Hardwood planting on abandoned farmland in Southern Ontario

F. W. von Althen

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HARDWOOD PLANTING ON ABANDONED FARMLAND IN SOUTHERN ONTARIO: REVISED GUIDE

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TABLE OF CONTENTS

	page
PREFACE	
INTRODUCTION	1
SELECTION OF PLANTING SITE	2
SITE PREPARATION AND WEED CONTROL	5
PLANTING STOCK	15
DIRECT SEEDING	17
PLANTING METHOD	19
SPACING	24
SPECIES MIXTURES	26
FERTILIZATION	31
PRUNING	32
RODENT CONTROL	35
GROWTH AND YIELD	38
SUGGESTED READING	41
APPENDICES	
I Summary of Planting and Tending Recommendations by Species	45
II District Offices of the Ontario Ministry of Natural Resources in Southern Ontario	68
III Estimated 1989 Costs per Hectare (2.5 ac) of Site Preparation, Planting, Weed Control and Plantation Tending During the First 3 Years after Planting	70
IV Fact Sheet for Glyphosate	71
V Calculation of Herbicide Dosage Required for the Spraying of Strips	73
VI Calculation for the Conversion of Active Ingredient of Herbicide to Quantities Found in Commercial Products	74
VII Fact Sheet for Simazine	75
VIII Recommendations for the Chemical Control of Grasses in Hardwood Plantations	77

Frontispiece: Twenty-year-old black walnut-white ash plantation, thinned twice.
Black walnut: height 14.5 m (48 ft), stem diameter 15.2 cm (6.0 in.)
White ash: height 13.7 m (45 ft), stem diameter 14.5 cm (5.7 in.)

PREFACE

"A Guide to Hardwood Planting on Abandoned Farmland in Southern Ontario" was first published in 1979. In the past 10 years, much new knowledge has been gained about species requirements and new techniques have been developed for successful plantation establishment. This revised guide presents the most up-to-date information on the general conditions necessary for successful establishment of 10 major and 15 minor plantation species.

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INTRODUCTION

Interest in hardwood planting increased markedly in southern Ontario in the 1960s. The main reasons for this surge of interest were greater appreciation of the environmental and aesthetic values of the landscape, a scarcity of high-quality hardwood trees for lumber and veneer and the loss of most elm (*Ulmus* spp.) trees to Dutch elm disease. In recent years, hardwood planting has become even more popular because of concern about the deleterious effects of pollution on forests and shade trees and because low prices for agricultural commodities have reduced farming profits on soils of marginal productivity and on those unsuited to mechanized farming.

Most hardwood plantations cover only a few hectares because successful establishment demands intensive labor, close attention to detail and sustained tending during the early years after establishment. These conditions make hardwood planting especially suitable for the small landowner and hobby farmer who has the time, interest, pride and money to make the planting a success.

Earlier plantings often failed because not enough was known about the growth requirements and cultural practices necessary to establish and maintain a plantation of healthy, fast-growing trees. Although our knowledge of the factors affecting hardwood plantation establishment is still incomplete, the information available now, if properly applied, is sufficient to guarantee a high rate of success.

Most hardwood species are very exacting in their site requirements and demand intensive tending to produce satisfactory growth. The successful establishment of hardwood plantations is therefore generally more difficult and more expensive than that of coniferous plantations. Before attempting to establish a hardwood plantation, a landowner should be well aware of the labor and cost requirements of plantation establishment and tending. Failure to complete all the necessary work will most likely result in plantation failure and the loss of time and money already spent.

SELECTION OF PLANTING SITE

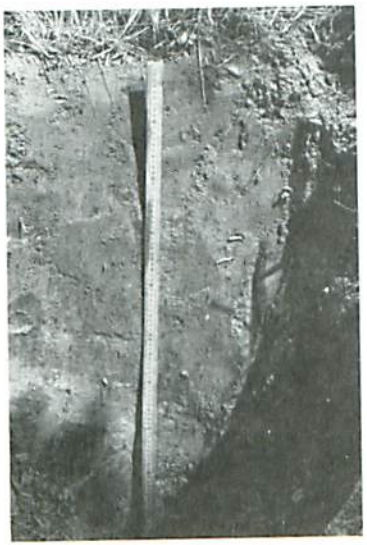
The most important factor in the establishment of a successful hardwood plantation is the selection of a suitable planting site. Most hardwood species are very demanding and selective in their site requirements and will grow well only on sites that satisfy their individual needs. If planted on sites where soil or drainage conditions are incompatible with the species requirements, seedlings will either grow poorly or die.

Soil texture, depth of topsoil, drainage and general fertility of the planting site must therefore be determined ***before*** a valid decision can be made on which species to plant. The Soil Survey Reports and maps published by the Research Branch of the Canada Department of Agriculture and the Guelph Agriculture Centre provide useful information on soil types in the area of the prospective planting site. However, this general information must be supplemented by detailed information about the conditions of the actual planting site. Soil texture, depth of topsoil and soil drainage must be determined by excavating a series of soil pits that cover the range of soil conditions on the prospective planting site. Assistance in evaluating site conditions may be obtained from the Ontario Ministry of Natural Resources (OMNR). Fertility may be assessed either by laboratory analysis of soil samples or by observation and assessment of the composition, density and vigor of the vegetation growing on the site. A dense cover of vigorously growing vegetation generally indicates good fertility, whereas sparse, slow-growing vegetation generally indicates poor fertility.

Each hardwood species has its own requirements, which determine if a site is optimum or unsuitable (Appendix I). Therefore, the closer the match between the requirements of the species and the actual conditions of the planting site, the greater the probability that the plantation will be a success.

Hardwood trees grow best in deep, fertile, moist, but well drained loams. However, these are also the best agricultural soils and are therefore seldom available in large tracts for

afforestation. What are generally available for planting are small areas on which farm machinery cannot be operated efficiently — areas that are either inaccessible for part of the year or unsuitable for farming. At the same time, most large afforestation areas that have been taken out of agricultural production because of infertility or poor drainage generally contain small areas that are capable of growing high-quality hardwood timber. These are the sites on which hardwoods should be planted. Although many afforestation sites may cover less than 1 ha (2.5 ac), a few black walnut (*Juglans nigra* L.) or red oak (*Quercus rubra* L.) trees of veneer quality or other hardwood species of sawlog quality grown in such a small area may yield a higher return than pulpwood grown in a much larger area. Hardwoods are also planted for their aesthetic and wildlife-habitat values. For advice on which species to plant on a particular site, phone the nearest District Office of OMNR (Appendix II).



A well drained, deep loam soil. This is an excellent soil for most hardwood species.

A shallow topsoil over infertile sand. This soil is too poor for adequate growth of most hardwood species.

In southern Ontario, good hardwood planting sites are usually found along creeks and streams, on lower slopes and in depressions where topsoil has accumulated, in abandoned orchards or gardens, and in agricultural fields where the topsoil is at least 40 cm (16 in.) thick. Hardwood seedlings will never produce high-quality timber or beautiful shade trees when planted on dry, exposed slopes and ridges, or in areas in which the topsoil is shallow and the subsoil consists of heavy, compacted clay.

SITE PREPARATION AND WEED CONTROL

The second most important factor in successful hardwood plantation establishment is the control of broadleaf weeds and grasses. Adequate site preparation and weed control for 3 or more years after planting is expensive but, without it, a plantation most likely will fail. The effectiveness of weed control during the first few years after planting depends largely on the intensity of site preparation; the most intensively prepared sites generally require the least weed control after planting.

Site preparation may be by plowing and disking, chemical eradication of the competing vegetation, or a combination of these techniques. The method used will depend on the condition of the soil, topography, accessibility, density and composition of the existing cover, and the cost of the various methods under consideration (Appendix III). Under no circumstances, however, should the success of a plantation be jeopardized by skimping on initial site preparation and weed control.

In areas to be planted in spring, the best method of site preparation consists of killing the established vegetation with glyphosate (trade names Roundup® and Vision®, Appendix IV)[1] applied in the previous autumn, followed by plowing and disking 1 or 2 weeks after spraying. This combination of treatments destroys all weeds, including deep-rooted perennials, and improves soil aeration and water movement. It also stimulates microbial activity and incorporates organic material in the soil, thereby improving organic-matter content.

