Volume

2

Site Preparation Tending and Maintenance

Northern Hardwoods Research Institute
Institut de recherche sur les feuillus nordiques

Best Management Practices Series

Artificial Regeneration of Maple

Preface

The Northern Hardwoods Research Institute is dedicated to equipping forest stakeholders with the knowledge and tools necessary to optimize the management of northern hardwoods and mixed forests. Our mission is rooted in fostering resource growth, maximizing timber value, and ensuring long-term sustainability. As forest landscapes evolve due to poor harvesting practices, agricultural land clearing, and the pressing impacts of climate change, artificial seeding and planting emerge as vital tools for regenerating hardwood stands. The anticipated shift toward greater red maple dominance (Ostrowsky and Ashton, 2022; Abrams, 1998) and the decline of high-quality sugar maple (Long et al., 2009) in eastern Canada highlight the need for proactive approaches, including human-assisted migration and increasing hardwood forest composition.

Climate change presents unprecedented challenges to long-lived tree species, with debates ongoing about their ability to adapt to rapid environmental shifts (Richter et al., 2012). The natural genetic adaptability of forest populations may be outpaced by today's accelerated changes, leading to adaptation lag (Matyas, 1996; Leites et al., 2012). This lag underscores the urgency of employing innovative strategies to mitigate further degradation of northern hardwood stands.

Although millions of hardwood seedlings have been planted in eastern Canada, many plantations have failed or underperformed, with sugar maple often proving less successful than other species on comparable sites. While softwoods generally yield higher returns under extensive management due to their broader site tolerance and cost-effectiveness, intensively managed hardwoods on suitable sites can produce exceptional returns while meeting diverse sustainability objectives. Success stories from other parts of the world (von Althen, 1964) affirm the potential of well-managed hardwood plantations to deliver economic and ecological benefits.

Modern forest management increasingly prioritizes objectives beyond timber production, such as wildlife habitat enhancement, forest diversity, and the establishment of resilient ecosystems. Despite the repeated challenges faced in regenerating sugar maple, both naturally and artificially, the ecological interest in its regeneration remains strong. This guide synthesizes the history and knowledge gained from hardwood plantation studies across the northern hardwoods range. It offers best practices for site selection, preparation, tending, and direct seeding to support the successful artificial regeneration of maple trees.

Our primary objective is to evaluate the operational viability of growing maple on various sites within New Brunswick, though this knowledge is equally applicable to small-scale private landowners. We learn a lot from maple syrup producers and apply that knowledge to growing maple trees for timber. By exploring long-term and creative solutions, this guide also extends its recommendations to a range of hardwood species, aiming to contribute to the broader goal of sustainable forest management and adaptive silviculture.

Executive Summary

Plantation planning and site preparation

Site assessment	Select sandy loams or loams for optimal water retention. Refer to soil maps, surveys, and consult a soil specialist or agronomist for site-specific guidance. Ensure sufficient soil depth to reduce drought risk. Avoid poorly drained areas and sites with excess water.
Soil preparation	Adjust soil nutrients on a small scale with fertilizers and lime as needed; but fertilization isn't recommended during the first growing season unless soil tests show nutrient deficiencies. Sugar maple growth may not always respond to fertilization, and liming at an industrial scale is complicated and costly.
Site preparation	Plowing and discing are the best method for comprehensive site preparation. Destroys weeds, loosens soil, stimulates microbial activity, and improves soil aeration, providing optimal conditions for seedling establishment. High initial costs are offset by long-term benefits, including improved seedling growth. Although, this should be combined with other methods.
Spring Planting	Sugar maple struggles with root establishment due to early leaf emergence and limited root growth. Sugar maple roots begin growing as early as mid-February, but limited root growth can affect the establishment of foliage. Use of growth inhibitors like abscisic acid can help delay shoot emergence and allow root establishment. Early spring planting is recommended in preparation for optimal root development.
Fall Planting	Challenges of fall planting include low physiological potential for root regeneration, frost heaving, and heavy browsing. Higher risk of seedling mortality compared to spring planting.
Optimal Planting Density	A planting density of over 1600 trees/ha is ideal for hardwoods to minimize large branch growth, with a minimum of 1200 trees/ha to ensure optimal straight-bole development.
Thinning Strategy	Aim to cultivate a moderate number of high-quality sawlog/veneer trees per hectare. Use a structured thinning approach to remove undesirable trees and retain the best-forming crop trees for long-term growth.
Plantation Spacing & Stocking	Proper spacing promotes growth and timber quality. Sugar maples are sensitive to competition, requiring careful spacing to avoid stagnation. Wider spacing improves diameter growth but can lead to poor form, while narrower spacing is better for high-quality timber. We recommend following the 4ft by 4ft spacing of traditional maple sugary plantations for sugar maple, as it has been proven to work.

Successfully establishing a hardwood plantation requires careful consideration of planting density, spacing, thinning, and maintenance strategies. The planting density of over 1600 trees/ha, coupled with structured thinning, ensures healthy tree growth and high-quality timber production. Proper plantation spacing is vital for avoiding competition and ensuring good tree form, with narrower spacing favored for high-quality hardwoods, but when you consider the effort, cost, and wasted trees this method takes, many would recommend a wider spacing that follows the 4m by 4m spacing of a sugar bush plantation. The layout of the plantation should also be thoughtfully planned to enhance both productivity and aesthetics.

Until more effective direct seeding methods are developed, planting nursery-grown seedlings remains the preferred approach for better controlled establishment. While softwood planting practices have been applied to hardwoods with limited success, the right strategies, including plowing, early spring planting, and appropriate spacing, can make hardwood plantation efforts worthwhile. Further attention to maintenance practices, such as regular rototilling and protection from pests, is essential during the first few years after planting.

Tending and Maintenance

Mixed-species plantations	• Having a mix of species (diversification) reduces risks from diseases, strong winds, and ice storms, making yields more reliable.Thinning prioritizes the removal of species with lower potential for early harvest revenue, which may require accepting an initial deficit to achieve greater future profits. • Provide shade, enhancing pruning and timber quality for preferred species
Competition in Open Fields	• Mainly grasses and sedges, herbaceous plants, some shrubs • Weed control for the first 3–4 years for competition purposes (timeline for tending may (and should) increase in high-predation areas) • Mulch, mowing, landscape fabric, and 2–3-foot weed-free zones around trees (Gauthier et al., 2014; Barkley, 2007). Black plastic and mulch are most effective in field trials (Agence forestière de la Montérégie, 2007a).
Competition in Forest Lands	• Competition comes from shrubs like pin cherry, raspberry, alder, and mountain maple. • In many cases natural regeneration of commercial tolerant (beech, red maple) and intolerant (poplar, white birch) species are considered competition as well • Control intensity depends on tree species' shade tolerance and desired outcomes
Chemical Control	• Glyphosate has been used successfully for yellow birch, red oak, sugar maple, and white ash on former farmland (Robitaille, 2003). Always follow local laws and regulations. Herbicide can only be applied by certified individuals after permits have been obtained due to potential risk to humans and wildlife.
Filling practices	• A 10% loss is typical for hardwoods • Replant in second or third year if survival is < 85%
Rodents, Deer, Moose	• Rodents prey on seeds and seedlings; manage by reducing weeds and using repellents or guards. Deer and moose browse seedlings and trees; strategies include repellents, fencing, and habitat management to minimize damage.

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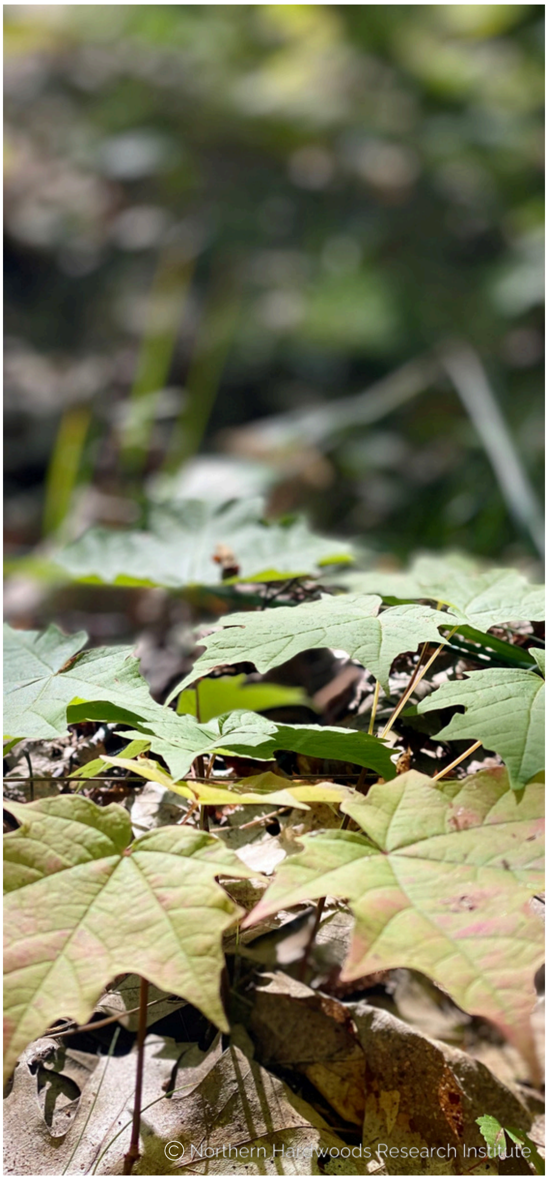
Chapter 1: Introduction

Hardwood plantations serve a variety of purposes, including high-quality timber production, floodplain restoration, afforestation, and supplementing regeneration in harvested stands. However, high-quality roundwood is best achieved through proper hardwood silviculture in existing stands, as planting—whether through direct seeding or nursery practices—cannot fully replace sustainable management. Plantations often present significant challenges, such as costly, time-consuming maintenance and frustrating tending requirements. If planting hardwoods becomes necessary, a well-thought-out plan with clear priorities and a thorough understanding of risks and rewards is essential. Successful plantation management requires careful planning, encompassing planting techniques, tending, thinning, and protection against threats like predation by rodents and ungulates. Without proper planning and protection for at least five years, plantations are unlikely to yield the desired benefits.

Sugar Maple (Acer saccharum):
A Keystone Species



Sugar maple is a cornerstone of northeastern and midwestern U.S. forests and eastern Canada. Its ecological, economic, and cultural significance cannot be overstated. The native range of sugar maple spans from the eastern edge of the prairies in Minnesota, Iowa, Missouri, and Kansas to the Maritimes in eastern Canada. A long-lived species, sugar maples typically reach 300 years of age and occasionally surpass 400 years. Commonly referred to as "hard maple," its wood is prized for furniture production, its sap for maple syrup, and its vibrant orange and yellow fall foliage for aesthetic enjoyment (Horsley et al., 2002).

Maintaining sugar maple's health in both managed and unmanaged forests is critical. Factors influencing its growth and vitality include:

- *Abiotic agents*: soil moisture imbalances, nutrient deficiencies (magnesium, calcium, potassium), de-icing salts, late spring frosts, midwinter thaw-freeze cycles, glaze damage, and atmospheric deposition.

