States. Deer browsing is rarely a significant problem on red pine.

Weather events can cause significant damage and can create conditions conducive to widespread disease epidemics. Drought and hail damage both favor outbreaks of Diplodia shoot blight and canker. Persistent wet weather, especially in the spring and early summer often results in Sirococcus shoot blight epidemics, especially in northern parts of Wisconsin and Minnesota, and Michigan's Upper Peninsula. Damage from heavy snow, ice, and wind is relatively common in dense plantations where trees have developed small crowns.

The most common damaging insects have been associated with seedlings and young stands. As long as older plantations are thinned on a regular cycle of 10-15 years, tree growth and vigor is generally maintained and tree mortality and/or growth loss is minimal.

Several diseases have become widespread because of inadvertent planting of infected nursery stock. The severity of some of these diseases has increased because of environmental and site factors that are favorable for pathogen development and spread.

In the Great Lakes region, red pine largely has been managed in monoculture plantations. Even natural stands are often relatively pure. Any tree species growing in largely pure stands is inherently at risk to outbreaks of insects or diseases. This concern is further compounded with red pine since the species has very limited genetic diversity. Fortunately, no major insect or disease threatens the existing resource at this time, though that could change with the introduction of an exotic species. Managers do have opportunities to develop diversity within existing plantations as well as when establishing new red pine stands. This process should reduce some of the risk associated with largely pure red pine stands.

It is often possible to manage red pine to reduce insect and disease risk and minimize losses. The emphasis should be on long-term strategies that prevent or reduce the risk of pest outbreaks. It is generally easier to prevent problems than it is to deal with an ongoing outbreak.

Detailed information on specific pest problems in red pine are described and discussed in the section titled Specific Pest Concerns. Pests are described based upon what part of a tree they damage. This section provides links to additional management guides and identification aides. Further pest information can also be obtained in a section on Pest Problems and Stand Development. This section details specific pest problems that are most likely to occur during various stages in the stand development of red pine.

Specific pest concerns

Red pine has an array of specific pest concerns that can influence management of the species. The most commonly encountered concerns are highlighted below. The following discussion is organized by the part of the tree damaged. Specific insects, pathogens and mammals damage different parts of trees including needles, shoots and branches, roots and the root collar region, main stem, and seeds and cones. This is done to assist managers in identifying pest problems. Photographs are included for further assistance. A number of links are provided as well, where available these should provide more detailed information.

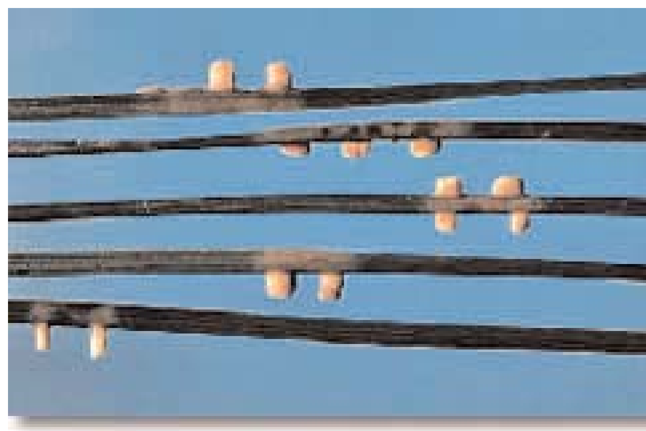
Red pine diseases are discussed in detail in a publication titled, Pocket guide to red pine diseases and their management. This is available electronically. Detailed pine pest insect guides for the Great Lakes region have also been developed. One of the best is " Insects of eastern pines". It is not available electronically. Complete references for all of the disease and insect guides are listed in the section, Sources of Technical Information."

It can be hard to generalize but damage to the roots and root collar region, and the main stem, is much more significant than damage elsewhere on a tree. Branch and twig damage can affect overall form but on larger trees this is rarely lethal. Needle loss can reduce growth rates but unless trees are defoliated completely, i.e. lose both old and new needles, tree mortality rarely occurs. Seed and cone insects are only a concern when regeneration from seed is an objective.