Where spraying, plowing and disking of the entire plantation area are not feasible or desirable (e.g., because the soil is too stony or subject to erosion, or the planting site is partially treed), strips at least 1.5 m (5 ft) wide should be prepared for planting as outlined above (Appendix V). Where mechanical site preparation is not possible or desirable, the established vegetation may be eliminated by spraying glypho-

[1] The identification of commercial products is solely for the information and convenience of the reader, and does not constitute an endorsement by Forestry Canada.

An entire plantation area sprayed with glyphosate, plowed, disked, planted and sprayed with 6.0 kg/ha of active simazine.

A reopened planting silt in a clay loam soil without mechanical site preparation.

Mechanical site preparation in strips, with six furrows plowed from either side to the middle and disked.

Herbicide spraying with a motorized backpack sprayer.

sate in August before spring planting. This method is not recommended on clay loam or clay soils, however, because drying and shrinkage of such soils after the removal of vegetation can cause re-opening of the planting slit, with resultant tearing of roots and loss of support to planted trees. In general, chemical site preparation alone or site preparation in strips is less effective in tree growth than chemical plus mechanical site preparation and treatment of the entire area.

Herbicide spraying with a hand-operated backpack sprayer.

Herbicide spraying with a 9-L (2-gal) pressurized sprayer.

Individual trees may be planted on weed-free spots prepared by an application of glyphosate in autumn before spring planting. The prepared spot should be at least 1.5 m (5 ft) in diameter. The larger the spot the better, because large spots promote seedling growth and reduce the danger of stem girdling by mice. However, the growth of seedlings on chemically prepared spots is generally inferior to that of seedlings planted in areas that have been sprayed, plowed and disked in their entirety or on strips that have been sprayed, plowed, disked or rototilled.

One serious difficulty encountered in spraying individual planting spots is application of the correct dosages of herbicides. To be able to apply the correct dosage per spot, one must know the concentration of the mixture, the size of the sprayed spot, the pressure in the spray tank and the spray time per spot. Since excessive dosages injure tree seedlings and insufficient dosages fail to control weed competition, it is essential that the person doing the spraying be thoroughly familiar with the correct application procedure, including calculation of dosage and method of application (Appendix VI).

Herbicide spraying with a tractor-mounted sprayer with long boom.

The same sprayer with a short boom to allow spraying between rows of trees.

Weed control for the first 3 years after planting is essential for successful hardwood afforestation. The most efficient method of control is herbicide application over the entire area, the prepared strips or the planting spots. However, many hardwood species are highly susceptible to damage by the dosages necessary for effective control.

Each species has its own herbicide tolerance for any given physiological state. This tolerance is modified by the texture, organic content and moisture of the soil, by climate, by seedling age, by time since establishment, and by time and method of application. To provide the best possible weed control without causing seedling damage, it is most important to apply the herbicides only at the recommended dosages and to measure all dosages carefully.

Unfortunately, there are no shortcuts in either the measurement of correct dosages or the actual spraying. Applied properly, herbicides control weeds very effectively, but improper application will do more harm than good. Anyone using herbicides must be fully aware of the danger of serious damage to crop plants and the environment. If proper application cannot be guaranteed, herbicides should not be used.

Although many herbicides are currently available and new chemicals are marketed every year, simazine (trade names Princep® and Simadex®, Appendix VII) remains one of the most useful herbicides in hardwood afforestation.

Table 1 is a guide for the application of simazine in hardwood plantations. The recommended dosages are shown in the form of active ingredient. For conversion of active ingredient to quantities used in commercial products, use the formula shown in Appendix VI.

In former corn (*Zea mays* L.) fields that have received repeated applications of atrazine, some weeds may have developed resistance to simazine. In these fields it may be necessary to apply a herbicide other than simazine or to control the competition mechanically.

In fields with an apparent resistance of some weed species to control with simazine, terbacil (trade name Sinbar®) has been applied with good success. However, we know too little at this time about the effects of Sinbar® on tree survival and growth to make recommendations. Furthermore, terbacil is much more expensive than simazine.

Grasses are a major vegetational component of most planting sites in southern Ontario. All grasses compete vigorously with tree seedlings for soil moisture and nutrients. A dense cover of sod also provides an ideal habitat for mice, which can cause severe damage by girdling the stems of young hardwood trees. Elimination of grasses by mechanical means is most difficult, and generally requires several years of intensive cultivation. Many herbicides (including simazine) that control most broadleaf weeds effectively are relatively ineffective in controlling grasses at dosages tolerated by most hardwood species. Glyphosate is, at present, the most effective herbicide for controlling grasses. Recommendations for control of grasses are given in Appendix VIII.

Table 1. A guide to the application of simazine in plantations of hardwood trees and shrubs planted on fully cultivated former agricultural land.

Species	Soil texture	Recommended dosages of active simazine[a]			
		Shortly after planting		In late autumn of the 1st and 2nd years or in early spring of the 2nd and 3rd years after planting	
		kg/ha	lb/ac	kg/ha	lb/ac
BLACK WALNUT (*Juglans nigra* L.)	loam and clay loam	6.6	6.0	6.6	6.0
BUTTERNUT (*Juglans cinerea* L.)	loam and clay loam	6.6	6.0	6.6	6.0
WHITE ASH (*Fraxinus americana* L.)	loam, clay loam and clay	3.3	3.0	4.4	4.0
RED ASH (*Fraxinus pennsylvanica* Marsh.)	loam, clay loam and clay	3.3 4.4	3.0 4.0	4.4 4.4	4.0 4.0
SUGAR MAPLE (*Acer saccharum* Marsh.)	loam, clay loam	4.4 5.5	4.0 5.0	5.5 5.5	5.0 5.0
SILVER MAPLE (*Acer saccharinum* L.)	loam, clay loam and clay	5.5	5.0	6.6	6.0
MANITOBA MAPLE (*Acer negundo* L.)	loam and clay loam	4.4	4.0	5.5	5.0
AMUR MAPLE (*Acer ginnala* Maxim.)	sandy loam and clay loam	3.3 4.4	3.0 4.0	4.4 4.4	4.0 4.0
RED OAK (*Quercus rubra* L.)	sand, loam and clay loam	6.0	5.5	6.0	5.5
BUR OAK (*Quercus macrocarpa* Michx.)	loam, clay loam and clay	5.5	5.0	6.6	6.0
EUROPEAN OAK (*Quercus robur* L.)	clay loam and clay	5.5	5.0	6.6	6.0
BASSWOOD (*Tilia americana* L.)	loam and clay loam	5.0	4.5	6.0	5.5
BLACK CHERRY (*Prunus serotina* Ehrh.)	sandy loam and loam	3.3	3.0	4.0	3.6
WHITE BIRCH (*Betula papyrifera* Marsh.)	sandy loam and clay loam	5.0	4.5	6.0	5.5
BLACK LOCUST (*Robinia pseudoacacia* L.)	loam and clay loam	4.4	4.0	5.5	5.0
NORTHERN CATALPA (*Catalpa speciosa* Warder)	loam and clay loam	5.0	4.5	6.0	5.5
AMERICAN SYCAMORE (*Platanus occidentalis* L.)	loam, clay loam and clay	3.3	3.0	4.4	4.0
TULIP TREE (*Liriodendron tulipifera* L.)	loam and clay loam	5.0	4.5	6.0	5.5
EUROPEAN MOUNTAIN ASH (*Sorbus aucuparia* L.)	loam and clay loam	5.0	4.5	6.0	5.5
EUROPEAN ALDER (*Alnus glutinosa* L. [Gaertn.])	loam and clay loam	5.0	4.5	6.0	5.5
AUTUMN OLIVE (*Elaeagnus umbellata* Thunb.)	loam and clay loam	4.4	4.0	5.5	5.0

[a] For conversion of active ingredient to quantities found in commercial products, use the formula shown in Appendix VI.

Where chemical weed control is not feasible or desirable, competition can be controlled by manual or mechanical methods. Hoeing around trees can be effective, but it is not recommended because it does not generally provide adequate control and it often injures tree stems and roots.

Excellent weed control can be obtained by disking or rototilling between rows of trees and spraying glyphosate on the unwanted vegetation within rows. In the past it has been common practice to disk between rows of trees without providing weed control between the trees within rows. Evidence has shown that most tree seedlings derive little or no benefit from this treatment. Even with disking between rows, seedlings are generally still surrounded by weeds that deprive them of moisture and nutrients and physically interfere with their growth.