- Biotic agents: defoliating insects, sugar maple borer, Armillaria root disease, and injuries from forest management practices.

A significant and recent concern is sugar maple regeneration. Traditional silviculture has often led to near monocultures of low-value, slow-growing American beech in northern hardwood stands. American beech thrives in closed-canopy conditions with high deer populations, due to its shade tolerance, unpalatability to deer, and prolific root sucker regeneration, particularly in trees affected by beech bark disease (Sage et al., 2003). Consequently, American beech now dominates the understory in many stands, posing challenges to sugar maple regeneration.

Future guidebooks will explore solutions, focusing on adapting silviculture practices to protect and revitalize sugar maple populations.

Silver Maple (Acer saccharinum):
A Versatile Candidate

Silver maple, a medium-sized tree with a natural tendency for short boles and multiple stems, is often used for ornamental purposes and floodplain restoration. With appropriate management, it could serve as a source of soft maple lumber or fast-growing hardwood pulp. Silver maple's range extends from New Brunswick and central Maine to southeastern Ontario and southern Quebec, reaching southwestern Ontario, Minnesota, South Dakota, and into southern states like Arkansas and Alabama.

Thriving on streambanks, floodplains, and lake edges, silver maple grows best in well-drained, moist soils. It exhibits rapid growth in pure and mixed stands, with a lifespan of over 130 years. Despite its potential, silver maple plantations are under-documented, though its rapid growth and competitive edge on floodplains suggest suitability for managed forestry applications.

Red Maple (Acer rubrum): A Generalist and Climate Winner

Red maple, one of North America's most abundant and adaptable species, spans southern Newfoundland, Nova Scotia, Quebec, Ontario, Manitoba, and much of the eastern and central United States. It thrives across diverse moisture conditions and grows in both small and large gaps, making it a "light generalist."

As a climate change "winner," red maple is projected to expand its presence in the coming decades (Ostrowsky and Ashton, 2022). It regenerates effectively through both seeds and stump sprouts, providing a model for understanding the dynamics of hardwood regeneration. Though not at conservation risk, red maple offers opportunities for experimental plantations, particularly in evaluating browsing impacts before introducing less adaptable species.

Hardwood Plantation Studies: A Historical Perspective

The history of hardwood plantations in Ontario dates to the 1880s, with interest fluctuating over the decades. Renewed focus since the 1960s stems from environmental appreciation, the decline of elm due to Dutch elm disease, and concerns over sugar maple and other species facing ecological pressures.

Key insights from sugar maple plantation studies:

- Vegetation Competition: Competition from weeds and grasses significantly hampers sugar maple growth, particularly in old-field settings. Intensive weed control for at least three years is crucial for plantation success (Von Althen, 1977).
- Planting Techniques: Container-grown seedlings, with peat pots removed, performed better than bare-root or wildling transplants in reducing transplant shock (Von Althen, 1977).
- Root Regeneration: Early spring planting or using cold-stored, fall-lifted nursery stock enhances root regeneration and survival rates (Webb and Von Althen, 1978).

Silver maple plantations are rarely documented but silver maple grew rapidly when planted on uncultivated upland sites in southeastern Iowa. It’s natural pruning was good, but seedlings tending to sprout multistems, which required thinning to one good stem. Some boles were often crooked and leaning. The maximum annual height growth was 3.4 feet, while mean annual height growth was 3.0 feet. Survival was generally good and growth was best on calcareous sands in valleys and on lower slopes. Heavy sprouting and poor form were the major faults of the species.

Red maple naturally germinates and becomes established on a variety of stand and soil types, yet direct seeding red maple on old agricultural fields or strip mines has met with some failure, with low germination rates, poor growth rate, and poor form. Managing red maple has long been difficult for forest managers because of the high proportion of these low-quality trees (Walters and Yawney, 1990).

This synthesis underscores the importance of comprehensive, site-specific strategies to address challenges and harness opportunities for regenerating sugar maple and other hardwood species in changing environmental conditions.

Chapter 2: Site planning

Unlike softwoods, hardwoods have specific growth requirements, making site suitability a critical factor. Key site conditions include soil depth, texture, structure, acidity, slope, and drainage, along with climatic factors like precipitation, temperature, and wind (Gauthier et al., 2014). Other considerations include topography, accessibility, and the presence of wildlife such as deer and moose (Agence forestière de la Montérégie, 2007a). Establishing hardwood plantations is highly demanding, as most species require deep, fertile, moist, and well-drained soils (Von Althen, 1972).

Hardwoods will not produce high-quality timber on dry, exposed slopes, shallow topsoil, or compacted clay subsoils (Von Althen, 1964). Proper silviculture practices are crucial, particularly for species like sugar maple, where plantation establishment and survivability are challenging. While previously hardwood-covered sites are ideal for plantations, replicating high-quality stands on types such as old fields, or clearcuts with extreme bouts of raspberry or cherry regeneration pose significant challenges regardless of what was on the site in the past. This suggests there is no ideal condition where planting would replace sustainable hardwood management.

Current research is exploring high-quality hardwood potential across the province, identifying areas where soil and climatic conditions could support future hardwood growth. This work is essential for plantation planning, underplanting, and climate adaptation strategies, particularly as softwood habitats become less suitable under changing environmental conditions.

Factors influencing site suitability

Sugar maple will frequently serve as an example throughout this technical note and other hardwood artificial regeneration materials. Its prominence stems from its economic and social significance, making its sustained health a critical concern in both managed and unmanaged forests. Additionally, sugar maple is particularly challenging to cultivate artificially, which drives a strong demand for research in this area.

A natural, mature sugar maple stand has a dense canopy high above the seedlings, letting in very little light, most of which is diffuse. It’s important to keep in mind the typical adaptability traits seen in sugar maple may only appear under this layered canopy, rather than in younger, plantation-style stands (Paquette et al., 2007).

Sugar maple naturally grows along creeks and streams, on lower slopes and depressions, abandoned orchards and gardens, and on agricultural fields where A & B soil horizons are at least 45 cm deep. For optimum growth, a minimum depth to water table of 3.5 feet has been recommended, with a pH range of 5.7 – 7.3 (von Althen, 1964).

It is important to understand the factors contributing to sugar maple growth and health.

Soil moisture deficiency or excess, nutrient deficiencies of magnesium, calcium, and potassium, highway de-icing salts, and extreme weather events including late spring frosts, midwinter thaw-freeze cycles, glaze damage, and atmospheric deposition are some of the abiotic agents. For a comprehensive explanation, consult NHRI Technical Note : Soil Factors That Influence High Quality Sugar Maple Potential

Sugar maple has different energy allocation strategies than other hardwood species (especially different from softwoods) and it has consistently shown slower root growth, poorer root establishment, and higher mortality rates in plantations (von Althen and Webb, 1978, Webb, 1977). Some of this is explained in our ARM guidebook volume 1: Seed collection and nursery practices, and more will be discussed in the planting section below.

Figure 1 - mature sugar maple stand

Table 1 - A list of commonly planted species in order of typical climate range from cold-adapted to warm-adapted.

Species	Soil drainage class	Soil type	Depth required	Growth	Typical climate range
White Birch	Good to moderate	Sandy to loamy	30 cm	Fast	Cool to temperate
Sugar Maple	Good to moderate	Sandy to loamy	40 cm	Slow	Cool to temperate
Black Ash	Moderate to poor	Loamy to clayey	30 cm	Medium	Cool to temperate
Northern Red Oak	Fast to moderate	Sandy to loamy	30 cm	Moderately fast (avoid calcareous soils)	Temperate
Swamp White Oak	Moderate to poor	Loamy to clayey	50 cm	Moderately fast	Temperate
Silver Maple	Moderate to poor	Loamy to clayey	30 cm	Fast	Temperate
Shagbark Hickory	Good to moderate	Loamy	50 cm	Slow	Temperate
Black Cherry	Good to moderate	Sandy to loamy	30 cm	Fast	Temperate to warm temperate
Bur Oak	Good to imperfect	Loamy	50 cm	Moderately fast in early stages	Temperate to warm temperate
White Oak	Good to moderate	Loamy	50 cm	Slow	Temperate to warm temperate
Bitternut Hickory	Good to imperfect	Loamy to clayey	50 cm	Moderately slow	Temperate to warm temperate
Black Walnut	Good to moderate	Loamy	80 cm	Fast	Temperate to warm temperate

Site assessment and soil preparation

PLANTING ASSESSMENT	FACTOR	INSTRUCTIONS
	Soil Texture and Structure	Select sandy loams or loams for optimal water retention. Sandy or gravel soils increase drought risk, while clay-heavy soils may compact, impeding drainage and seedling establishment. Refer to soil maps, surveys, and consult a soil specialist or agronomist for site-specific guidance.
	Site Moisture	Ensure sufficient soil depth to reduce drought risk, especially for young seedlings with shallow roots. Avoid poorly drained areas and sites with excess water, which can restrict oxygen flow, hinder nutrient uptake, and increase disease risk.
	Slope	Avoid steep slopes, which lead to soil erosion and can deplete the fertile soil needed for hardwood growth. South- and west-facing slopes: less favorable for species adapted to shade and moisture East- and north-facing slopes: favor more shade-tolerant and moisture-demanding species (Barkley, 2007).
	Vegetation Survey	Conduct a vegetation survey before planting. Some species, like goldenrod and aster, interfere allelopathically with sugar maple, reducing dry weight, altering nutrient contents, and decreasing nitrogen and phosphorus availability (Von Althen, 1972).
	Soil Chemistry	Adjust soil nutrients on a small scale with fertilizers and lime as needed. Fertilization isn’t recommended during the first growing season unless soil tests show nutrient deficiencies. Sugar maple growth may not always respond to fertilization (Von Althen, 1972).