Needle damage

Needle diseases
Needle diseases such as Lophodermium needle cast and pine needle rust can be found on young trees but seldom cause significant damage.

Lophodermium needle cast, Lophodermium seditiosum, is primarily a problem in nurseries where it can defoliate and kill seedlings. On older trees it tends to affect needles in the lower crown. If not controlled in the nursery, infected trees can be inadvertently shipped and planted in the field. Spores are released from fruit bodies on killed needles in late summer and early fall and windblown to susceptible current-year needles where infection and fungus development takes place. The fungus overwinters in these needles that eventually turn brown and are cast early the following summer.



Spore structures of pine needle rust on red pine needles.

Pine needle rust, Coleosporium asterum, requires two hosts in its life cycle, red pine and an alternate host, either goldenrod or big leaf aster. Spores that develop on infected needles are wind borne and infect alternate hosts in early summer. These spores cannot infect other pines. Another spore type develops on the alternate host, it is this spore that infects pine needles in late summer. The fungus overwinters in infected needles completing the disease cycle. Pine needle rust is most severe on sites where alternate hosts are abundant. On these sites, seedlings and small trees can suffer growth loss and on rare occasions, mortality. Needle rust can be reduced by avoiding planting sites with goldenrod and aster unless they can be removed by mowing or with the use of a registered herbicide.

Needle feeding insects
Red pine does not have a major insect defoliator that erupts into regional outbreaks. However, there are defoliators that undergo localized outbreaks, causing growth loss and on occasion, tree mortality. Redheaded pine sawfly is the most likely species to cause significant damage. Pine tussock moth feeding can also kill trees.

The following insect defoliators can be divided into groups that feed during different times of the year. The species that feed very early in the spring are limited to eating older needles from previous years. Insects feeding in the late spring, summer and fall have the opportunity to eat both new needles as well as older needles. The few species that will eat both the new and old foliage are the greatest concern, this includes the redheaded pine sawfly and pine tussock moth.

Early spring needle feeders - Both red pine sawfly, Neodiprion nanulus nanulus, and European pine sawfly, Neodiprion sertifer feed very early in the spring, prior to new needle expansion. Larvae of the two species look very similar. Only needles from previous years are eaten and therefore, damage is minimal. The European pine sawfly is an exotic species that is limited to warmer parts of the region, specifically the southern half of Wisconsin, southern one-third of Minnesota, and the Lower Peninsula of Michigan.

European pine sawfly larvae.

Late spring needle feeders - Jack pine budworm, Choristoneura pinus pinus, is a major pest of jack pine. However, it will, on occasion, be found feeding on red pine needles. Outbreaks are cyclic, occurring every 7-11 years, each outbreak tends to last 1-3 years. In red pine, growth loss and top-kill can occur. Red pine trees growing in close association with jack pine are most likely to be infested though infestations can occur in pure red pine stands.

Jack pine budworm, late instar larva.

Pine tussock moth, Dasychira plagiata, has infrequent outbreaks that have been generally restricted to northwestern Wisconsin. These outbreaks tend to be short-lived, usually one year. However, trees are often stripped of both old and new needles and tree mortality can be significant.

Summer needle feeders - Redheaded pine sawfly, Neodiprion lecontei, outbreaks have occurred throughout the Lake States. Heavy feeding is more prevalent on young trees (< 20 ft tall), and on sites that would be defined as stressful for red pine. These sites include highly disturbed sandy areas, frost pockets, and along hardwood edges. This sawfly can kill large numbers of young pine during outbreak periods.

Redheaded pine sawfly larvae.

Pine webworm, Tetralopha robustella, forms conspicuous nests of excrement held together with silk. Though commonly encountered in young plantations in the Great Lakes region, large outbreaks have not been reported and damage is generally minimal.

Late summer/fall needle feeders - Feeding by the red-pine needle midge, Thecodiplosis piniresinosae, occurs throughout the summer, but the characteristic needle browning does not develop until late fall. In early summer, midge larvae tunnel into the base of needle fascicles. Feeding causes premature needle mortality referred to as fall browning or needle droop. Damage is often concentrated in the tops of young trees where terminal mortality can occur. Persistent midge populations have been associated with plantations growing on poor quality red pine sites, basically very dry, nutrient poor sandy soils. Outbreaks have been reported in parts of central and western Wisconsin.