Disking or rototilling once per month from May to September will keep the area between the rows relatively weed free. Glyphosate is most effectively applied with a backpack sprayer. Mix 30 ml (1 fl. oz) of commercial product (Roundup® or Vision®) with each 4.5 L (1 gal) of water and wet the foliage of the unwanted vegetation. Although glyphosate is a contact herbicide that will injure or kill all vegetation sprayed, it is relatively easy, if care is taken, to avoid spraying the leaves of tree seedlings. Spraying should start when the weeds are 10 to 15 cm (4-6 in.) tall. Spraying at this early stage of growth will require a second application in July to kill the late-emerging weeds. However, if spraying is delayed until the weeds are as tall as or taller than the tree seedlings, it is impossible to spray the weeds without having some spray drift onto the tree leaves, and furthermore, seedling growth will already have suffered from the competition. More frequent spraying will further improve tree growth.

Mulching to control weed competition has become standard practice with many vegetable growers. In forest plantations, however, mulches have been applied only experimentally. Organic mulches such as bark, sawdust, peatmoss, hay and straw have generally failed to provide weed control for long

periods. These mulches also shelter rodents, which may girdle young hardwood trees. Plastic film has been used successfully in windbreak plantings but the high cost makes this method economically unattractive for use in plantations. Although well laid plastic film provides effective weed control for several years, the persistence of plastic makes this option environmentally undesirable.

An 8-year-old black walnut plantation. Left foreground: competition mowed for 8 years; right background: behind figure, chemically weeded for 8 years.

The same plantation, with competition mowed for 4 years and chemically weeded in years 5 to 8.

Mowing between trees has proven ineffective in improving tree growth and may even be harmful because it can stimulate root growth of the weed species and thereby intensify competition for soil nutrients and moisture. Mowing may be useful in preventing weed species from producing seed and in reducing cover for rodents; it is ineffective, however, as a substitute for mechanical or chemical weed control.

A promising new weed control method, especially on land that is subject to erosion, is the replacement of the natural weed cover with legumes. Although clean cultivation has generally resulted in the highest survival and height increment of planted black walnut, seeded herbaceous legumes like hairy vetch (*Vicia villosa* Roth), common lespedeza (*Lespedeza officinalis* [L.] Lam.) or sericea lespedeza (*Lespedeza cuneata* Dumont Maxim.) have significantly improved the growth of black walnut over that in plots with a natural weed cover.

Another innovative approach to weed control is intercropping of valuable hardwood trees with agricultural crops. The hardwood trees are planted at a spacing of 12 m (40 ft) between rows and 3 m (10 ft) within rows, and an agricultural crop is grown between the rows of trees. Cultivation of the agricultural crop provides weed control for the trees. The disadvantages of this afforestation method are increased agricultural costs and inferior stem quality of the open-grown trees.

PLANTING STOCK

The success of any plantation also depends on the quality and suitability of the planting stock. Good planting stock should have sturdy stems with well developed terminal buds, well branched root systems and balanced top-to-root ratios. Seedling size is generally more important than seedling age and the diameter of the root collar is a good indicator of seedling size (Table 2).

Table 2. Recommended planting stock grades for hardwoods planted in Ontario.

	Length of stem				Root-collar diameter			
	Minimum		Preferred		Minimum		Preferred	
Species	(cm)	(in.)	(cm)	(in.)	(cm)	(in.)	(cm)	(in.)
Black walnut	20	8	30	12	0.8	6/20	1.0	8/20
Butternut	20	8	30	12	0.8	6/20	1.0	8/20
White ash	30	12	40	16	0.6	5/20	0.8	6/20
Silver maple	30	12	50	20	0.6	5/20	0.8	6/20
Sugar maple	20	8	30	12	0.6	5/20	0.8	6/20
Red oak	30	12	50	20	0.6	5/20	0.8	6/20
Bur oak	30	12	40	16	0.6	5/20	0.8	6/20
Black cherry	30	12	50	20	0.6	5/20	0.8	6/20
Basswood	20	8	30	12	0.6	5/20	0.8	6/20

Forest managers have often expressed a preference for large transplant stock in the belief that planting large trees would eliminate the need for site preparation and weed control. This is probably true for individual, large trees. However, when transplants 1.2 m (4 ft) high and up to 5 years old were planted in a weed-infested soil without prior site preparation or subsequent weed control, they did not grow as well as seedlings planted on the same site with site preparation and post-planting weed control. Transplant stock is very expensive to produce, transport and plant, and growth of all classes of planted stock on unprepared sites is generally inferior to that of seedlings planted in plowed and disked soils

treated with herbicides. Hence, it is much more economical to spend the available money on site preparation and weed control than on the purchase of large transplant stock.

Most tree planters have no control over the quality of the planting stock that they receive from the nursery. However, the quality of the stock should be assessed when it is received, and undersized or damaged seedlings should be discarded, as they seldom produce trees of acceptable size or form. Money spent on planting inferior seedlings is wasted.

First-year mortality is often the result of poor handling practices from the time the seedlings leave the nursery until they are planted. During transportation to the planting site the bundles of trees must be protected from direct sun and drying wind. Although the tree roots are generally packed in moist peat moss or sealed in polyethylene-lined paper bags, excessive heat from direct sunlight or exposure to drying winds can quickly dry out the roots and cause irreparable damage. This damage may not be apparent at the time of planting but manifests itself in high first-year mortality or poor growth.

Seedlings should be planted as soon as possible after they arrive at the planting site. If delay is unavoidable, the seedlings should be stored in a cool place and their roots should be kept moist at all times. Cold-storage facilities at nearby orchards are ideal for storage, but if these are not available, root cellars, basements, barns, or other cool places may be used. If planting is delayed more than one week and no cold-storage facilities are available, the seedlings should be removed from the shipping containers and heeled-in in a shaded, well drained location. This is done by digging a trench deep enough to hold the roots, placing the individual bundles of trees in the trench and covering the roots with soil. During planting, care must be taken to keep the tree roots moist.

By contacting the nearest District Office of OMNR (Appendix II), any landowner can secure technical assistance and application forms for nursery stock.

DIRECT SEEDING

Although, on the basis of our current knowledge, planting of nursery-grown seedlings guarantees more consistent success than does direct seeding, the latter method offers certain advantages: (1) the development of a natural root system, which is important in species with pronounced tap roots such as the oaks (*Quercus* spp.), black walnut, butternut (*Juglans cinerea* L.), and the hickories (*Carya* spp.), (2) elimination of injuries resulting from planting, and (3) reduction of regeneration costs. The greatest disadvantage is the uncertainty of satisfactory establishment.

Hardwood species with relatively small seeds, such as white ash (*Fraxinus americana* L.) and silver maple (*Acer saccharinum* L.), are generally unsuitable for direct seeding. Species with large seeds, such as the oaks and black walnut, have occasionally been seeded successfully. However, before seeding is attempted on former agricultural land, all weed competition must be eliminated mechanically or chemically or by a combination of these two methods.

Autumn seeding is easier than spring seeding because it eliminates the necessity for seed stratification (cold treatment). To seed walnut or oak, simply dig holes 2.5 to 5 cm (1 to 2 in.) deep with a shovel or mattock. Place two seeds in each hole and cover with soil.

For spring seeding, nuts and acorns must be stratified over winter to break their dormancy. The easiest method of stratification is to dig a soil pit at least 40 cm (16 in.) deep in a well drained spot. Place nuts or acorns in the pit and cover with soil. In early spring, remove the seeds from the ground and sow them immediately.

The hulls of black walnut, which are green and firm in autumn, will rot during the winter and produce a dark brown pulp with a high staining capacity. To grade the nuts, remove the brown pulp by washing, then place the nuts in a tub of

water. Full, viable nuts will sink, whereas empty nuts will float. Discard the floaters and seed the sinkers.

Autumn-seeded nuts may be graded in the same manner; however, the hulls must be removed. This is difficult in autumn when hulls are green and firm. One method of removal is to place the walnuts in a cement mixer together with water and several fist-sized, sharp-edged rocks. The tumbling action of the cement mixer causes the sharp-edged rocks to remove the hulls without damage to the nuts.