Site conditions for sugar maple

Table 2 -Optimal Site Conditions for Establishing a Sugar Maple Plantation (adapted from Gautier et al. 2014)

Texture Category	Soil Textures	Excessive Drainage (0)	Rapid Drainage (1)	Good Drainage (2)	Moderate Drainage (3)	Imperfect Drainage (4)	Poor Drainage (5)
Fine Textures	Sandy clay	n.d.	Poor	Moderate	Poor	Poor	Poor
Medium Textures	Silty clay loam	Poor	Moderate	Moderate	Moderate	Moderate	Poor
	Clay loam	Poor	Moderate	Good	Moderate	Moderate	Poor
	Sandy clay loam	Poor	Moderate	Good	Moderate	Moderate	Poor
	Silt	Poor	Moderate	Excellent	Good	Moderate	Poor
	Silty loam	Poor	Moderate	Excellent	Good	Moderate	Poor
	Loam	Poor	Moderate	Excellent	Good	Moderate	Poor
Coarse Textures	Sandy loam	Poor	Moderate	Excellent	Good	Moderate	Poor
	Silty sand	Poor	Moderate	Good	Moderate	Poor	Poor
	Sand	Poor	Poor	Poor	Poor	Poor	Poor

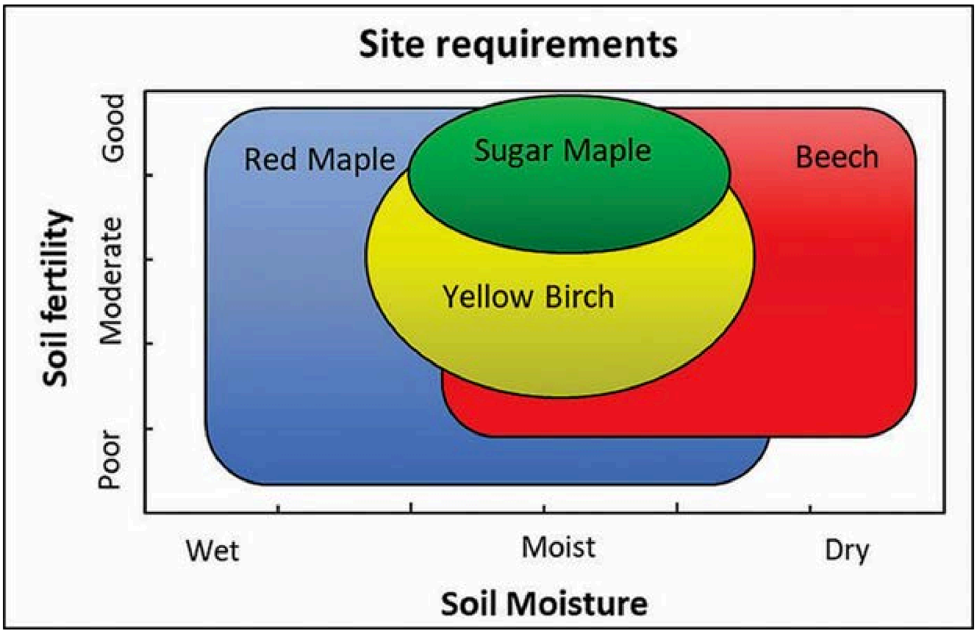


Figure 2 - A graphical representation of site requirements of other commercial hardwoods.

Chapter 3: Site preparation

The second most important factor in plantation establishment next to site selection is site preparation. This is the creation of favourable growing conditions for tree seedlings.

- Proper site preparation enhances seedling survival and growth by improving soil conditions and minimizing competition.
- Benefits include increased nutrient availability, better aeration, and improved water infiltration, among others.
- Risks of improper preparation: soil erosion, water quality degradation, and negative impacts on biodiversity and wildlife (Edge, 2004; von Althen, 1981).

Figure 3 - Pin cherry and raspberry competition already present at planting site will make it extremely challenging to establish a hardwood plantation, regardless of extreme measures.

Herbaceous plants negatively affect hardwood seedlings by:

- Competing for light, moisture, and nutrients.
- Smothering seedlings with accumulated dead plant material.
- Providing habitat for pests like rodents and rabbits.
- Some weeds having toxic or allelopathic effects (von Althen, 1964).

Figure 4 – An oak seedling surrounded by grass and herbaceous competition in an open field setting, with maintenance very high and survivability extremely low.

The choice of site preparation method depends on:

- Soil type and texture.
- Topography and vegetation density.
- Accessibility and operational capacity.
- Cost considerations.
- Direct seeding versus planting seedlings (direct seeding methods will be presented in another technical note).

Although some methods have high upfront costs, their long-term benefits in seedling establishment and growth may outweigh these initial expenses.

Types of site preparation methods

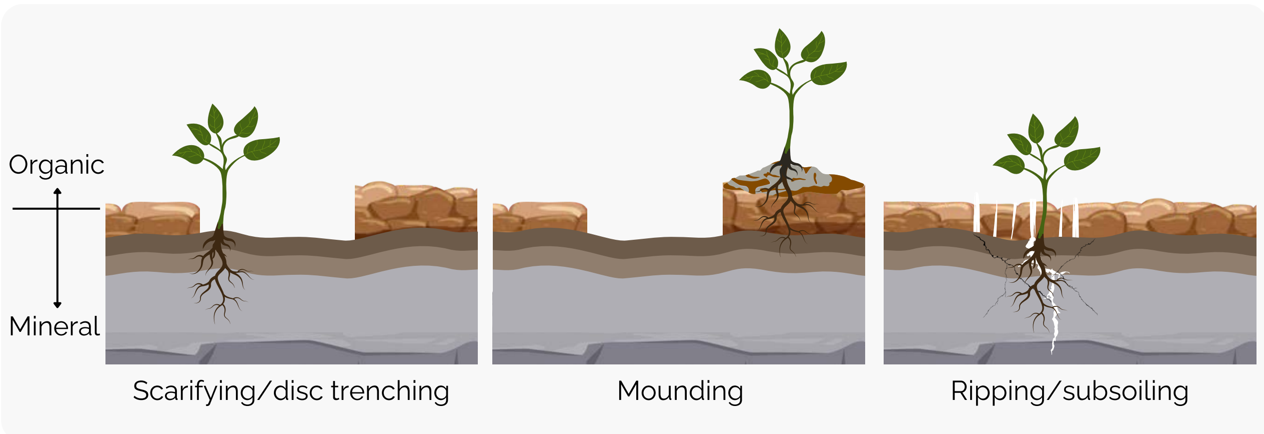


Figure 5 - Schematic description of three types of mechanical site preparation and their main effect on soil structure (modified from Lof et al 2012)

Our partners at AV Group, planting maple on License 1 site almost two years after mechanical scarification.

Table 3 - Common site preparation practices with usages and examples

PLOWING AND DISCING

Considered the best method for comprehensive site preparation. Destroys weeds, loosens soil, stimulates microbial activity, and improves soil aeration. Enhances nutrient cycling and provides optimal conditions for seedling establishment. High initial costs are offset by long-term benefits, including improved seedling growth (Van Althen, 1972).

Figure 6, top left - AV Group site scarification.

Figure 7, bottom left - Image of a disc trenchers *https://www.brackeforest.com/products/disc-trenchers*

MOWING OR CLIPPING

Commonly used for removing vegetation around hardwoods but less effective over time, as mown plants regrow quickly. Useful for gaining initial access and providing short-term weed control.

Figure 8, right- UNB graduate student James Broom tending a hardwood plantation at Kingsclear provincial nursery by clipping

SUBSOILING OR RIPPING

Loosens dense subsoils to improve root penetration and reduce compaction. Exposes less mineral soil compared to other methods, which helps avoid establishment of unwanted pioneer species. Trenches may take a full growing season to close, which can expose seedling roots and reduce survival if not properly closed (Raper, 2005).

Figure 9 - Subsoiling (ripping) operation (continuous MSP) on a former agricultural field in the Lower Mississippi Alluvial Valley, southern USA. The rig is spraying a band of herbicide over the ripped row. (Ray Soute, retrieved from Löf et al 2012).

BEDDING (MOUNDING)

Used for poorly drained or clay-rich soils by raising the root zone above the water table and poor soil conditions. Enhances seedling survival in wet areas.

Figure 10 - Mounding on a wet clay soil in eastern USA (Justin Schmal, retrieved from Löf et al 2012).

Chemical Weed Control

Herbicides offer a more economical control, but many hardwood species are highly susceptible to damage by the dosages necessary for effective control. The chemical weed control information in this guide is only meant to be informative. No specific brands or doses of herbicide are specifically condoned by NHRI or our collaborators. All chemical weed control must follow provincial and local legislation. We have included some guidance for New Brunswickers in this guide for your information, but official legislation and guidelines for inside and outside New Brunswick should be consulted before applying any herbicide. Each province has their own jurisdiction when it comes to the application of herbicides, and we use New Brunswick as an example. The Department of Environment and Local Government (DELG) enforces several pesticide regulations in New Brunswick, which includes glyphosate herbicides. These measures add increased safety for human health, the environment, and wildlife living near any provincial treatment sites. Refer to Appendix, Table A2 Case Study: A New Brunswick Example of Herbicide Regulations as of 2023.

Chapter 4: Plantation establishment

Options for establishing a plantation: starting your own nursery, purchasing seedlings, purchasing seeds, or contracting nurseries (Landis, 1995). If you choose to collect your own seeds and grow maple, refer to Artificial Regeneration of Maple: Volume 1 in our Resource Toolbox. For guidance on growing other species, please contact us directly.

Option	**Benefits**	**Drawbacks**
Purchasing Seedlings	Saves time and money; avoids nursery management responsibilities	Limited control over thegrowing process
	Reduces risks and hassles of growing seedlings	Seedlings may not be fully adapted to the planting environment
Purchasing Seeds	Cost-effective and allows for greater control over genetic selection	Requires additional time, expertise, and resources to grow seedlings
	Easier to store and transport	Higher risk of germination failure or poor seedling development
Contracting Nurseries	Ensures professional expertise and high-quality seedlings	Can be more expensive than managing your own nursery
	Offers flexibility and reduces the need for in-house nursery management	Limited control over the growing process and timing

Planting

Planting timing varies by species and season, with no universal solution. For spring-planted sugar maple seedlings, success depends on allowing enough time for root establishment before the rapid growth phase. Sugar maple has relatively slow root development compared to other species (Kramer and Kozlowski, 1960). This is due to its longer chilling requirements and lower root regeneration capacity (Webb, 1977). Sugar maple's roots need time to develop, but the species often flushes quickly after a few warm days in April or May. Root growth can restart as early as mid-February or March, depending on temperature and light. However, the reality is that operations delay spring planting until roads are clear, and snow has melted, leading to late spring planting that misses the optimal root establishment window. This delay affects foliage development, as new growth relies on stored carbohydrates, which may already be depleted by late planting (Dumbroff and Webb, 1978).

Poor root growth in sugar maple is also linked to the "check" condition—growth stagnation—frequently observed when seedlings face significant herbaceous competition (Webb, 1976). To optimize spring planting, consider applying growth inhibitors like abscisic acid to delay bud emergence, allowing roots more time to establish. Alternatively, invest in tools and preparation for early spring planting to take advantage of thawed soils.

Spring planting: the reality is that conditions needed for operations delay spring planting and miss the optimal root establishment window for sugar maple.

Fall planting presents its own challenges for all hardwood species, including low root regeneration potential at that time of year (Larson, 1970), as well as increased risks of frost heaving and heavy browsing. Both factors make fall planting less favorable for sugar maple, and other hardwoods.

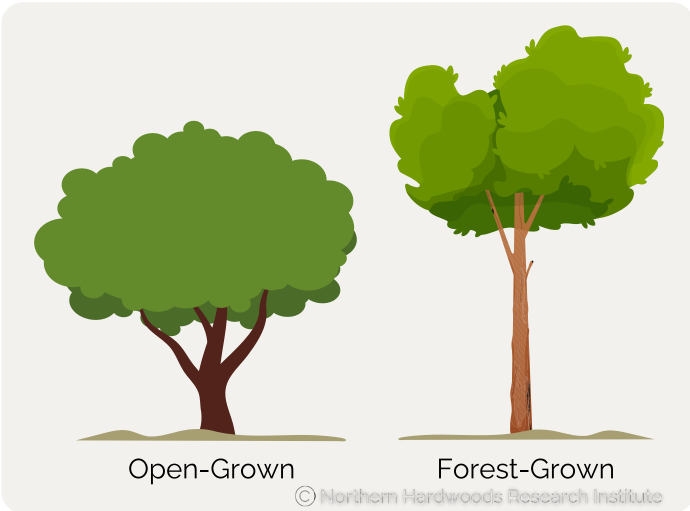
Key points to remember during planting:

- Bare-root seedlings should be planted so that all roots are buried, well-spread, and not coiled.
- Bare-root seedlings should be buried up to the root collar.
- For container-grown seedlings, the root system should be level with the soil.
- Seedlings must be planted as vertically as possible.
- The soil should be compact enough so that the seedling does not move when pulled.
- Ideally holes are filled with silicone and packed with extra soil to provide moisture retention and prevent frost pockets

Figure 6 – A planted Bur oak seedling that has been browsed and is now frost-covered.