Pine webworm nest.

Shoot and branch damage

Shoot blight and canker diseases

In the Lake States region, red pine trees are often invaded by two fungi that can kill shoots and develop into cankers on larger branches and main stems of trees. Diplodia shoot blight and canker and Sirococcus shoot blight are two of the most important diseases of red pine. They can be prevalent on trees of all ages but the most significant damage is generally restricted to seedlings and saplings. Both pathogens have unpredictable outbreak patterns that are often dictated by weather events. Diplodia outbreaks tend to occur during droughts or following hail storms, while Sirococcus outbreaks often occur following cool, wet spring weather. During outbreaks many seedlings and small trees can be killed or deformed. Multi-cohort red pine management, or growing small red pine under larger red pine, will increase the risk of disease development. This is because spores produced on infected large trees are rain-splashed onto seedlings and smaller trees growing below them.

Diplodia shoot blight damage (USFS).

Diplodia shoot blight and canker (also referred to as Sphaeropsis) is caused by the fungus Diplodia pinea. The fungus causes shoot blight on large trees, shoot blight and cankers on sapling and pole-sized trees, and shoot blight and collar rot on seedlings. Trees are infected through succulent shoot tissues, branch stubs and wounds. The fungus can grow from infected shoots into branch and stem wood where cankers develop, often girdling and killing trees.

Diplodia is often an episodic disease, existing at low levels for years in some areas without causing significant injury to trees. Some evidence even indicates that many trees carry latent infections that do not express themselves until a stress event occurs. Weather can play a major role in the epidemiology of this disease. Epidemics are often preceded by several years of drought, which stresses trees making them susceptible to Diplodia infection. Epidemics are often initiated locally after hailstorms, which create wounds in branches and stems that can be quickly exploited by the pathogen. This type of scenario, hail damage and a Diplodia outbreak, can destroy entire plantations in 1 - 2 years.

Diplodia canker on the main stem (USFS).

Infected reserve trees and red pine windbreaks are often the sources of fungal inoculum. Spores are released from fruiting bodies on infected bark, needles and cones during wet weather and are disseminated to adjacent trees. Therefore, growing small red pine trees near larger infected trees is risky.

Planting seedlings that were infected in a nursery but not displaying disease symptoms at the time of shipment has likely contributed to the widespread occurrence of this disease. The risk of Diplodia can be reduced by planting healthy stock obtained from nurseries known to protect seedlings from infection and by not planting or growing red pine near infected trees. Since this pathogen is especially damaging on stressed trees, avoid planting red pine on very dry, nutrient poor sites. These would be areas where jack pine would probably be more appropriate. Control of competing vegetation to maintain high tree vigor can also reduce disease impact.

Sirococcus shoot blight is caused by the fungus Sirococcus conigenus. Epidemics occur periodically, closely following extended periods of wet spring weather. Damage can be significant. Young red pine seedlings and saplings can be killed outright. Many trees are deformed by the loss of shoots and smaller branches. Trees growing under or adjacent to infected red pine can be severely damaged when conditions are optimum for fungus dissemination and development. Sirococcus shoot blight is most likely to be a problem in northern parts of Wisconsin and Minnesota and in Michigan's Upper Peninsula.

Sirococcus shoot blight damage.

Spores are released in spring and early summer from fruiting bodies that developed on the previous year's infected shoots. The fungus infects needles and grows into current year's shoots. It is not uncommon to have trees and individual shoots infected by both Sirococcus and Diplodia, collectively increasing damage and losses from these diseases.

Similar to Diplodia, outbreaks of Sirococcus are episodic and the incidence and severity of the disease can rapidly increase. Removing infected overstory trees and pruning infected shoots on understory trees before spore dispersal in early spring will reduce the major sources of inoculum and minimize future disease incidence.