PLANTING METHOD

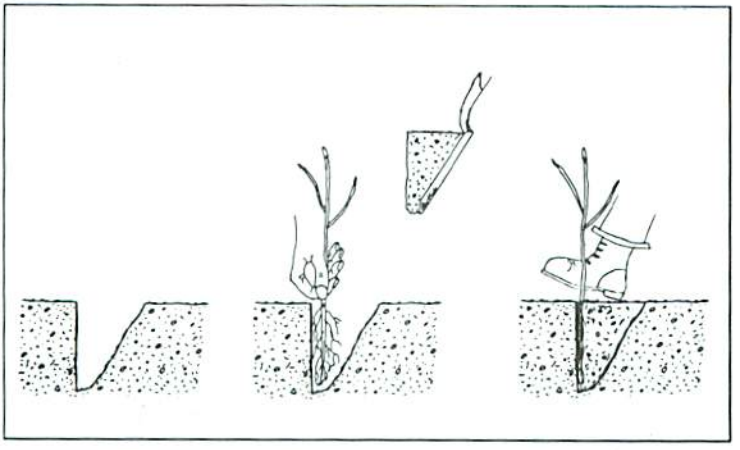
One- or 2-year-old hardwood seedlings may be planted with either a planting machine or a spade. On well prepared, easy-to-plant sites an experienced three-man crew can machine-plant up to 1200 seedlings per hour. However, planting performance will vary greatly from site to site depending on the texture, stoniness and moisture of the soil, as well as the topography of the planting site, size and suitability of the planting machine, and experience of the planting crew. Not all tree-planting machines are suitable for planting hardwoods. Machines in which the planted seedling must pass under a bar or the seat of the planter are generally unsuitable because they damage the terminal bud of seedlings 30 cm (1 ft) high or more. They also cause large seedlings to lean, and thereby induce the development of a new vertical shoot from the root collar or along the stem. When this happens the original stem must be pruned; extra work is required and valuable height increment is lost. Planting machines suitable for hardwood planting should have an unobstructed passage behind the planting shoe. This will allow the planting of seedlings or whips of all sizes without danger of injury.

Side view of a small planting machine with a three-point hitch, suitable for pulling with a small farm tractor.

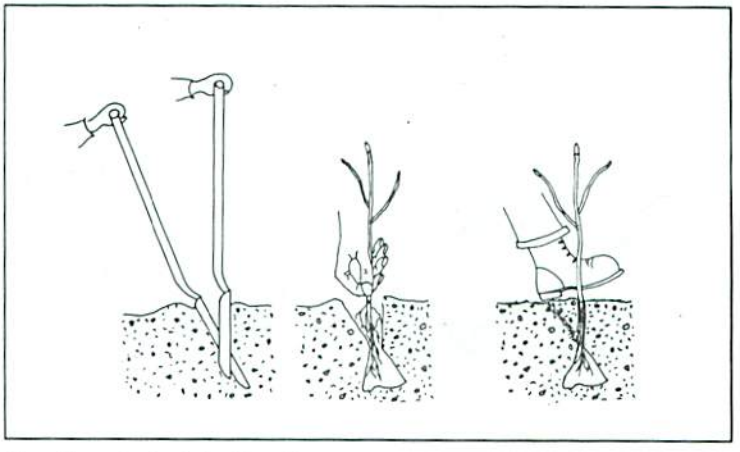
Rear view of the same planting machine. Note the unobstructed passage behind the packing wheel, which allows planting of tall seedlings.

Most planting machines developed for the planting of coniferous seedlings are fitted with V-blades or moldboards that scalp the ground or plow a furrow. Furrowing is used to provide temporary relief from competition. For hardwood planting these blades or moldboards must be removed since hardwood seedlings should never be planted in the bottom of furrows. However, since hardwood seedlings should never be planted in weed-infested soils, scalping or furrowing is unnecessary. If furrowing is used to control weed competition the temporary relief obtained seldom compensates for the loss of growth that results from the lower fertility of the subsoil, the loss of the seedlings' height advantage, and the increased danger of flooding and frost damage. Furrows are also the preferred runways of mice, which often cause extensive girdling damage.

Planting with a shovel or spade is much less efficient than machine planting. However, on steep slopes, in very moist soils, in wooded pastures, or in other locations in which a planting machine cannot operate efficiently or a suitable planting machine is not available, shovel planting has its place.



The wedge method of planting.

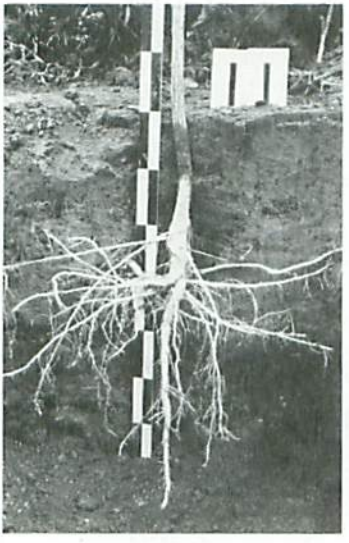


The slit method of planting. Note the possible air pocket at the base of the planting hole.

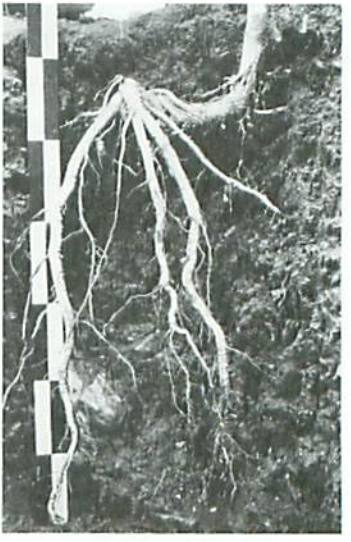
The best method is wedge planting, in which a wedge of soil is removed, the tree roots are inserted in the hole and the wedge is replaced. The slit method, in which the roots are inserted in a slit made by pushing the handle of the shovel back and forth, should be used only in soils that are very stony or wet, in which it is impossible to use the wedge method. The slit method is vastly inferior to the wedge method as it tends to leave an air

pocket at the base of the slit. This prevents root contact with the surrounding soil and may cause the tree's roots to dry out.

Large seedlings or transplants with spreading root systems are most efficiently planted in holes made with a tractor-mounted or hand-held post-hole auger with a bit 25 to 30 cm (10 to 12 in.) in diameter. Trees with stem diameters of several centimetres may be transplanted by specially designed, tractor-operated tree spades that remove up to 1 m^3 (1.3 yd^3) of soil together with the tree roots.



A good root system of a well planted walnut seedling.



A poor root system of a walnut seedling planted in a shallow hole.

Walnut, butternut, oak and hickory seedlings have large tap roots, whereas the maples (*Acer* spp.), basswood (*Tilia americana* L.), white ash and others have spreading, fibrous root systems. Although it would be ideal to plant the entire root mass of all seedlings, most planting machines can accommodate a maximum root length and width of only 20 and 10 cm (8 and 4 in.), respectively. Shovel-planting seedlings with roots longer than 15 cm (6 in.) is also very inefficient and generally leaves part of the root exposed above the soil surface.

If the seedlings are not root-pruned in the nursery, this must be done in the field. To obtain the proper length and shape, prune all roots individually with pruning shears or a sharp knife. Roots should not be cut with an ax while the trees are still tied in a bundle, for invariably some roots will be cut too short while others will be left too long. All cuts should be made cleanly to promote rapid healing.

SPACING

There is no ideal spacing for planting all species on all sites. Spacing is therefore determined mostly by a compromise among the growth requirements of the species, the purpose of the planting, the wishes of the plantation owner, and the economics of plantation establishment and tending. It is known that trees grown at wide spacings generally grow faster in diameter whereas trees grown at narrow spacings generally produce stems of better form. However, spacing has little effect on height growth except in very dense or very widely spaced plantations.

Traditionally, in European practice, hardwoods have been planted at close spacings. When thinned regularly such plantations have produced trees of excellent form and acceptable diameter growth. Recently, plantations have been established at wider spacings and acceptable form has been obtained by pruning.

The main advantages of wide spacing are: (1) rapid diameter growth, (2) low planting costs, and (3) few or delayed thinnings. The disadvantages are: (1) inefficient utilization of the growing space for a major part of the rotation, (2) delay in canopy closure which, in turn, delays natural weed control by shading, (3) poor stem form and heavy branching, and (4) a possible shortage of crop trees.

For most plantations, therefore, it is recommended that more trees be planted than are required for full stocking at rotation age. One may either plant more trees of the same species or interplant with another species that can be removed when the crop trees require additional growing space.

At present, a spacing of 3 m (10 ft) between rows and 1.5 m (5 ft) within rows is recommended. This spacing requires the planting of 2222 trees/ha (871 trees/ac). It allows the passage of a medium-sized tractor between rows of trees for chemical or mechanical weed control, promotes reasonably early canopy closure to shade out the competing vegetation, and

allows for possible mortality and trees of poor form. The disadvantage of this spacing is that it necessitates at least one precommercial thinning. Table 3 shows the number of trees required for other spacings.

