TECHNICAL NOTE

Artificial regeneration of hardwoods

Tending and Maintenance

Institut de resecherche sur les feuillus nordiques
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INTRODUCTION

Hardwood plantations serve diverse purposes, from high-quality timber production to floodplain restoration, afforestation, and supplementing regeneration efforts in harvested stands. It's important to remember that high-quality roundwood is best produced by managing stands with proper hardwood silviculture. Planting, through direct seeding or nursery practices, is no replacement for the proper management of already existing hardwood stands. This is because the resulting conditions make tending and maintenance very frustrating, costly, and time consuming. But if it is decided for one reason or another that you must plant hardwoods, it is important to have a checklist of priorities, and a good understanding of risk and reward. 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.

HIGHLIGHTS

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.

HIGHLIGHTS

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.

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 1 - 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 2 - 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 1 - 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.

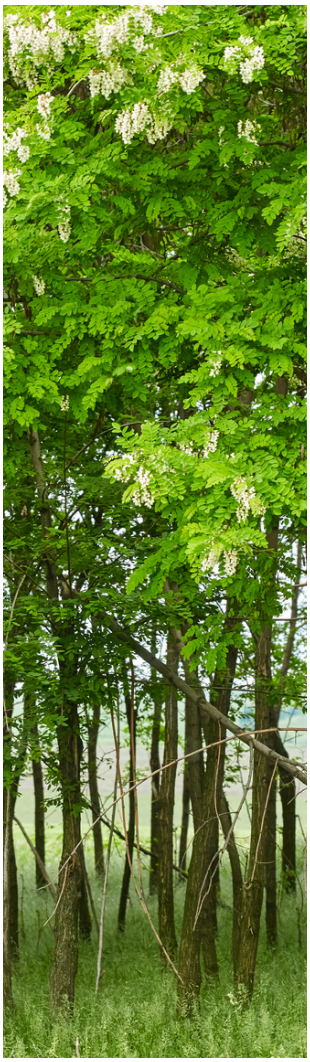
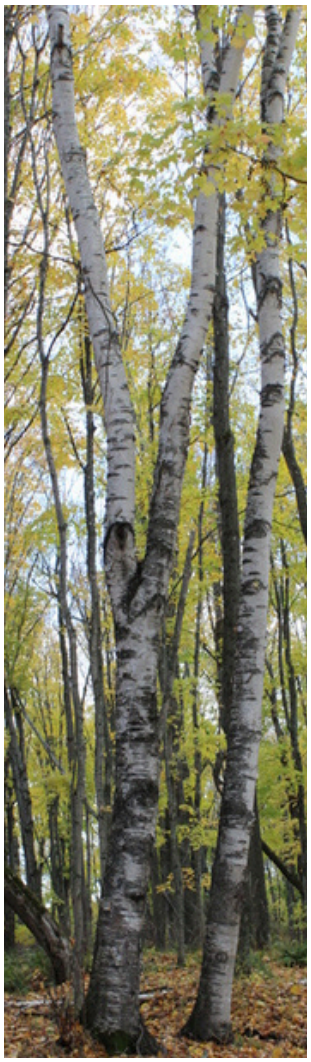
UNDERPLANTING / COVER CROPS

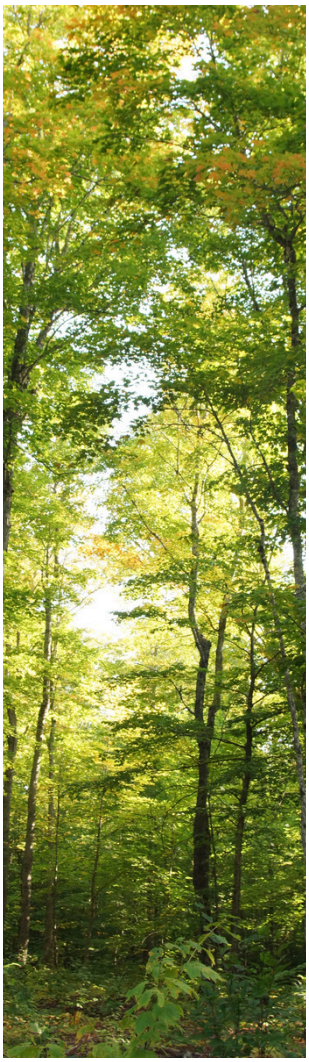
Effective competition control is a crucial aspect of successful plantation management, as it helps optimize tree growth by reducing the pressure from competing vegetation. Various methods can be employed to manage competition, each with its own set of advantages and disadvantages. Growers mostly rely 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.