Plantation Spacing and Stocking Considerations

Proper spacing in hardwood plantations is critical for promoting growth and ensuring high-quality timber production. But spacing can be achieved one of two ways: Initial spacing or proper thinning schedules. Both overly dense or too sparse planting can negatively impact height growth, with sugar maple being particularly sensitive to competition, leading to growth stagnation or "check." The optimal spacing depends on the desired end product, thinning frequency, and expected seedling survival.



Wider spacing encourages faster diameter growth but may result in undesirable tree forms, such as excessive taper or knotty wood. While wider spacing may suit pulpwood production, narrower spacing is preferred for high-quality timber.

The tradeoff of a larger diameter and crown versus increased branching, and its relationship with sawlog yield is now well-known (Prediction Tool for Product Basket by Using Tree Form and Risks - Northern Hardwoods Research Institute, Stand Competition-Tree Characteristics & Wood Quality-SM - Northern Hardwoods Research Institute).

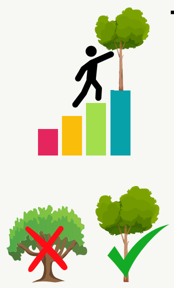
But the implementation of thinning schedules versus the negative impacts of growing maples more openly should be very well thought out. Maple syrup producers and researchers in New Brunswick have found that a wider initial spacing is a better investment. There are those who preferred an initial target spacing of 4 meters by 4 meters resulting in a stocking density of 625 stems/ha without any plans for thinning until the commercial stage.

Stocking can be calculated using the formula:

$$\text{Stocking (stems/ha)} = \left(\frac{100}{\text{Spacing between rows (m)}}\right) \text{ x } \left(\frac{100}{\text{Spacing between rows (m)}}\right)$$

Density and Thinning Guide

Optimal Planting Density: A high planting density (>1600 trees/ha) is recommended for hardwoods to minimize large branch growth, with an absolute minimum of 1200 trees/ha to ensure optimal straight-bole development.



Thinning Strategy:

- Start with a goal of developing a reasonable number of high-quality sawlog/veneer trees per hectare.
- Use a structured thinning approach to remove less-desirable trees and maintain the best-forming crop trees.

Spacing and Density Examples:

Table 4 - Example of a recommended spacing and thinning trial from McKenna and Farlee 2013.

		Example approximate number of trees remaining per hectare			
Example spacing (ft)	Initial number planted per ha	1st thinning (8 – 12 years)	2nd thinning (15 – 25 years)	1st harvest and thinning (35 – 45 years)	2nd harvest (50-75 years
8 x 6	2250	1240	400	148	50
10 x 6	1800	1100	400	148	50
12 x 6	1500	980	400	148	50
Percent reduction		-35	-60	-60	-30
Number of trees harvested				120- 150	75 - 100

Plantation Layout Patterns

The layout of a plantation plays a significant role in its management, productivity, and aesthetic appeal. Three primary patterns are commonly used: square, row, and quincunx. Each has specific advantages and applications depending on the species being planted, the site conditions, and the intended purpose of the plantation. For aesthetic considerations, orienting rows parallel to roads can create a more natural look. Alternatively, planting a border parallel to the road while keeping the main plantation perpendicular can combine practicality and visual appeal. Windbreaks using trees with larger branches can also enhance plantation durability.

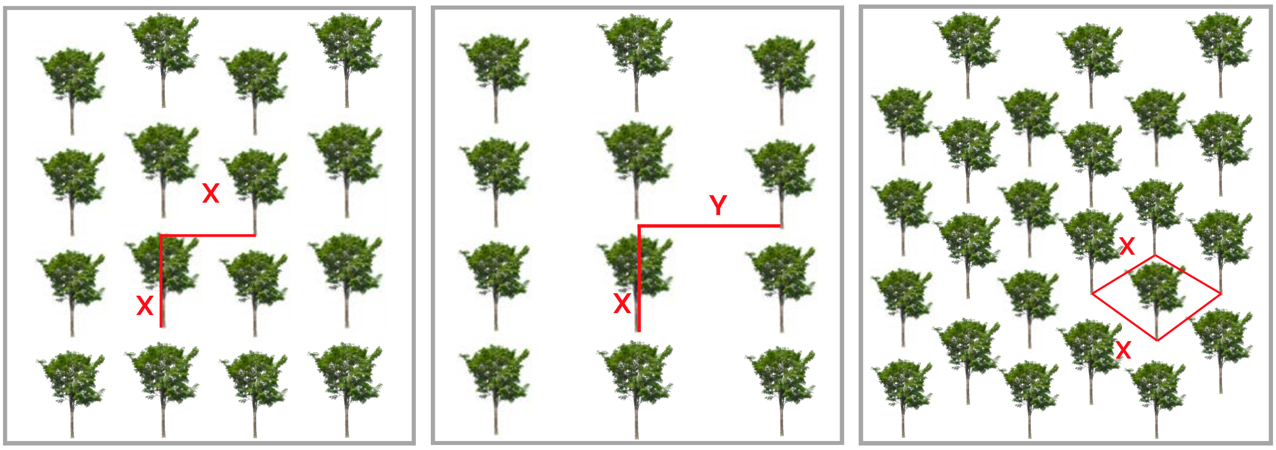
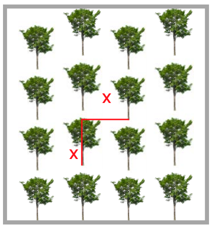
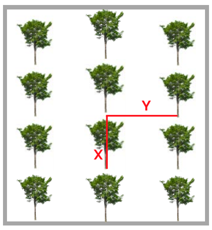
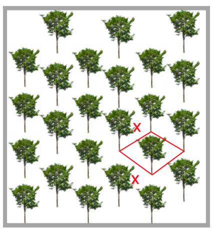
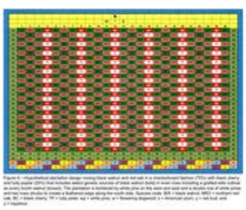
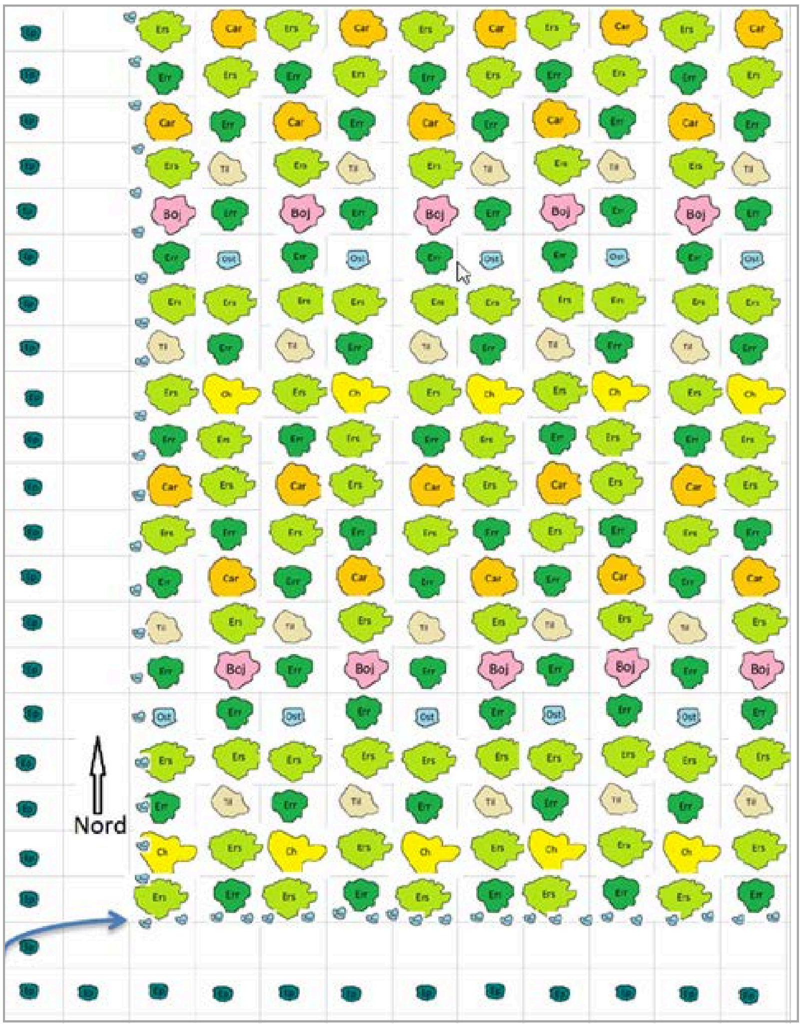


Figure 7: Plantation layout: Square, Row, Quincunx (modified from Gauthier et al 2014)

Pattern	Usage and photo	Advantages
Square Pattern	Commonly used for softwoods 	Facilitates machine access for future operations
		Allows for the installation of plastic mulch
Row Planting	Suitable for most tree species 	Provides space for machinery access for maintenance (e.g., mowing, herbicide application)
		Enhances operational efficiency
Quincunx Pattern	Ideal for hardwoods 	Promotes better canopy cover
		Optimizes wood production per hectare
		Provides wind protection, particularly in exposed areas
Aesthetic Layout	Plantation borders or specific row orientation 	Rows parallel to roads enhance visual appeal
		Borders with trees producing larger branches serve as windbreaks and improve aesthetics

Layout Recommendation

The layout recommendation provided by NHRI is based on a maple syrup production out of Quebec. Although maple sugaries are classified as agriculture and not forestry, there is much to be learned from plantations of sugar maple as well as other farming operations such as Christmas tree plantations.



Example 1: Quebec high diversity maple plantation
Spacing: 4m x 4m (13 ft x 13 ft)
Crown projection on the ground: 16 m² or 169 ft²
Initial planting density: 625 stems/ha
Initial planting density (maples): 406 stems/ha

The diagram shows alternating species in a systematic grid layout, optimized for biodiversity and structural goals.

LEGEND
Light Green (Ers): Sugar maple
Dark Green (Err): Red maple
Orange (Car): Hickory
Pink (Boj): Yellow birch
Teal (Ep): Alders and Spruces at the edges form a windbreak.
Blue (Ost): Ironwood
Tan (Til): Basswood

Figure 8 - David Lapointe, ingénieur forestier presentation on Maple and its Environment: What Science Teaches Us Ministère de l'Agriculture, des Pêcheries et de l'Alimentation, Quebec 2019

It is important to consider diversification of species, as suggested in the layout above. It reduces risk of pests and disease, and provides wildlife habitat in the short and long term without impacting harvest schedules. If it is true for maple syrup farms, it is true for lumber production as well.