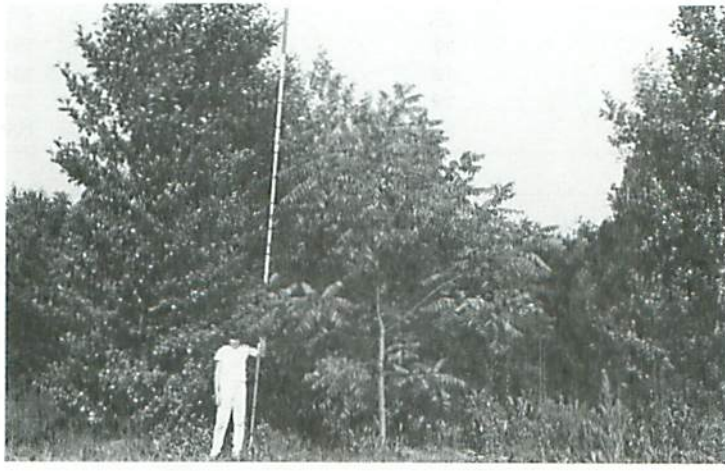
Table 3. The number of trees required for different spacings.

Square spacing			
Distance between trees		No. of trees required to plant	
(m)	(ft)	one ha	one ac
0.3 (0.3 x 0.3)	1 (1 x 1)	111,111	43,560
0.6	2	27,778	10,890
0.9	3	12,346	4,840
1.2	4	6,944	2,722
1.5	5	4,444	1,742
1.8	6	3,086	1,212
2.1	7	2,268	889
2.4	8	1,736	681
2.7	9	1,372	538
3.0	10	1,111	436
3.4	11	865	360
3.7	12	730	302
4.0	13	625	258
4.3	14	541	222
4.6	15	473	194
4.9	16	416	170
5.2	17	370	151
5.5	18	331	134
5.8	19	297	121
6.1	20	269	109
Rectangular spacing			
Distance between trees		No. of trees required to plant	
(m)	(ft)	one ha	one ac
1.2 x 2.4	4 x 8	3,472	1,361
1.5 x 3.0	5 x 10	2,222	871
1.8 x 3.7	6 x 12	1,502	605
3.0 x 4.6	10 x 15	725	290
4.6 x 6.1	15 x 20	357	145

SPECIES MIXTURES

Hardwood species may be planted either in pure plantations or in mixtures with other hardwoods or conifers; each procedure has advantages and disadvantages. In their natural environment, trees of most hardwood species grow in association with those of other species, and plantations of mixed species approximate this natural state. Species mixtures may also produce the highest yield since a mixture of different species generally utilizes a planting site more fully than do trees of a single species. However, the greatest advantage of mixed plantations is that they avoid a monoculture, which is more susceptible to devastating attacks by insects or diseases.

The principal advantage of pure plantations is that, per unit area, they yield the largest number of trees of the most desirable species. This ensures that sufficient trees are available for the selection of the best crop trees in a fully stocked stand at rotation age. In plantations of black walnut or other valuable species, pure plantations may therefore produce the highest stumpage value. Another advantage of pure plantations is that they permit freedom of choice with respect to the methods of site preparation, planting and weed control used for the establishment and management of the species planted.



European alder planted as a nurse species for black walnut.

Since planting either a single species or a mixture of several species will not be suitable for the afforestation of all sites, the choice and number of species planted always depends on site conditions, the wishes of the owner, the availability of planting stock, and the economics of plantation establishment, management and expected yield.

On intensively managed, highly productive sites, it is generally most economical to plant only the most valuable species. Such plantations may best be compared with fruit orchards. Where intensive management cannot be guaranteed, on less productive sites, and for purposes other than that of high-quality timber production, it is recommended that a mixture of several hardwood species be planted. However, all of these must have compatible growth rates and must be suited to the site. For amenity or erosion-control plantings, any species may be selected as long as its growing requirements match those of the afforestation site.

Species mixtures may be planted in a variety of arrangements depending on the aim of management, the number of species planted, the relative number of trees per species, the training and supervision of the planting crew and, last but not least, the cost of plantation establishment and management. The simplest and most common arrangement is the planting of alternate rows of two species. This facilitates differential weed control and the subsequent removal of less valuable species to provide additional growing space for preferred species.

Alternate rows of different hardwood species have proven useful where one species provides shelter or improves the site for another species in the next row. For example, interplanting of black locust (*Robinia pseudoacacia* L.), European alder (*Alnus glutinosa* L. [Gaertn.]) or autumn olive (*Elaeagnus umbellata* Thunb.) has increased walnut growth by providing additional soil nitrogen, competition control, and protection from damage by wind. Planting of silver maple in alternate rows with black walnut has increased walnut growth by providing natural competition control and protection from wind, and by forcing walnut height growth.

Ten-year-old black walnut in a completely random mixture.

Group planting can be employed successfully when a small number of trees (4-12) of one species is planted in mixture with a large number of trees of another species, because the chances of survival and adequate growth are greater for trees planted in groups than for individuals scattered throughout the plantation. Group planting also facilitates weed control, thinning and protection from browsing to favor the best individuals within a group.

A black walnut/white pine plantation mixture, 3 years after planting.

A variation of group planting is the planting of trees in blocks. The blocks of different species are generally planted in a checkerboard pattern with 5 to 10 rows of 10 to 20 trees each. Smaller or larger blocks may be planted, but very small or very large blocks defeat the purpose of this method of mixed plantings.

The planting of completely random mixtures of species has its place in the afforestation of medium-quality sites and the establishment of amenity forests or wildlife habitats. Completely random mixtures are obtained by opening one bundle of seedlings of each species and mixing all seedlings. The seedlings are then planted as they occur in this mixture. To increase the number of trees of the most valuable tree species within a random mixture, increase the percentage of seedlings of the desirable tree species in the mixture.

The greatest disadvantage of complete species mixtures is the limitation in the application of chemical weed control treatments. Because each species has its own level of tolerance to a specific herbicide, the maximum dosage that may be applied safely is that tolerated by the species with the lowest tolerance level. On sites with intense weed competition this dosage may prove insufficient to control weed growth.

Most hardwood species should not be grown in mixture with conifers because the conifers provide an ideal habitat for rabbits, which will browse the tops and gnaw the bark of the hardwood seedlings. In plantations with even relatively low rabbit populations the browsing and bark gnawing will prevent most hardwood seedlings from producing stems of acceptable size and quality.

Black walnut is less palatable to rabbits, and damage from browsing and gnawing is therefore generally less severe than in plantations of white ash, red oak, basswood or others. More than 200 mixed plantations of black walnut and white pine (*Pinus strobus* L.) have been established in southern Ontario. The interplanted white pine is expected to (1) shade out the herbaceous vegetation, thereby increasing the available soil moisture and nutrients; (2) deprive meadow voles (*Microtus pennsylvanicus* Ord.) of cover and food and prevent them from girdling young walnut trees; (3) decrease damaging wind, force walnut height growth and shade out the lower branches of the walnut, thereby improving the tree's stem form; and (4) utilize juglone (a natural chemical produced by the walnut) as a built-in thinning mechanism 25 to 30 years after planting. However, the success of this method depends on a relatively low rabbit population and the maintenance of effective artificial weed control around the walnut seedlings until the pines are able to provide natural weed control.

FERTILIZATION

Since low fertility is a common characteristic of abandoned farmland, fertilization appears to offer possibilities for improving tree growth on nutrient-deficient sites. Studies have shown that the growth of some hardwood stands can be improved significantly by nitrogen fertilization. However, when fertilizer was applied to newly planted hardwood seedlings neither survival nor growth was greatly improved. The reason for this is not fully known.

Until more information is available, fertilization at the time of planting is not recommended because it may do more harm than good by increasing weed competition. Fertilization is also expensive, and money spent on fertilizer applications at the time of planting could be put to better use by intensifying site preparation and weed control treatments of proven benefit.

Fertilization of older plantations appears to have greater potential, but there is not enough information available about it to support recommendations.