Scleroderris canker, caused by the fungus Gremmeniella abietina, is a disease most serious on young trees, seldom causing damage to trees taller than 6 feet. The disease develops on lower branches under snow cover and the incidence and severity of the disease is generally greatest in frost pockets and in areas where deep snow accumulates.

Characteristic lower branch mortality due to scleroderris canker.

Windblown spores are disseminated during wet weather from April to October. The spores infect buds and needles. Infected branch tips are usually dead by the following summer. The fungus can grow from the branch into the main stem where a canker develops that can girdle and kill young trees. The fungus produces a second spore stage that is disseminated by rain splash from killed branches to adjacent trees, increasing the disease incidence.

Preventing damage by Scleroderris canker begins with planting disease-free nursery stock and avoiding establishment of plantings on sites where Scleroderris canker is present or in frost pockets and cold air drainages where the disease can become most severe. Pruning the lower branches on infected and healthy trees will reduce disease incidence.

Shoot- and tip-mining insects

Shoot and tip-mining insects cause damage by affecting tree form and growth rates. Over most of the range of red pine, this group of insects would not be considered a major concern. However, there are two moth species that do cause considerable damage in some areas. The European pine shoot moth occurs in warmer parts of Lower Michigan and the southeastern portions of Wisconsin. The red pine shoot moth is prevalent in areas dominated by outwash sands, such as the Central Sands region of Wisconsin.

European pine shoot moth, Rhyacionia buoliana, has been a pest in Lower Michigan since the 1950s. Larvae feed on buds and shoots. Damage occurs when a heavy infestation destroys the buds in the top whorl of young trees, creating twisted, multi-stemmed trees. Distribution of this insect is limited by its inability to survive cold winter weather. It can be found in Lower Michigan, southeastern Wisconsin, and a few other locations where consistently heavy snow cover provides insulation for winter survival. Many trees attacked and deformed when young do, over time, recover and grow into reasonably straight trees.

European pine shoot moth damage (USFS).

Red pine shoot moth, Dioryctria resinosella, was initially identified as a significant pest in the 1980s in the Central Sands region of Wisconsin. Larval shoot feeding resulted in height growth losses of 38-65% and radial growth losses of 16-42% over a 9-year epidemic period. Following outbreaks, tree crowns changed from straight-stemmed and conical to a bushy and flat-topped appearance. In some plantations, tree form was altered enough to make it difficult to develop products such as utility poles and cabin logs.

Red pine shoot moth damage.

Management of shoot and tip moths can be difficult, very little can be done to limit damage in the areas susceptible to these two insects. On small trees, corrective pruning may be useful, especially on trees that have their terminal shoot damaged.

Sapsucking insects

Sapsucking insects can reduce tree health or vigor by removing large quantities of sap. But, what is more important, their feeding often creates wounds that eventually plug and permanently reduce sap flow through twigs and branches. Wound sites can also serve as entry points for pathogens. Sapsucking insects include aphids, adelgids and spittlebugs.

Saratoga spittlebug, Aphrophora saratogensis, has historically been the most significant insect pest of young red pine across northern portions of Michigan, Minnesota and Wisconsin. Outbreaks were prevalent in the 1950s through the early 1980s. Adult Saratoga spittlebugs insert their straw-like mouthparts into red pine shoots. Large spittlebug populations cause extensive wounding that can kill branches. Tree mortality can occur and plantation failures have been reported. High populations are associated with abundant sweetfern, the plant that serves as a host for the immature stage of the spittlebug. Planting red pine into areas where sweetfern is abundant creates a high risk of spittlebug attack. Several other plants can also serve as an alternate host including willows and raspberries/blackberries.

Young tree dead in sweetfern.

Root and root collar damage

Root and root collar diseases

Armillaria root disease, caused by several species in the fungal genus Armillaria, is common on stressed and weakened trees. Many trees are probably infected with Armillaria but only exhibit symptoms when stressed by other factors. The fungus causes decay that kills roots. Decay can extend into the lower portions of the main stem. Root diseases often spread out from one infected tree to neighboring trees creating disease centers of dead and dying trees. Typical of root and butt rot diseases, affected trees are subject to wind throw. Damage is often prevalent on young trees growing on cutover hardwood sites. The stumps and dead and dying root systems of the hardwood trees provide a source of fungal inoculum that infects pine seedlings.