Conclusion

In conclusion, successfully establishing a hardwood plantation requires careful consideration of planting density, spacing, thinning, and maintenance strategies. The planting density of over 1600 trees/ha, coupled with structured thinning, ensures healthy tree growth and high-quality timber production. Proper plantation spacing is vital for avoiding competition and ensuring good tree form, with narrower spacing favored for high-quality hardwoods, but when you consider the effort, cost, and wasted trees this method takes, many would recommend a wider spacing that follows the 4m by 4m spacing of a sugar bush plantation. The layout of the plantation should also be thoughtfully planned to enhance both productivity and aesthetics.

Until more effective direct seeding methods are developed, planting nursery-grown seedlings remains the preferred approach for better controlled establishment. While softwood planting practices have been applied to hardwoods with limited success, the right strategies, including plowing, early spring planting, and appropriate spacing, can make hardwood plantation efforts worthwhile. Further attention to maintenance practices, such as regular rototilling and protection from pests, is essential during the first few years after planting.

The next two chapters will delve into the option of a direct seeding approach and provide in-depth guidance on tending and predation control methods to help optimize hardwood plantation success.

Chapter 5: Establishing hardwood plantations via direct seeding

Introduction

Hardwood establishment by direct seeding has been investigated as an alternate method to planting of nursery-grown stock. Very little has been done to test and record the direct seeding of maple plantations. The direct seeding technique for afforestation of former agricultural fields was pioneered by foresters in Iowa, Minnesota and Wisconsin in the late 1990's. In many sites where hardwoods were not growing previously, direct seeding involves mechanical and chemical site preparation and so we can learn much from ecological restoration of hardwoods and apply it to silviculture to grow high-quality timber. Establishing hardwood trees by sowing seed is a relatively new method that has several advantages over traditional planting of seedlings, and this note highlights those advantages, disadvantages and best practices that are more specific than seedling stock planting recommendations found in the rest of this series of notes: Plantation planning and tending and maintenance.

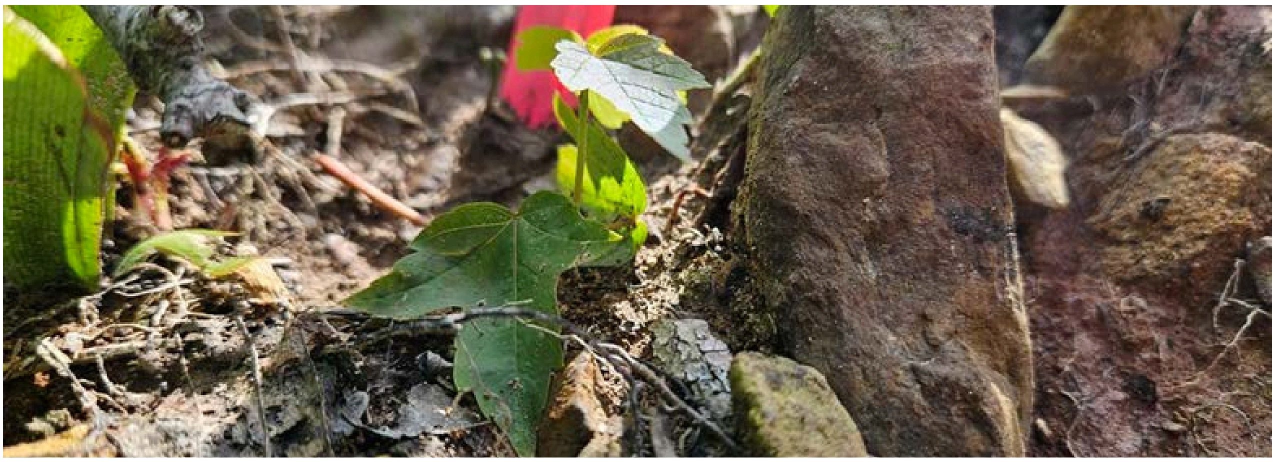


Figure 9 - successfully germinated and tagged direct seeded maple at NB License 1 plantation experiment in 2022.

Highlights

Seed size significantly influences success in direct seeding. Large-seeded hardwoods like oaks and walnuts generally perform well, while light-seeded species such as ash, birch, and maple are less reliable and remain experimental due to lower germination and survival rates.

Managing seed collection and storage can be challenging, especially for large-scale operations. For small plantings, seed predation by wildlife poses a significant risk. Fall sowing is often preferred to maintain seed viability and avoid storage issues, though spring sowing may reduce predation.

Broadcast seeding allows for high stand densities and is suitable for light-seeded species but requires intensive site preparation and thinning. Mechanical or spot seeding is more efficient in seed use and density control, though calibration issues and high costs can be obstacles, particularly for larger seeds.

Figure 10 - Broadcast seeding at a high density makes sense in a controlled nursery bed where there is high intensity site preparation, thinning, and monitoring opportunities. Many seedlings get their start in this way and are later transplanted. Applying this method to an operational scale landbase is much more risky and hard to measure success (Photo by Marcel Faucher).

Effective site preparation is essential. In agricultural fields, mowing, tilling, and selective use of chemical site preparation can suppress weeds and reduce erosion. In forest sites, combining mechanical scarification with chemical preparation enhances germination conditions.

Post-establishment care is critical, with 3-4 years of weed control necessary to ensure seedlings compete effectively for sunlight and moisture. This involves mowing, herbicide applications, and regular monitoring to manage invasive species.

Figure 11 - Glyphosate being applied during site preparation of a sugar maple plantation (Faucher, M.) The photo is from the 90's in Quebec, and much of the legislation has changed since then. Always consult with local DNR and recommendations when it comes to chemical site preparation.

Mechanical seeding for hardwoods remains a challenge due to high equipment costs and technical issues, despite newfound drone and robotics technology. Manual planting is often necessary, particularly for species like sugar maple, which do not fare well with seeders. Success depends on consistent maintenance and monitoring.

Advantages

- Better and quicker establishment: Direct seeding establishes thousands of seedlings per hectare rather than hundreds with traditional planting. Trees reach "crown closure" and begin shading out vegetative competition earlier. Follow-up weed control typically only needs to be done for two years after seeding, instead of eight to 12 years with planting.

- Higher quality timber: Greater density of seedlings forces trees to grow straighter due to side competition from nearby stems. Competition decreases pruning needs and produces higher quality hardwood saw logs.

- Better use of natural selection: Trees best suited to a particular site will dominate because of large numbers of seed and species.

- Better adaptation to variations in site conditions: Small variances in site conditions aren't planned for when planting seedlings. If direct seeding includes diversification of species, then species and specimens best suited will take over in each area.

- More natural appearance: Direct seeding is a much closer approximation of mother nature's hardwood establishment method than seedling planting in rows.

Better ability to withstand animal predation: Animals such as deer, while still causing damage by browsing, will be less likely to devastate a direct seeding operation than a traditional seedling plantation due to far higher stems per hectare.

Figure 12 - Red and white oak direct seeding plantation in Nebraska (Arens, C. 2019 retrieved from https://www.farmprogress.com/conservation-and-sustainability/5-advantages-to-direct-tree-seed-planting)

Disadvantages

Higher initial cost: Establishing seeds may be somewhat costlier than planting seedlings ($1200/ hectare vs. $850/ hectare on average). Keep in mind, however, that part of the higher cost can often be offset by collecting some seed yourself or doing your own site preparation. Follow-up care costs will be compressed into the first two to three years, but should be less than with seedling planting, due to earlier crown closure.

Inconsistent seed availability: If you commit to direct seeding, the densities required for a higher likelihood of success in your plantation can be very draining on seed supplies. In a species that masts rarely such as sugar maple this is of greatest concern. For information on seed and seed supply issues, please read our first volume in this series, Seed collection and nursery practices.

Figure 13 - 19-year-old direct seeded Nuttall oak stand. Note the difference in size among blue and orange flagged trees despite their age similarity. Blue flags mark trees that would be removed in a thinning operation when they reach a commercial harvest size. (https://extension.msstate.edu/publications/thinning-hardwood-plantations)

Direct seeding methods

The size of the seed has been found to affect the success rate and should be considered in your decision to direct seed versus planting seedlings. In many cases, hardwood species with relatively small seeds such as ash and birch were generally found to be unsuitable for direct seeding (Scholz 1964, Bjorkbom 1969), and Von Althen (1964) claimed that only oaks and walnuts had any success. In a more recent study by Edge (2004), walnut had very high success, followed by many species of oak, but they concluded that much more research is needed on light-seeded hardwoods such as ash, maple, and birch. Direct seeding with light-seeded hardwoods should be considered experimental (Edge, 2004). In yet other research, lighter seed was more successful and easily implemented into new technologies such as robotics and drone technology, and lighter seed is less preferred by rodent predators.

Collecting, transporting, and storing large amounts of seed is not easy, so keep the size of your direct seeding plantation manageable. For large plantings, consider doing part with seed and the rest with seedlings or establish the plantation over several seasons. On the other hand, be cautious with very small plantings. Research with southern oak species found the greatest nut predation by mice, squirrels, and deer were within plantings of less than two acres in size, especially plantings within existing forest cover (Stoeckeler et al. 1950). Spring seeding may be an option to help avoid heavy seed predation in these small, forested plantings, but fall sowing is the best method to avoid potential storage problems and maintain high seed viability.

Site preparation for direct seeding

Herbaceous competition is especially hard on newly germinated seed, and it can slow seedling growth for years, or cause “check” in sugar maple. Heavy discing in forest stands or strips, or tillage of agriculture fields is an excellent way to eliminate a sod layer and create soil conditions that are good for seed germination, but keep in mind that operating machinery may be more difficult on freshly tilled soil. A variety of weeds may become established from the seed bank or get blown in from adjacent areas. Cover crops can help this problem, however, in some studies, the germination and survival rates appeared to be no better in the plantations with a cover crop (Edge, 2004). An option for agriculture fields is to seed directly into mowed grass stubble, then kill the grass with glyphosate prior to tree seed germination in the spring. This method leaves a layer of dead grass to limit soil erosion and suppress weed growth. Pre-emergent herbicide must be used with caution during the first growing season to avoid chemically killing or damaging germinating tree seed. It is also important to mention that herbicide use in Canada is under provincial jurisdiction and there is legislation to adhere to.

Please contact your local department of natural resources for regional laws and information. Many foresters have preferred to apply only good site preparation and monitor the planting during the first growing season.

In forest sites, it is recommended to conduct intensive site preparation such as with disk trenchers. Prior to mechanical scarification, there are options for chemical site preparation.