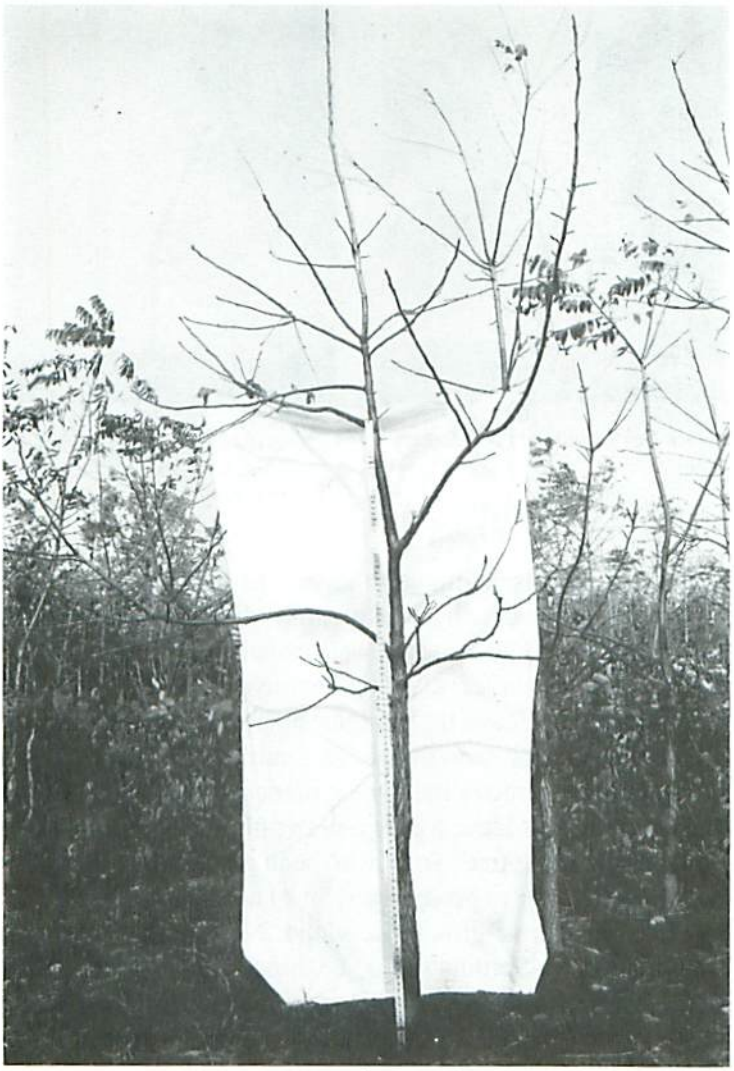
PRUNING

Unlike conifers, many hardwood species lack the drive to upward growth. They frequently develop forked leaders and, at wide spacings, tend to develop large, spreading crowns with branches on the lower stem that persist for many years. To produce high-quality logs for veneer or lumber, it may therefore be necessary to prune trees to maintain single leaders and to remove lower branches. Pruning of live branches generally reduces total tree growth because it reduces the leaf area used for photosynthesis. However, pruning will also concentrate growth on fewer shoots, thereby increasing their growth. To avoid excessive loss of growth, pruning often but lightly is recommended.

The best time to prune depends on the tree species and the availability of labor. The traditional time to prune has been the dormant season, between leaf fall and spring growth. Most hardwood trees may also be pruned in summer or autumn. Some species, such as black walnut and the maples, bleed heavily if pruned in late winter or early spring. Although the effect of bleeding on tree growth has not been fully evaluated, it is recommended that pruning of these species during periods when bleeding occurs be avoided.

Small branches are most easily and efficiently cut with hand clippers. The cut should be made as close to the main stem as possible without injuring the bark of the stem. Large branches are best cut with special pruning saws. These saws have many short teeth and a curved blade. Large branches have a definite bark ridge above the branch. This is the dividing line between the branch and the main stem and your guide to proper pruning. Place the saw in front of the ridge and cut downward and slightly outward (i.e., do not cut branches flush with the main stem). For the removal of heavy branches, first make an undercut on the lower side of the branch to avoid peeling the bark off the main stem when the branch falls. Do not paint the wound, other than for cosmetic reasons, because wound dressings have generally failed to prevent rotting. If you wish

to paint the wound, use a very thin coat of a commercially available wound dressing. Do not use house paint.



Tree with good stem form. Large branch on right side of crown should be removed.

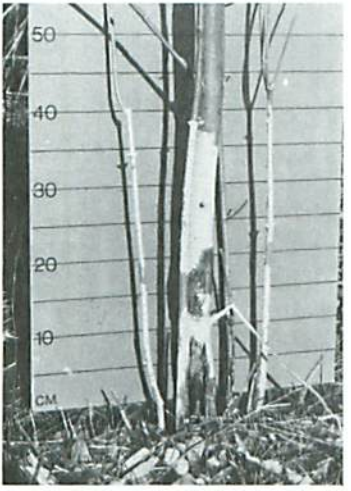
Black walnut seedling with forked leader.

Same seedling with weaker leader removed. Stem will straighten within 1 or 2 years.

Do not prune seedlings in the year of planting because the young trees need their total photosynthetic area to produce sufficient energy to become well established. Starting in the second summer after planting, remove one side of forked leaders. Always leave the straightest, strongest leader and clip all other leaders close to their base. Starting in the third summer after planting, remove the lowest branches every 2 to 3 years. However, always leave a crown of two-thirds to one-half of the total height of the tree. Trees with such poor form that they are not expected ever to produce a stem of acceptable form should be cut 5 cm above ground in winter. New sprouts will grow from the stump. Sprouts should be thinned to leave three stems during the next year. Always favor sprouts that originate closest to the ground because these are most stable. In spring of the following year, remove all but the best sprout.

In older plantations, prune trees in 5- to 10-year cycles to a height of 50% of the tree. In older plantations that have never been pruned, start the cycle with a light pruning to avoid the development of epicormic branches.

RODENT CONTROL

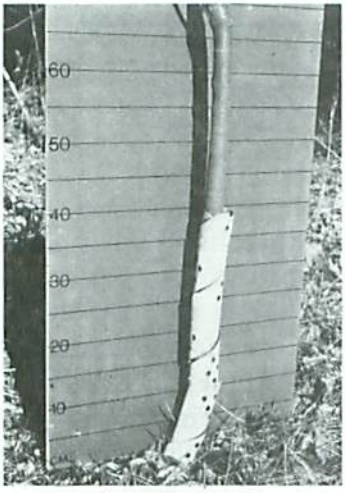


A white ash seedling girdled repeatedly by mice.

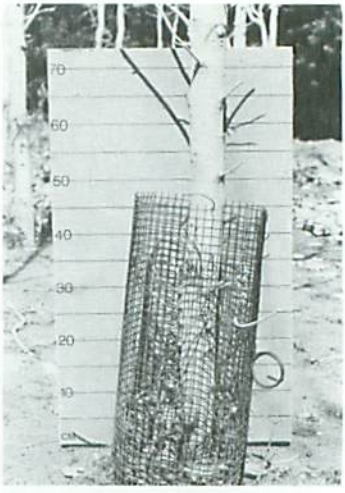
Stem girdling by mice, browsing and bark gnawing by rabbits, and browsing by deer cause serious damage in young hardwood plantations. Both rabbits and mice prefer the bark of some species to that of others. The order of preference for rabbits appears to be red oak, white ash, basswood, sugar maple (*Acer saccharum* Marsh.) and autumn olive. Black walnut, butternut, and silver maple appear to be less palatable. Mice appear to prefer the bark of white ash, sugar and silver maples, basswood and autumn olive to that of black walnut and butternut seedlings. All rodents prefer the bark of young seedlings to that of saplings or older trees. Saplings with root-collar diameters of 10 to 13 cm (4 to 5 in.) are generally safe from girdling damage except in years of extremely high rodent populations, or under very unusual weather conditions that prevent rodents from feeding on more palatable vegetation.

The best protection from rodent damage is elimination of the weed cover. This deprives the animals of shelter and food and makes the plantation a hostile environment for rodent survival and reproduction. Also, elimination of weed competition increases the growth of planted seedlings; fast-growing trees are less vulnerable to rodent damage because they soon outgrow the danger.

Plastic tree guards placed around the stems of young trees and tree shelters that enclose the entire seedling provide excellent protection. Their only disadvantage is high cost.However, the protection provided may fully justify the cost for plantations with small numbers of valuable trees.

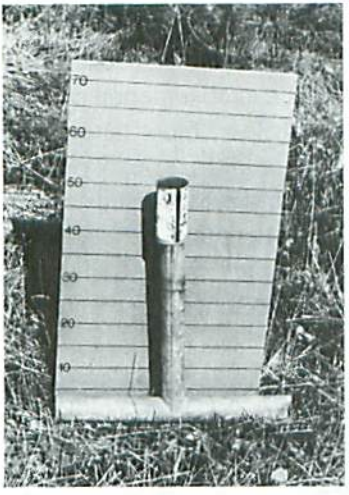


A white ash seedling protected by a plastic tree guard.