Young red pine killed by armillaria root disease.

Mycelial white fans of the fungus found under the bark, at the base of recently dead or dying trees, is a reliable sign of the disease. Stunting and yellowing of infected trees are the first symptoms of disease. Mushrooms may develop at the base of infected trees in the fall.

To reduce the incidence of Armillaria root disease maintain high tree vigor and avoid planting red pine on sites with abundant hardwood stumps that may harbor the fungus.

Annosum root rot is caused by the fungus Heterobasidion annosum and like Armillaria, can result in centers of dead and dying trees. Although Annosum root rot has not been a widespread problem in red pine, the disease can potentially be damaging after thinning and harvesting in some stands. At this time Annosum root rot has been reported in Michigan and rarely in Wisconsin. It has not been observed in Minnesota. However, there is evidence that this disease is spreading in Wisconsin and is likely to be found soon in Minnesota red pine.

Infection takes place in the spring and fall through freshly cut stumps and fresh wounds. The fungus grows into the root systems and can spread underground to adjacent trees.

To reduce the risk of Annosum root disease conduct thinning and harvest operations during the winter. This should reduce the likelihood of infection by spores that can occur via fresh wounds. All fresh stumps on sites where the disease is present should be treated with borax (sodium tetraborate decahydrate) to prevent infection. Infected trees should be removed from the stand or burned to reduce fungal inoculum.

Inonotus root and butt rot caused by Inonotus tomentotus causes a root and butt rot of mature trees, but it can also damage seedlings and young trees on sites where the fungus was present in the previous stand. The fungus infects trees through wounded roots and root collars where a resinous canker will develop. Affected trees have reduced growth and are susceptible to wind throw.

Fruiting bodies of inonotus tomentotus root and butt rot. (B. Livingston)

On seedlings and small red pine trees, the fungus Diplodia pinea (Diplodia) can cause a canker type of injury at the root collar that can kill trees. Diplodia has caused extensive mortality of newly planted seedlings in some years, especially dry years. Seedlings can become infected in nursery beds prior to planting.

Red pine plantations in some parts of the Great Lakes region often develop expanding pockets of dead and dying trees. Some of these pockets can be referred to as red pine pocket decline. The cause of these pockets has not been clearly determined but they appear to be related to a combination of root disease organisms and weevil species that feed on roots and the root collar region (see below) and bark beetles infesting the main stem. Most red pine pockets have been reported in areas dominated by outwash sands in Wisconsin, but this malady also occurs in Michigan and Minnesota.

Once established, pocket decline persists, creating slowly expanding pockets of dead and dying trees. These areas have reached several acres in size in some plantations. Control measures are under evaluation.

Characteristic mortality observed with red pine pocket decline. An Annosum root diseas pocket can look very similar.

Root and root-collar insects

Several insects feed on the roots and in the root collar region of red pine. On occasion, some of these have been significant pests especially on seedlings. This includes white grubs, and several weevil species.

White grubs (Coleoptera:Scarabaeidae) are the immature stage of beetles referred to as May and June beetles. There are several different species of white grubs that can feed on pine roots. The grub stage, also referred to as larvae, live in the soil and feed on fine roots of many plants, including young pine. They have been responsible for planting failures throughout the Lake States region. Most damage has occurred when planting into existing sod. Damage to seedlings can occur at grub populations as low as 0.25 larvae per square foot of sod.

White grubs.