Seeding methods

Broadcast seeding

Broadcast seeding is a method by which seeds are scattered over site-prepared soil, where there is no predetermined spacing or arrangement. The advantages of broadcast seeding include the ability to achieve very high stand densities and more options for incorporating light-seeded species. This method may allow the grower to select for what appears to be the superior tree when thinning. Thinning is the process of removing excess seedlings in high-density stands once they have developed their first set of true leaves. This allows the other seedlings room to grow and access to nutrients. Thin the crop to the correct stand density by cutting or pinching out the stem to prevent disturbing the root system of the remaining seedlings. . Contact with the soil is especially important in broadcast seeding, so site preparation is just as important as with planting or mechanical seeding.

Figure 14 – Direct seeding operation on site prepared agricultural field in Minnesota. Their biggest finding was the adaptability of the different microsites to specific species 5 to 10 Soil details Mount Carrol Silt Loam, 2 to 6 % slopes on approximately 6 acres • Mount Carrol Silt Loam, 6 to 12 % slopes on approximately 1.9 acres Stand area: 8 acres. Species target: red oak. Retrieved from https://silvlib.cfans.umn.edu/direct-seeding-hardwoods-former-agricultural-site-observations-soil-compaction-mn-dnr

Mechanical seeding

Seed supply is often the most limiting factor for direct seeding, so mechanical seeding makes sense, when possible. Mechanical or spot seeding is a much more efficient use of seed than broadcast methods. Mechanical seeding allows better control over the final stand density and keeps planting costs lower over hand seeding. The location within the soil matrix that is most likely to provide optimal soil moisture and temperature is difficult to predict since they vary through the soil, so there are ongoing improvements and suggestions to mechanical seeding methods.The depth at which a seed is sown is important to optimize germination rates when it comes to direct seeding because of the risk of predation, desiccation, and wind but must not be sown too deep, otherwise the seed may struggle to emerge (Masarei et al 2019). There are issues with mechanical seeding as well. If a seeder was used for sowing, it may not have been correctly calibrated to the size of the seed, resulting in skipping and/or the seeds being planted too shallow or too deep. The cost of a larger seed hardwood seeder is usually well beyond the scope of a hardwood plantation, so spot seeding is recommended.

As an example, a study of direct seeding of hardwoods in Wisconsin included a density of hardwoods broad seeded at 7500 – 20000 seeds per hectare on former agricultural fields. Most sites were planted using a hardwood seeder or drill, but sugar maple was hand planted because it couldn’t be run through a seeder. AV group NB recently had similar issues where mechanical seeders did not work for hardwoods. They decided to hand plant/ direct seed maple species because a seeder on a disc trencher had an estimated cost over $100k.

Developments in drone technology seeding methods

Seed pods

One company working to improve the direct seeding world is Tree Track Intelligence. Over 200,000 seed pods were deployed across 120 hectares of forested land, demonstrating the potential for scalable, efficient reforestation methods. Behind this achievement is a year of rigorous testing, during which 500,000 seed pods and 200 + unique formulas were evaluated to combat environmental challenges.

Figure 15 - https://treetrack.ca/a-milestone-in-reforestation-tree-tracks-first-forest-germination-results/

Wooden seed carriers

Another example is a biodegradable seed carrier referred to as E-seed. This seed carrier, fashioned from wood veneer, could enable aerial seeding of difficult-to-access areas, and could be used for a variety of seeds or fertilizers and adapted to many different environments.

Engineered Magic: Wooden Seed Carriers Mimic the Behavior of Self-Burying Seeds - News - Carnegie Mellon University

Calculating seeding for sugar maple
The lighter seed (ash, maple) should be broadcast seeded and dragged in lightly. It is recommended to only seed the actual trenches made by the scarifier. Sugar maple requires a minimum of 144 litres/acre or 356 litres/ha. Therefore, when direct seeding after site preparation such as done with a disc trencher and only treating the trenches (about 30% of gross area), the number of seeds required to treat a full hectare is approximately 107 litres.

Post establishment weed control
Controlling grass and weed competition until seedlings reach "crown closure" (which often happens in about 3-4 years) is crucial to the success of any seeding project. If weeds are not controlled, tree seedlings will be outcompeted for moisture and sunlight. Typically, for direct seeding, a pre- or post-emergent herbicide has been used early in the first season and a post-emergent herbicide has been used later in the first year, but local recommendations and legislations must be adhered to, and permits and certifications are required for those applying any herbicide. If broadleaf weeds become a problem in year one, mow the area. The area will need to be scouted often to determine weed control needs. More information on tending and weed control options, especially important considerations before deciding to use chemical weed control are presented in Chapter 4, tending and maintenance of plantations.

Figure 16 - If this much herbaceous competition exists on your site, intensive site preparation and maintenance would be required for direct seeding of hardwoods to be successful.

Conclusion

In conclusion, direct seeding offers a promising alternative to traditional hardwood planting methods, with several advantages including quicker establishment, higher stand densities, and better adaptation to site conditions. However, challenges such as seed predation, inconsistent seed availability, and the need for intensive site preparation and post-establishment care must be carefully managed. While mechanical seeding methods are still evolving, broadcast and manual seeding can be effective, especially when paired with good site preparation and weed control practices. Although more research is needed, particularly for light-seeded species like maple, direct seeding has the potential to enhance hardwood plantation success under the right conditions, and it's methods are a great reference for the early phases of tree growth and starting a plantation. The technical note will provide more detailed guidance on tending and predation control methods, encouraging long-term planning for direct seeding and plantation projects.

Figure 17 – This broadcast seeded sugar maple nursery from the 1990's was expanded and site prepared for the transplanting of select trees for the plantation. This encourages natural selection, genetically favouring the best future trees, planted on the right soil, at the right site. The land surrounding it also has a fence to keep out predators (Faucher, M. 2019)

Chapter 6: Tending and Maintenance

Successful plantation management requires a comprehensive plan encompassing planting techniques, tending, thinning, and managing threats like predation by rodents and ungulates. Without proper planning and protection for at least five years, plantations are unlikely to deliver the desired benefits.

Key factors influencing early growth include selecting appropriate seedling stock types, because they will have a noticeably easier time competing with herbaceous plants and shrubs. Foundational elements such as site preparation, seedling arrangement, and specific planting requirements are detailed in the Plantation Planning Technical Note. Building on those foundational steps, this note focuses on tending practices like thinning, controlling herbaceous and woody competition, and addressing challenges like low survival rates and predation. Together, these technical resources provide a cohesive framework, culminating in the Artificial Regeneration of Maple Guidebook Volume 2. Here, we explore practical solutions and strategies for effective hardwood plantation management to ensure successful outcomes.

Plantation in a Harvested Area

Planting in a harvested area requires significant follow-up. Competition in these areas tends to be very aggressive in the first few years, severely hindering the establishment of seedlings. Ideally, planting should be done under partial canopy cover during a partial harvest. A delay of at least three years is necessary for the seedlings to develop a strong root system capable of competing effectively when the residual canopy is removed. If these measures are not feasible, harvesting should preferably occur between July and mid-September, when trees are allocating energy to aerial growth. Logging residues should be arranged in windrows to facilitate the work of reforestation crews.

Figure 18 - This image demonstrates a site that has soil conditions suitable for hardwood regeneration, but canopy removal has led to extreme bouts of competition such as pin cherry and raspberry outcompeting the sugar maple, and causing the “check” condition that is known to occur in open-grown maple.

Control of Competition

Effective competition control is a crucial aspect of successful plantation management, as it helps optimize tree growth by reducing the pressure from competing vegetation. Various methods can be employed to manage competition, each with its own set of advantages and disadvantages. Growers mostly rely on mechanical mowing and applications of herbicides for weed control in fields. However, herbicides can be phytotoxic to non-target plants, can cause environment-related issues, and their repeated application can even cause herbicide-resistant weeds. Table 1 summarizes common techniques for controlling competition around tree plantations.

Figure 19 - Planters planting maple in scarified rows between raspberry, pin cherry, and natural regeneration; all of which is major competition for the nursery grown seedlings. The thick layer of slash in this area could provide the perfect habitat for rodents and other predators that will make survival of these seedlings difficult.

Table 5 - Methods of herbaceous and woody plant competition control and their advantages and disadvantages.

Method	Description	Advantages	Disadvantages
	Applying organic or synthetic material around trees to suppress weeds and retain soil moisture.	Reduces competition, retains moisture, improves soil health.	Requires periodic replenishment, may attract rodents.
	Placing biodegradable coconut fiber mats around trees to suppress weeds and retain soil moisture.	Reduces competition, retains moisture, improves soil health.	Requires periodic replenishment, may attract rodents.
	Regularly cutting vegetation around trees. Two-Foot to Three-Foot Weed-Free Zones	Maintains tree visibility, reduces weed competition temporarily.	Labor-intensive, requires frequent repetition.
	Installing permeable fabric around trees to block weed growth.	Long-lasting weed suppression, reduces soil moisture loss.	Can be expensive, may inhibit root expansion if improperly installed.
	Glyphosate application during the first three years at six liters per hectare (McKenna & Farlee, 2013; Dumont, 2003).	Highly effective at reducing weed competition, economical for large areas.	Risk of off-target damage, environmental concerns, and public perception issues.
	Using companion species to provide shade and reduce competition (McKenna & Farlee, 2013).	Improves microclimate, reduces weed competition naturally, increases biodiversity.	Requires careful species selection and management, can increase complexity.