A wire cage to protect a sugar maple seedling from bark gnawing by rabbits.

In the past, the most common method of mouse control has been the broadcast application of poisoned grain. The most common rodenticide is zinc phosphide. Grain or cracked corn treated with zinc phosphide is available in most agricultural supply stores. Although this method is effective in decreasing the number of mice, the relief is generally only temporary because of migration into the area from adjacent, untreated fields. Furthermore, the exposed, poisoned grain may harm non-target mammals and birds. Feeder stations installed at a 20-m (65-ft) grid spacing (25 stations per ha, 10 per ac) and filled with poisoned grain provide longer-lasting control and better safeguards. Although the cost of purchase and installation of the stations and the frequency with which the stations must be replenished with grain seem to make this method economically unattractive, it is recommended whenever rodents are observed in a plantation. July is the best month for application of bait, before rodent populations reach their peak in August.



A feeder station to dispense poisoned grain.

Browsing by rabbits may be controlled by repellants painted on the trees. However, this method is rather expensive for the degree of protection afforded. The best protection against rabbit browsing is elimination of the weed cover.

GROWTH AND YIELD

Plantation performance is difficult to predict because it is affected by many factors such as site, establishment technique and management intensity. Nevertheless, most landowners will want to know what growth they might reasonably expect before they invest time and money in the establishment of a plantation. Since most plantation owners take great pride in the development of their plantation, they may also wish to compare the growth of their trees with that in other plantations

A 2-year-old black walnut plantation with excellent weed control.

growing on similar sites. To facilitate such a comparison, the average growth of trees in some good black walnut, white ash, red oak, basswood and silver maple plantations is listed in Table 4. Also shown is the average growth of less common plantation species planted experimentally in southern Ontario. Although growth in these plantations probably approaches optimum performance for southwestern Ontario conditions, too few plantations of minor species have been established to determine their full growth potential.

The same plantation 20 years after planting and thinned twice. Height 14 m (46 ft), DBH 20 cm (7.8 in.).

Table 4. Survival and growth of hardwood species in intensively managed research plantations growing on former farmland in southwestern Ontario.

Species	Soil			Species arrangement	Age (yr)	Survival (%)	Mean DBH (cm)	Mean height (m)	Mean annual height increment (cm)
	Texture	Depth of A+B horizons (cm)	Drainage						
Black walnut	silty clay	100	good	mixed	20	thinned	15.2	14.5	72
	sandy loam	80	good	pure	20	thinned	20.0	14.4	73
	silt loam	70	imperfect	mixed	15	93	12.0	9.4	62
White ash	silty clay	100	good	mixed	20	thinned	14.5	13.7	68
	silt loam	70	imperfect	mixed	15	83	9.7	9.9	66
Red oak	loamy sand	60	good	pure	20	thinned	11.6	11.7	58
	loamy sand	60	good	pure	10	90	–	5.7	57
Basswood	silt loam	70	imperfect	mixed	15	82	10.9	9.8	65
	clay loam	50	imperfect	pure	10	88	–	6.2	62
Silver maple	silt loam	70	imperfect	mixed	15	82	17.7	11.7	78
	sandy loam	65	good	mixed	5	98	–	4.9	97
Sugar maple	sandy loam	60	good	pure	15	92	7.8	7.3	49
	loam	60	good	pure	10	92	5.2	5.6	56
Butternut	silt loam	70	imperfect	mixed	10	87	4.9	4.4	44
	loam	65	good	mixed	5	94	–	2.3	46
Black cherry	sandy loam	60	good	pure	15	thinned	10.7	9.5	63
	silty loam	70	imperfect	mixed	15	78	5.5	5.4	36
Bur oak	clay	50	poor	pure	10	96	–	3.7	37
European oak	clay	50	poor	pure	10	95	–	4.4	44
Tulip tree	silt loam	70	imperfect	mixed	15	85	8.3	5.8	58
Catalpa	silt loam	70	imperfect	mixed	15	69	13.9	9.4	63
Sycamore	silt loam	70	imperfect	mixed	15	37	11.5	9.9	66
Black locust	silt loam	70	imperfect	mixed	15	87	14.6	11.1	74
European mt. ash	silt loam	70	imperfect	mixed	15	77	6.3	7.2	48
Hackberry	loam	65	good	mixed	5	60	–	1.4	27
Manitoba maple	loam	65	good	mixed	5	96	–	4.5	90

SUGGESTED READING

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APPENDICES

APPENDIX I
Summary of Planting and Tending Recommendations by Species

Species	*Page*
Basswood	46
Black cherry	48
Black locust	49
Black walnut	51
Bur oak	52
Northern red oak	54
Red ash	56
Silver maple	57
Sugar maple	59
White ash	61
Minor plantation species	
American sycamore	63
Amur maple	63
Autumn olive	63
Butternut	64
European alder	64
European mountain ash	64
European oak	65
Manitoba maple	65
Northern catalpa	65
Red maple	66
Shagbark and bitternut hickories	66
Tulip tree	66
White birch	67
White oak	67

BASSWOOD

(*Tilia americana* L.)

Where to plant: For optimum growth, plant in deep, fertile, moist but well drained sandy loams, loams, silt loams or molded tills with a silt-plus-clay content of at least 35%. This species is very demanding and requires fertile soils for satisfactory growth.

Where not to plant: in infertile, eroded, or poorly drained soils, on dry, sandy, gravelly or exposed ridges and in any soils with a yellow sand subsoil 40 cm (16 in.) or less below the soil surface

Site preparation: In weed-infested former fields and pastures, spray 4.7 L/ha (½ gal/ac) of Vision® or Roundup® over the entire plantation area. One week after spraying, plow and disk or rototill the sprayed area. In fields currently under cultivation, plow and disk after harvest. On sites on which mechanical site preparation is not possible or desirable, spray 4.7 L/ha (½ gal/ac) of Vision® or Roundup® in August in strips at least 1.5 m (5 ft) wide.

Species mixtures: Because basswood does not grow well in pure plantations, plant only in mixture with other hardwoods such as black walnut, white ash, black cherry, red oak or other hardwood species suitable for the soil and drainage conditions of the planting site.

Basswood should not be grown in mixture with conifers because conifers provide an ideal habitat for rabbits, which browse the tops and gnaw the bark of the basswood seedlings. In plantations with even relatively low rabbit populations the browsing and bark gnawing will prevent most basswood seedlings from producing stems of acceptable size and quality.

Spacing: Plant at 3 m (10 ft) between rows and 1.5 m (5 ft) within rows.

This spacing requires the planting of 2,222 trees/ha (871 trees/ac). It allows the passage of a medium-sized tractor between rows of trees for chemical or mechanical weed control, promotes reasonably early canopy closure to shade out competing vegetation, and allows for possible mortality and trees of poor form.

Planting stock: 2+0 seedlings

Time of planting: 20 April to 15 May

Method of planting: machine planting or spade planting by the wedge method

Weed control after planting: Shortly after planting spray 5.0 kg/ha (4.5 lb/ac) of active simazine over the entire plantation area or the site-prepared strips. In October of the first and second years or April of the second and third years after planting, spray 6.0 kg/ha (5.5 lb/ac) of active simazine over the same area. Where necessary, continue spraying after the third year until the trees have outgrown the weed competition.

Rodent control: On sites with dense rabbit populations it may be necessary to protect the young seedlings from browsing by intensive hunting, fencing of the total plantation area, or wire screening of individual seedlings. Where stem girdling by mice is a problem, eliminate weeds or place tree guards around the main stems.

Pruning: Sprouting from the root collar and the lower stem is characteristic of basswood. To obtain maximum growth on the main stem, remove all sprouts from the lower stem starting in the third year after planting and prune individual branches to improve stem form. However, always leave a crown of two-thirds to one-half of the total height of the trees.

BLACK CHERRY

(*Prunus serotina* Ehrh.)

Where to plant: For optimum growth, plant in deep, fertile, moist but well drained sandy loams or loams. Seedlings will also grow in soils ranging from sand to stony tills. However, tree growth on these sites will be slower than on the loams.