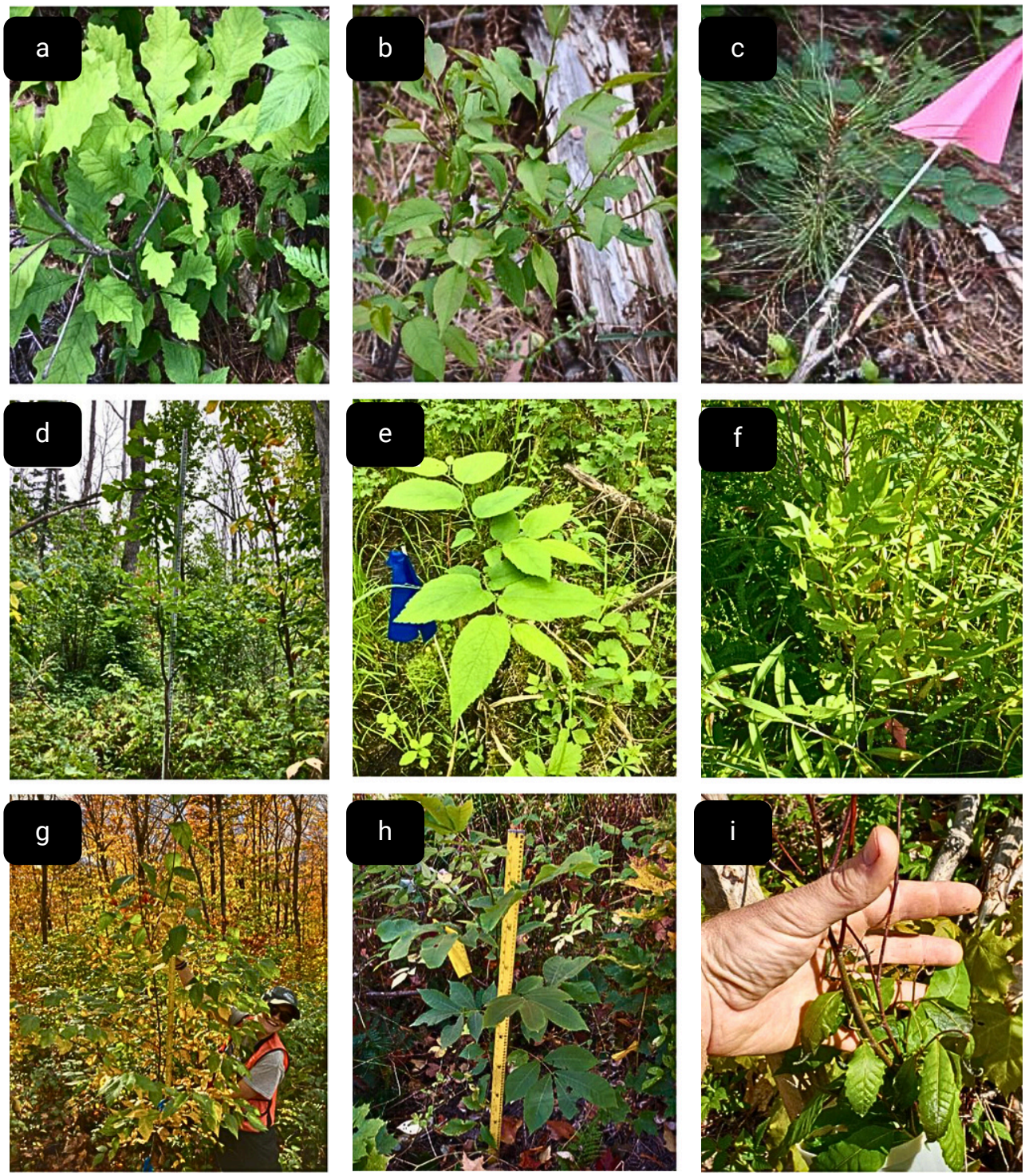
Combination Example:

- 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.