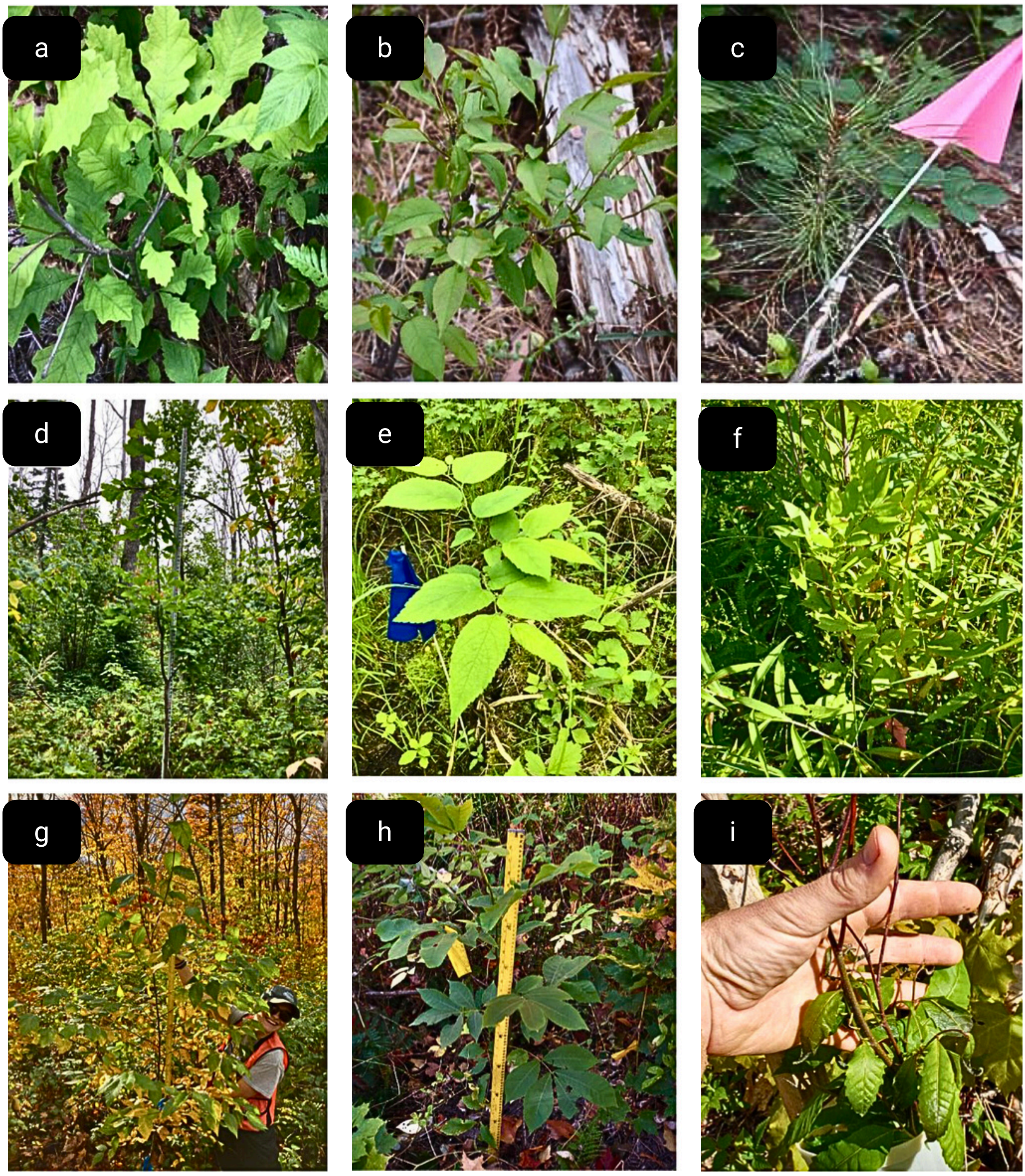
Underplanting / Cover Crops

Underplanting is a promising approach for long-term forest management, especially when direct seeding or planting of climax hardwoods is challenging. This method involves planting under pioneer species (either softwoods or hardwoods), which can create favorable conditions for establishment. Underplanted species benefit from reduced grass competition, and shelterwood environments can protect seedlings from large herbivores like deer. Underplanted species in shelterwood settings also experience better stem height and reduced lateral branch development.

Combination Example:

- Pioneer Species (e.g., black locust in the south, white birch in the north)
- Climax Hardwood Species (e.g., red oak, sugar maple)
- Pioneer species can be used as nurse crops, supporting the survival and growth of tolerant hardwoods. Shelterwood cuts before planting can improve light availability and reduce competition from overtopping trees.

This system works well in various topographies and can be effective in early-successional stands on fertile soils, but it is still prone to various forms of failure when compared to naturally regenerated stands.



Examples of assisted range expansion (RE) and species migration (SM) in the field, which is really a type of underplanting. Images (a)–(c) are planted in a red pine forest in northern Minnesota, USA, as part of the Chippewa National Forest-Adaptive Silviculture for Climate Change experiment (CNF-ASCC); images (d)–(f) are planted in a black ash dominated wetland in northern Minnesota, USA, as part of the Chippewa National Forest-Emerald Ash Borer experiment (CNF-EAB); images (g)–(i) are planted in northern hardwood and spruce–hardwood mixedwood forests in New England, USA, as part of the Second College Grant-Adaptive Silviculture for Climate Change experiment (SCG-ASCC). Panels (a) white oak (RE), (b) black cherry (RE), (c) ponderosa pine seedling from a Black Hills, South Dakota seed source (SM), (d) 8-year-old swamp white oak (RE), (e) hackberry (RE), (f) Manchurian ash (SM), (g) black birch (RE), (h) bitternut hickory (RE), and (i) American chestnut (RE) exhibiting winter injury maladaptation to extreme cold temperatures.

Predation Management

Predation by large herbivores (deer, moose) and smaller animals (voles, mice, rabbits) can hinder hardwood forest regeneration. Seedlings struggle to survive predation. Moose tend to favor shrubs and young tree growth, while deer are more likely to feed on the leaves, buds, and acorns of various hardwoods. Rodents, especially squirrels and chipmunks, often feed on seeds (such as acorns or beech nuts) and tree bark, while species like mice may also target young saplings and twigs. The most effective method to deter white-tailed deer is the installation of a fence. However, it will not prevent hares or rabbits from interfering. Therefore, a combination of measures is needed to address a potentially disastrous situation. The size of the seedlings, both in height and diameter, is one of the primary characteristics to consider. Planting large seedlings, especially bare-root ones, offers several advantages. The root spread of a bare-root plant provides excellent establishment, allowing for vertical growth in the first few years, potentially placing it out of the reach of deer more quickly. A trunk with a diameter of over one centimeter is less attractive to hares or rabbits. Some hardwood species, like walnuts, have higher tannin content in their tissues, making them less appealing to grazers and rodents.

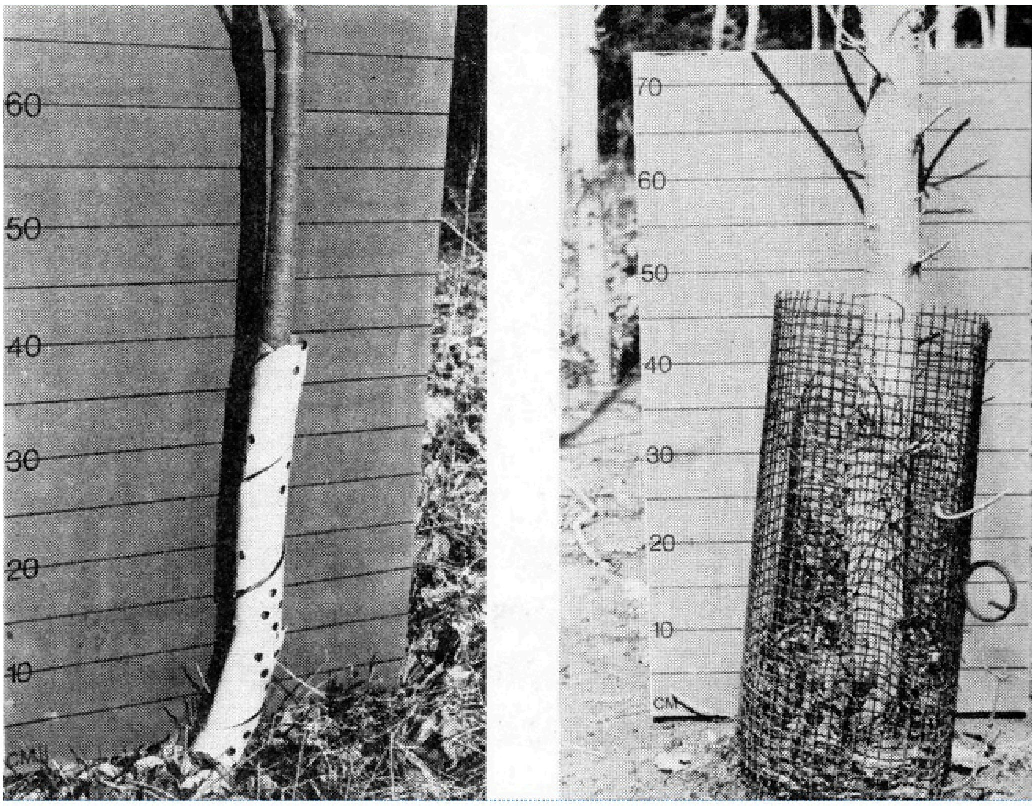
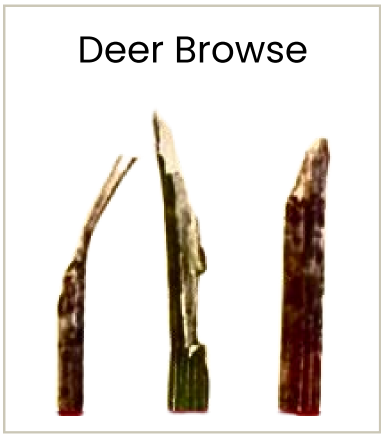


Figure 20 – Left; a wrap-around plastic tube provides good protection against small mammals and grows with the tree. The holes are for aeration to prevent creating a perfect environment for pathogens to grow. One downside to these is insects like the spongy moth, an increasing problem with high-quality hardwoods, tend to like to create nests in there. Right; another option with mesh but in this case, you can see the branching occurring which could have been encouraged through mechanical damage when installing the mesh, so it's crucial to plan for time and labour to install these correctly and remove them when the time is right. Neither of these would provide protection against deer or moose browsing (Photo from Faucher, M. 2019)

Table 6 - Common commercial hardwood species and their palatability to deer, moose, and rodents.

Species	Preferred by deer	Preferred by moose	Preferred by rodents
Sugar Maple (Acer saccharum)	Saplings, leaves	-	Seeds, saplings
Red Maple (Acer rubrum)	Leaves, seedlings	Leaves, saplings, bark	Seeds, bark
Oak spp. (Quercus spp)	Acorns, young shoots	-	Acorns
American Beech (Fagus grandifolia)	Leaves, saplings	-	Beech nuts, bark
Yellow Birch (Betula alleghaniensis)	Leaves, young stems	-	Seeds, bark
White Birch (Betula papyrifera)	-	Twigs, bark, leaves	Seeds, bark, twigs
Trembling Aspen (Populus tremuloides)	-	Bark, twigs, shoots	Bark, twigs
Willows (Salix spp.)	-	Twigs, leaves	Leaves, twigs
Black Cherry (Prunus serotina)	-	Fruit, leaves	Seeds, bark, fruit

Rodent control is essential for protecting seedlings, particularly against voles and mice, which are significant predators under herbaceous cover (Gill and Marks, 1991). Effective methods include weed elimination to deprive rodents of food and shelter, while repellents for mice and rabbits, though costly, provide some protection. Removing herbaceous vegetation helps improve seedling survival by reducing rodent habitat.



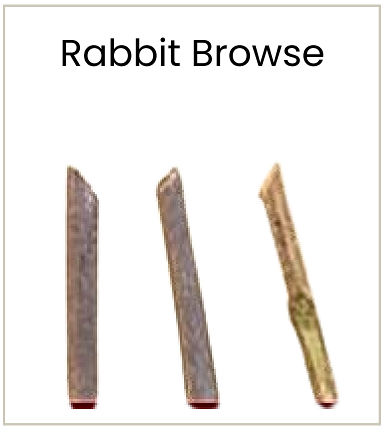


Figure 21 - Modified from http://octrackers.com/analyzingthedeertrack.htm

Moose browsing is more prevalent near forest edges with dense vegetation and natural regeneration, where they tend to prefer non-commercial species over plantation trees (Desgagnes et al., 2022). Managing naturally regenerating stands under 25 years old and reducing edge density can help minimize browsing intensity.

Deer browsing, which is not a new problem, has historically damaged over 80% of sugar maple seedlings in the Lake States (Stoeckler and Limstrom, 1950). Browsing is especially severe in areas lacking preferred species like Eastern white-cedar or Eastern hemlock. Effective protection includes using plastic film mulch for weed control, applying deer repellent, and constructing fencing around the plantation.