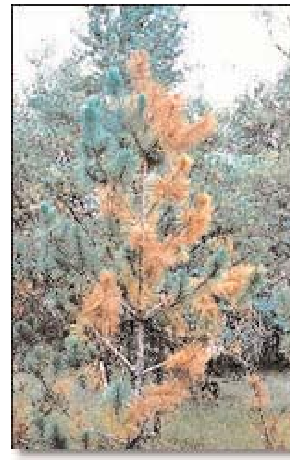
Pine root collar weevil, Hylobius radicis, can be a serious pest of young (5-15 year old) red pine. Larvae feed at the base of trees, the root collar region, where they can girdle trees or cause stem deformity. Heavily infested trees often break at the damaged site and tip over. Damage is associated with poorly stocked stands growing in heavy grass often on very sandy soils. Windbreak trees and trees growing along the edges of plantations are most likely to be infested. Scotch pine, Pinus sylvestris, is very susceptible to this weevil and red pine growing in association with Scotch pine is more likely to become infested.

Pine root collar weevil infested trees have a constricted base and black, resinous stem at the soil line.

The root tip weevil, Hylobius rhizophagus, is most often found attacking red pine growing in close association with jack pine. Jack pine is regarded as the main host for this weevil and its presence appears to attract the weevils into red pine stands. Interestingly, little damage is observed on jack pine but, infested red pine trees are often killed. Infested red pines have flagged (dead) branches and can appear stunted. The symptoms can be very similar to Saratoga spittlebug attacks or some of the shoot pathogens. Proof of root tip weevil attack consists of finding larvae or root damage. This weevil does not attack at the root collar, but feeds on the outer portions of the root systems.

Root and root collar weevils have been found associated with a decline syndrome called red pine pocket decline. These weevils along with a couple of bark beetle species (Ips pini and Dendroctonus valens) appear to play a role in introducing root invading fungi that initiate expanding pockets of mortality in plantations.

Root feeding mammals
Pocket gophers, Geomys spp., can eat the roots off young red pine trees. This damage tends to be isolated to sandier sites and often on areas dominated by grass cover. Damaged trees often tip over and can be easily pulled from the ground. In many instances the entire root system is chewed off. Traps and poisons can be used to eliminate gophers from an area. Large trees are not damaged.



Root tip weevil damage.

Main stem damage

Stem decays
Extensive stem decay is not common in red pine, even very old trees generally have little decay. When decay is prevalent it is often associated with old fire scars.

Phellinus trunk rot is caused by the fungus Phellinus pini. It causes a white pocket rot of mature trees sometimes called red ring rot because of the color of the wood in the early stages of decay. Symptoms include swollen knots, punk knots (masses of brown fungal hyphae protruding from decayed branch stubs) and brown conks on trunks of infected trees. Infection is through wounds and broken branches. There are no effective control measures other than to avoid wounding trees.

Ips pini nuptial chamber and egg gallery.

Bark and wood infesting insects
Pine bark beetles in the genus Ips are found in association with almost every red pine that dies. They are generally viewed as secondary pests, meaning that in most cases they cannot successfully infest and kill a healthy, vigorous tree. Healthy red pine trees can defend themselves by producing pitch or resin. Trees stressed by drought, old age, fire injury, root disease or intense competition (dense plantations) produce little resin and become susceptible to attack.

Red pine is attacked by several species of Ips in the region. The most common is the pine engraver, Ips pini. Other species include Ips grandicollis, and Ips perroti. In general, Ips attacks rarely occur in plantations younger than 25 years of age. Past that point, outbreaks are often associated with lack of thinning and drought. In most situations, outbreaks are limited to small groups (3-5) of trees. However, during periods of significant drought, several acres of trees can be killed. Logging operations can also trigger local outbreaks. Freshly cut logs left in the woods in the spring and early summer can provide breeding material that produces large beetle populations. Population increases of 10-fold can occur in one growing season, with three generations of Ips pini possible. Thus, a local population of 1,000 can increase to 1,000,000 individuals in one season. A single downed large tree can produce as many as 80,000 beetles.

Characteristic pitch tube that forms during a red turpentine beetle attack.

The red turpentine beetle, Dendroctonus valens, is a common bark beetle found attacking at the base of trees or attacking fresh stumps. Attacks occur from the ground-line up about 3-4 feet. Characteristic popcorn-like pitch tubes are diagnostic. These beetles are not considered tree killers but their tunnels and feeding further reduces tree vigor making infested trees susceptible to infestation by Ips bark beetles or Armillaria root disease.