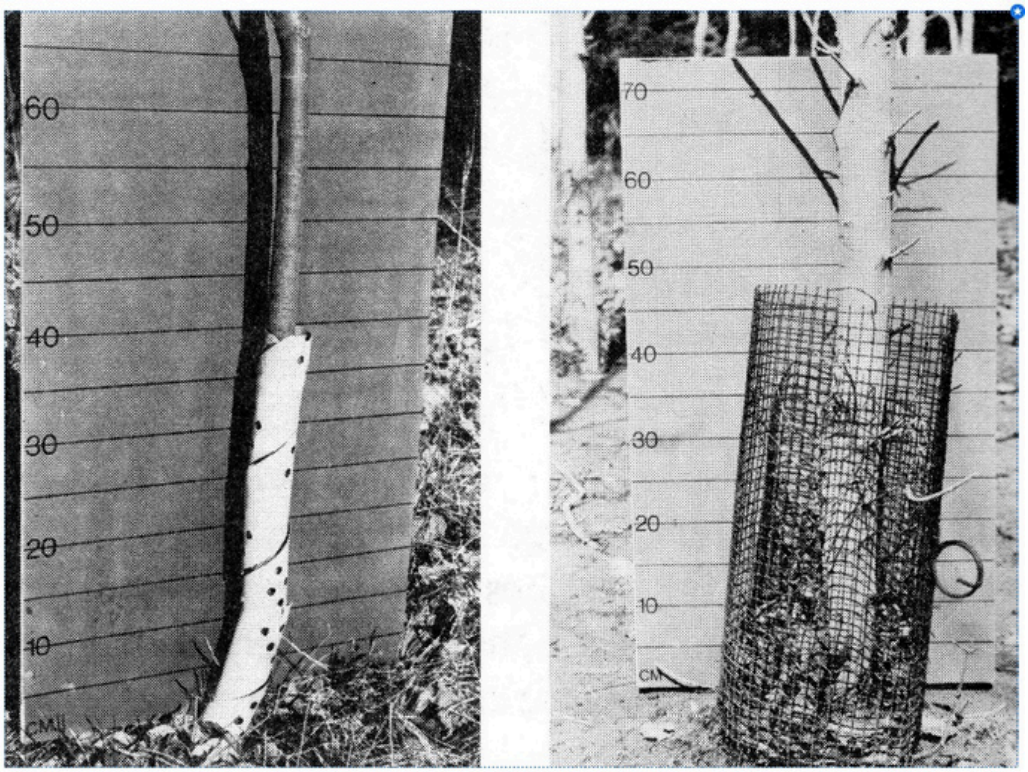


Figure 3 – Left; a wrap-around plastic tube provides good protection against small mammals and grows with the tree. The holes are for aeration to prevent creating a perfect environment for pathogens to grow. One downside to these is insects like the spongy moth, an increasing problem with high-quality 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 2 - 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.

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.

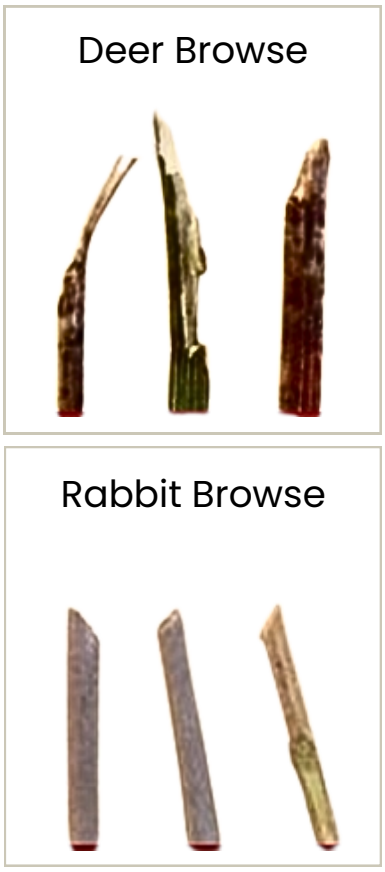


Figure 4 - Modified from http://octrackers.com/analyzingthedeertrack.htm

Figure 5 - 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 6 - 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.