Figure 22 - Various examples of predator damage in grasslands. Top and right are Neil's flats along the Nashwaak river, Fredericton NB typically a silver maple floodplain, and the bottom left is at Kingsclear provincial nursery in an assisted migration and competition trial.

Figure 23 - Seedlings completely wrapped in plastic mesh on a floor of wood chips. These would have a much higher chance of success against deer and herbaceous competition than previous mesh photos. Photo © Carmen Hauser Retrieved from https://thumbs.dreamstime.com/b/rows-tree-seedlings-bark-mulch-covered-plastic-meshes-floor-wood-chips-182230617.jpg

Multiple varieties of repellent and deterrent are still being improved upon. One study tested the effectiveness of a commercially available deer repellent on red oak seedlings, applied before leaf drop in November 2021 and again before bud break in April 2022. Results showed that the deterrent reduced deer browse significantly (15.9%) compared to control seedlings (38.1%), though it was less effective than exclosures, which had no browse but were occasionally damaged by wind. Deterrent-treated seedlings also had lower severe browse (7.9%) compared to control (15.9%). Further research is needed to refine and improve such repellents for long-term use. We recommend reaching out to product developers for pros and cons of different commercial repellents.

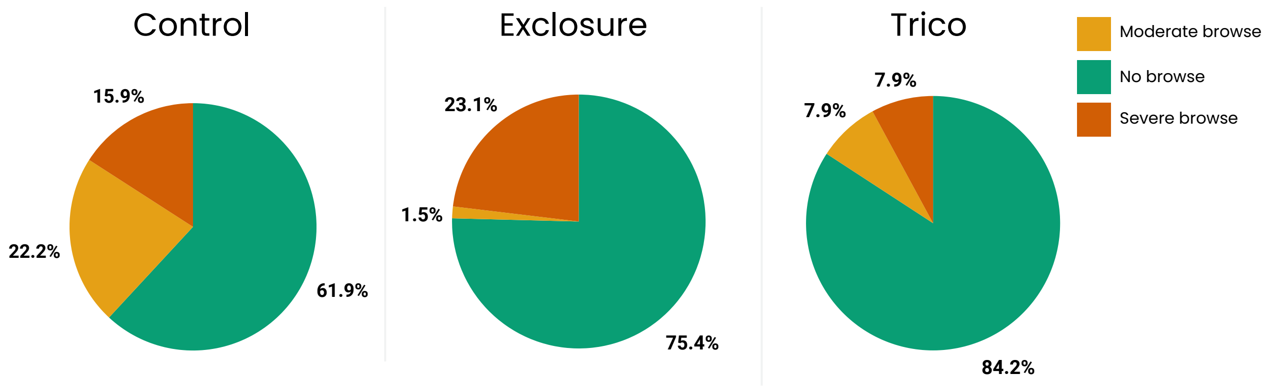


Figure 24 -Trico® Deer Browse Repellent Trial at the Holt Research Forest, Arrowsic, Maine. (Maine TREE Foundation, 2022). This is one of many commercially available ungulate deterrents on the market.

Table 7 - Management highlights for managing for rodents, deer, and moose. Much more detailed information on each type of management can be found in our guidebook.

Predator	Main Issues	Management Highlights
Rodents	• Significant predation on seedlings, especially under herbaceous cover. • Habitat created by weeds increases predation risk. • Predation on seeds and fruits as well as twigs and seedlings.	• Weed elimination to reduce rodent food/shelter. • Elimination of slash, coco mats, or other burrowing areas if rodents are a major problem • Use repellents (ex. capcaisin) and tree guards.
Deer	• Browsing damages >80% of seedlings in some regions. • Protection challenges as seedlings outgrow barriers.	• Use plastic mulch and repellents. • Deer fencing for small areas. • Plant alternative food sources (e.g., winter wheat, cedar shelterbelts).
Moose	• Prefer browsing non-commercial species but may damage plantation trees. • Browsing intensity high near forest edges.	• Manage young regenerating stands (<25 years old). • Reduce edge density to minimize browsing. • Use high visibility techniques (e.g., reflective materials, plastic flags). • Provide seasonal protection during key browsing periods (e.g., winter, early spring).

Figure 25 - A forestry company in the UK, CK Forestry, planting hardwoods in the late fall (a). They have wood stakes and 3ft tall tubes to go around every seedling to protect against predation (b), and help the trees grow tall and straight. This is done in several locations including roadsides, industrial scale plantations (c), and restoration projects. Photo (d) Shows some conifers that were eliminated via brush saw to favour the 2-3 year hardwood species (Figure 7 -Trico® Deer Browse Repellent Trial at the Holt Research Forest, Arrowsic, Maine. (Maine TREE Foundation, 2022). This is one of many commercially available ungulate deterrents on the market.). Some of these tubes had been designed in the past to encourage apical dominance via phototropism (growing straighter and faster toward the sun) but experience showed the downsides of overheating and moisture trapping caused many issues.

Tending hardwood plantations beyond free to grow stage

If you have been successful in protecting a hardwood plantation to its sapling stage, the next step is to ensure the tending schedule is followed to ensure high quality lumber production will meet expectations for return on investment.

Formative Pruning and Thinning
When a landowner decides to engage in hardwood planting, the goal is to produce high-quality wood for the sawing or veneer industry.

The main characteristics to be achieved are:

- The shape of the stem
- The size of the stem
- The absence of knots and defects on the stem

Therefore, to produce high-quality wood, it is essential to perform formative pruning (which addresses the shape of the stem) and thinning (which promotes the production of knot-free wood). This is especially true if initial planting density was low.

Pruning Priorities

1. Ensure the terminal leader is well-defined.
2. Remove dead, diseased, or broken branches.
3. Remove branches with steep insertion angles.
4. Remove branches with a diameter greater than half of the trunk's diameter.
5. Shorten strong or competing branches to limit their growth in diameter.
6. Retain low branches to preserve two-thirds of the live crown.

Ideally, any section of the trunk that reaches 10 cm in diameter should no longer have branches.

Plantation Filling

A 10% loss is typical for hardwoods, but some sites and processes will see much higher mortality.

Replanting in second or third year is recommended if survival is less than 85%.

NHRI is exploring the development of a tool that assesses the likelihood of a plantation's success based on chosen factors; we also continue to update our plantation cost simulator tool.

Figure 26 – Sugar maple plantation near Beaumont (Qc) owned by Pierre Fontaine and Elisabeth Bossert, professional foresters. From the image and based on the natural selection happening, it appears ready for thinning and initial formative pruning.

Case Study: Reforestation of Sugar Maples by Marcel Faucher

In 1983, Marcel Faucher took over his father's sugar bush in Quebec during a period of severe decline in maple stands. Working in R&D at the Ministry of Environment, Faucher focused on acid rain analysis and collaborated on research about the decline of maple stands. To combat the effects of acid rain, Faucher applied mineral fertilizers with lime and trace elements, leading to significant improvements in forest health by 1985.

In 1987, Faucher expanded his project by purchasing additional land for reforestation with sugar maples. The goal was to cultivate sugar maples with higher resistance to acid rain and increased sugar yield. Faucher collaborated with the US Forest Service to sample and evaluate sugar maples for sugar content, focusing on genetic traits rather than environmental factors for long-term improvements in sugar yield.

1993

2001

2007

2017

A nursery was established to optimize growth conditions for young maples, including seed collection, stratification, and planting, with detailed attention to soil preparation and maintenance. Faucher implemented strategies to control weeds, pests, and diseases, using herbicides, mulching, and manual weeding. Continuous monitoring ensured the health and growth of the plantation.

Over several years, Faucher collected data on tree growth and sap yield, showing improvements in sugar content and overall productivity. He emphasized the importance of site selection, thorough land preparation, and proper maintenance for successful hardwood plantations. Faucher planned to start a second generation of trees using the best-performing individuals from the first generation.

Marcel Faucher's comprehensive approach to reforesting sugar maples, combining genetic research, practical fieldwork, and continuous improvement strategies, led to significant advancements in the health and productivity of sugar maple plantations. His work serves as a valuable case study in sustainable forestry and genetic selection.

Applying these principles to lumber-producing stands, similar methods can be used to enhance the quality and yield of timber. By focusing on genetic selection, optimal growth conditions, and rigorous maintenance, high-quality sugar maple can be cultivated specifically for lumber production. This approach ensures that the trees are well-suited for timber, providing a sustainable and economically viable source of high-quality wood.

Conclusion

Many of our prior technical notes and guides can assist in decision making, such as whether to manage your stand as a two-age or multi-age stand before considering conversion to a plantation. Many notes also provide background information on related topics that can assist in growth and thinning decisions past the free to grow stage (Hardwood site potential indicator - Northern Hardwoods Research Institute, Effect of CT on Species Regeneration in Tolerant Hardwood Stands - Northern Hardwoods Research Institute, What Size of Tree Should We Grow for Timber Production - Northern Hardwoods Research Institute, Case Study: Stocking Guide for Density MGMT - Northern Hardwoods Research Institute)

Summary of Best Management Practices

Until more successful seeding methods are developed, planting of nursery-grown seedlings is recommended for better plantation establishment than direct seeding. Seedlings can be grown or purchased depending on your resources.

Softwood planting practices are often applied to hardwood planting, with limited success and some outright failures. These practices combined with the attempts to reforest abandoned agricultural land or to shift hardwood composition to an area where hardwoods did not frequent just before harvesting have led researchers to abandon hardwood plantation studies and records for many years.

However, planting select hardwood species on suitable forest sites are worth investigating once again if the steps in this guide are followed:

- Plow and repeated discing of the total plantation area in summer and autumn of year before any spring planting is recommended
- Planting before the end of April: Survival and growth can be vastly improved by planting very early in the spring compared to planting late in the spring. The increase is attributed to the greater root regeneration capabilities during that time.
- A general rule for spacing is to plant closer on higher quality sites and further apart on less fertile sites. Tight spacing helps to control competing vegetation and fully utilize the site.
- Sugar maple must be planted at relatively close spacings to correct the forking problems that result from the frequent loss of the terminal bud in this opposite-branched species.
- For high quality hardwood tree production seedlings should be spaced closer together to encourage straight boles and smaller lower branches that self prune
- Rototilling and hoeing is recommended at least four times per year for the first 3 years after planting
- Protection of the seedlings from browsing by deer and rabbits, and stem girdling by mice.

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Appendix

Case Study: A New Brunswick Example of Herbicide Regulations as of 2023

Category	Roles and Responsibilities
Landowners	• Use GIS technology to minimize off-target drift. • Establish buffer zones around private land and watercourses. • Post signs detailing treatment and timelines at access points.
Provincial Government (DELG)	• Certify and train applicators; issue permits for herbicide use. • Inspect operations and enforce compliance with safety regulations.
Federal Government (PMRA)	• Review scientific research and update forestry chemical regulations and label instructions.
Crown Land Licensees (DNR)	• Submit herbicide schedules based on visual assessments or plot data for naturally regenerated cuts.
General Public Notifications	• Publish treatment notices in major New Brunswick newspapers.

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