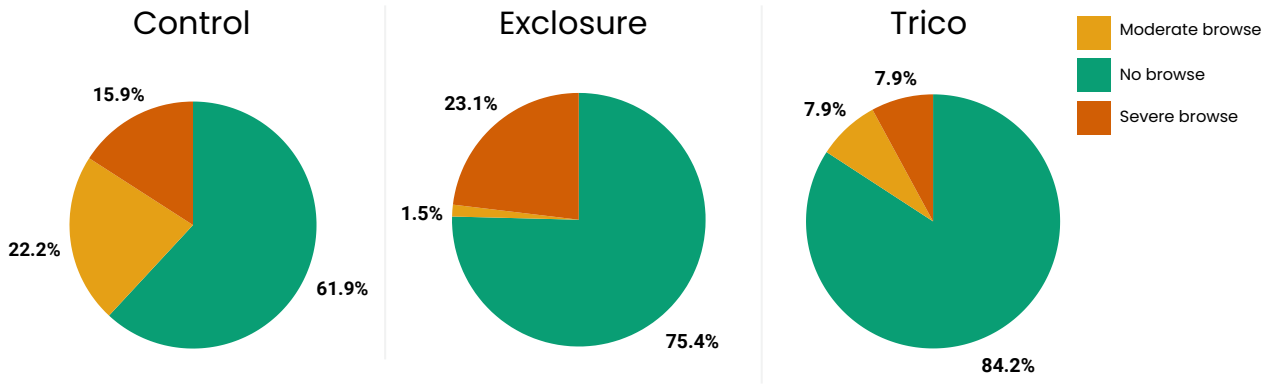


Figure 7 -Trico® Deer Browse Repellent Trial at the Holt Research Forest, Arrowsic, Maine. (Maine TREE Foundation, 2022). This is one of many commercially available ungulate deterrents on the market.

Table 3 - 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 8 - 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.
7. 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 9 – 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.

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.

1993

2001

2007

2017

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).

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APPENDIX

Table A1: Checklist of plantation tending and maintenance

Category	Questions to Consider	Check
Plantation Goals	• Are the primary goals of the plantation clearly defined (e.g., timber production, afforestation, regeneration)?	
	• Is the plantation designed to meet both short-term and long-term objectives?	
Site Preparation	• Has the site been adequately prepared (e.g., scarification, soil testing)?	
	• Are site conditions (e.g., soil type, moisture, fertility) suitable for the selected species?	
Species Selection	• Are the selected species suited to the site conditions and goals?	
	• Are drought- or pest-resistant species considered?	
	• Is a mixed-species plantation being considered to reduce risks (e.g., diseases, strong winds, ice storms)?	
	• Are species selected to complement each other and prevent competition based on site conditions?	
	• Is thinning schedule meant to favor less successful species?	
	• Will the mix of species provide shade to enhance pruning and timber quality?	
Seedling Stock	• Are the selected seedlings of high quality and suited for the site?	
	• Are stock types (e.g., bare-root vs. containerized) appropriate for the planting plan?	
	• Have seedlings been properly hardened off prior to planting?	
Competition in Open Fields	• Has competition from herbaceous plants, grasses, and some shrubs been addressed?	
	• Is weed control planned for the first 3–4 years to reduce competition?	
	• Are techniques like mulch, mowing, landscape fabric, or weed-free zones being considered for competition control?	
	• Are black plastic and mulch considered effective for weed control in field trials?	
Competition in Forest Lands	• Is competition from shrubs (e.g., pin cherry, raspberry, alder, mountain maple) and natural regeneration of commercial species addressed?	
	• Does the plantation plan take into account the shade tolerance of tree species when managing competition?	

APPENDIX

Table A1: Checklist of plantation tending and maintenance, cont'd

Category	Questions to Consider	Check
Chemical Control	• Are chemical controls (e.g., glyphosate) being considered to manage competition from shrubs or other vegetation?	
	• Has glyphosate been successfully used for hardwoods like yellow birch, red oak, and sugar maple on former farmland?	
Filling Practices	• Is replanting planned if survival rates fall below 85% in the second or third year after planting?	
Rodents	• Are rodents a threat to seeds and seedlings?	
	• Are rodent control measures (e.g., weed removal, repellents, guards) being implemented?	
Deer	• Are deer populations high enough to pose a risk to seedlings?	
	• Are protective measures, such as fencing, repellents, or mulch, planned for deer management?	
Moose	• Are moose likely to browse the plantation trees?	
	• Have management strategies, such as reducing edge density or providing seasonal protection, been considered?	
	• Are moose deterrents (e.g., repellents, fencing) planned for high-risk areas?	
Harvested Area Plantations	• Is planting under a partial canopy feasible?	
	• Has sufficient time been allowed for seedlings to establish before removing residual canopy?	
	• Will the harvested area be actively managed to prevent overgrazing or overbrowsing?	
Monitoring and Adaptation	• Is there a monitoring plan in place to track plantation progress and health?	
	• Will adjustments be made based on monitoring results (e.g., species composition, pest management)?	
	• Are adaptive management strategies incorporated to respond to changes in climate or pest outbreaks?	
	• Are there scheduled assessments for plantation growth, survival rates, and overall sustainability?	

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