Where not to plant: on clays and clay loams and all excessively dry or poorly drained soils

Site preparation: In weed-infested former fields and pastures, spray 4.7 L/ha (½ gal/ac) of Vision® or Roundup® in late August over the entire plantation area. One week after spraying, plow and disk or rototill the sprayed area. In fields currently under cultivation, plow and disk after harvest. On sites on which mechanical site preparation is not possible or desirable, spray 4.7 L/ha (½ gal/ac) of Vision® or Roundup® in August in strips at least 1.5 m (5 ft) wide.

Species mixtures: Because black cherry does not grow well in pure plantations, plant only in mixture with other hardwoods such as red oak, white ash, basswood, sugar maple or other hardwood species suitable for the soil and drainage conditions of the planting site.

Black cherry should not be grown in mixture with conifers because conifers provide an ideal habitat for rabbits, which browse the tops of black cherry seedlings. In plantations with even relatively low rabbit populations, the browsing and bark gnawing will prevent most black cherry seedlings from producing stems of acceptable size and quality.

Spacing: Plant at 3 m (10 ft) between rows and 1.5 m (5 ft) within rows. This spacing requires the planting of 2,222 trees/ha (871 trees/ac). It allows the passage of a medium-sized tractor between rows of trees for chemical or mechanical weed control, promotes reasonably early canopy closure to shade out competing vegetation, and allows for possible mortality and trees of poor form.

Planting stock: 1+0 or 2+0 seedlings

Time of planting: 20 April to 15 May

Method of planting: machine planting or spade planting by the wedge method

Weed control after planting: Black cherry has a low tolerance for simazine and is easily damaged by dosages tolerated by most other tree species. Shortly after planting, spray 3.3 kg/ha (3.0 lb/ac) of active simazine over the entire plantation area or the site-prepared strips. In October of the first and second years or April of the second and third years after planting, spray 4.0 kg/ha (3.6 lb/ac) of active simazine over the same area. Where necessary, continue spraying after the third year until the trees have outgrown the weed competition.

Rodent control: On sites with dense rabbit populations, it may be necessary to protect the young seedlings from browsing by intensive hunting, fencing of the total plantation area, or wire screening of individual seedlings.

Pruning: Starting in the second summer after planting, prune one side of forked leaders. Starting in the third summer, remove the lowest branches every 2 to 3 years. However, always leave a crown of two-thirds to one-half of the total height of the trees.

BLACK LOCUST

(*Robinia pseudoacacia* L.)

Where to plant: This species grows well on many soils but prefers sandy loams and loams to clay loams and clays. Because it is able to survive on poor or shallow soils, it is a preferred species for the afforestation of eroded or severely disturbed sites.

Where not to plant: on soils with consistently high water tables

Site preparation: On shallow or eroded soils with sparse vegetation, do *not* site prepare because this may increase erosion. In weed-infested former fields and pastures, spray 4.7 L/ha (½ gal/ac) of Vision® or Roundup® in late August over

the entire plantation area. One week after spraying, plow and disk or rototill the sprayed area. In fields currently under cultivation, plow and disk after harvest. On sites on which mechanical site preparation is not possible or desirable, spray 4.7 L/ha (½ gal/ac) of Vision® or Roundup® in August in strips at least 1.5 m (5 ft) wide.

Species mixtures: On shallow or eroded soils, plant black locust alone. On fertile soils, plant in mixture with other hardwood species. Black locust is also an excellent nurse species for black walnut.

Spacing: In shallow, eroded soils, plant at 1.8 x 1.8 m (6 x 6 ft) to promote early canopy closure and to allow for possible mortality. This spacing requires the planting of 3,086 trees/ha (1,210 trees/ac). Plant black locust as a nurse species in alternate rows with black walnut at 3 m (10 ft) between rows and 1.5 m (5 ft) within rows. This arrangement requires the planting of 1,111 black locust trees/ha (435 trees/ac). It allows the passage of a medium-sized tractor between rows of trees for chemical or mechanical weed control, promotes early canopy closure to shade out competing vegetation, and forces walnut height growth.

Planting stock: 2+0 seedlings

Time of planting: 20 April to 15 May

Method of planting: machine planting or spade planting by the wedge method

Weed control after planting: On shallow or eroded soils with sparse vegetation, do not apply weed control because this may increase erosion. On all other sites, spray 4.4 kg/ha (4.0 lb/ac) of active simazine over the entire plantation area or on the site-prepared strips shortly after planting. In October of the first and second years or April of the second and third years after planting, spray 5.5 kg/ha (5.0 lb/ac) of active simazine over the same area. Where necessary, continue spraying after the third year until the trees have outgrown the weed competition.

Rodent control: Where stem girdling by mice is a problem, eliminate weeds or place tree guards around the stems.

Pruning: Because it has little value as a timber species, black locust is seldom pruned. However, removal of one side of forked leaders will improve stem form.

BLACK WALNUT

(*Juglans nigra* L.)

Where to plant: For optimum growth, plant in deep (topsoil 50 cm [20 in.] or deeper), fertile, moist but well drained loams or clay loams. This species is very sensitive to soil and drainage conditions and will not grow well in sands or clays or on shallow or poorly drained soils.

Where not to plant: in infertile, eroded or poorly drained soils; on dry, sandy or gravelly exposed ridges; and in any soil with a topsoil depth of less than 40 cm (16 in.)

Site preparation: In weed-infested former fields and pastures, spray 4.7 L/ha (½ gal/ac) of Vision® or Roundup® in late August over the entire plantation area. One week after spraying, plow and disk or rototill the sprayed area. In fields currently under cultivation, plow and disk after harvest. On sites on which mechanical site preparation is not possible or desirable, spray 4.7 L/ha (½ gal/ac) of Vision® or Roundup® in August in strips at least 1.5 m (5 ft) wide.

Species mixtures: On intensively managed, highly productive sites, plant black walnut alone. Such plantations may best be compared with fruit orchards. On all other sites plant black walnut either in alternate rows with autumn olive, European alder or white pine or in random mixture with white ash, silver maple, basswood or other hardwood species suitable for the soil and drainage conditions of the planting sites.

Spacing: Plant at 3 m (10 ft) between rows and 1.5 m (5 ft) within rows. This spacing requires the planting of 2,222 trees/ha (871 trees/ac). It allows the passage of a medium-sized

tractor between rows of trees for chemical or mechanical weed control, promotes reasonably early canopy closure to shade out competing vegetation, and allows for possible mortality and trees of poor form.

Planting stock: 1+0 seedlings

Time of planting: 20 April to 15 May

Method of planting: machine planting or spade planting by the wedge method

Weed control after planting: In pure walnut plantations spray 6.6 kg/ha (6.0 lb/ac) of active simazine over the entire plantation area or on the site-prepared strips shortly after planting. Repeat this treatment in October of the first and second years or April of the second and third years after planting. Where necessary, continue spraying after the third year until the trees have outgrown the weed competition.

Rodent control: Protection is rarely required because chemical compounds in black walnut bark make it one of the least attractive species for browsing by rabbits or stem girdling by mice. To protect the interplanted species from browsing or stem girdling, eliminate the weed cover. This deprives the rodents of shelter and food.

Pruning: Never prune in late winter or early spring because heavy bleeding will occur. Starting in the second summer after planting, prune one side of forked leaders. Starting in the third summer, remove the lowest branches every 2 or 3 years. However, always leave a crown of two-thirds to one-half of the total height of the tree.

BUR OAK

(*Quercus macrocarpa* Michx.)

Where to plant: For optimum growth, plant in deep, moist, but well drained loams, clay loams and clays. This species is very tolerant of a wide range of soil and moisture conditions. It is

one of the few species that grow well in poorly drained clay. It is also an excellent tree for planting in urban environments because of its resistance to damage by air pollutants.

Where not to plant: in excessively dry, wet or shallow soils

Site preparation: In weed-infested former fields and pastures, spray 4.7 L/ha (½ gal/ac) of Vision® or Roundup® in late August over the entire plantation area. One week after spraying, plow and disk or rototill the sprayed area. In fields currently under cultivation, plow the total field after harvest. On sites on which mechanical site preparation is not possible or desirable, spray 4.7 L/ha (½ gal/ac) of Vision® or Roundup® in August in strips at least 1.5 m (5 ft) wide.

Species mixtures: On poorly drained clay soils, plant bur oak in pure plantations. On well drained loams and clay loams, plant bur oak in mixture with white ash, black walnut, silver maple, basswood or other hardwood species suitable for the soil and drainage conditions of the planting site.

Bur oak should not be grown in mixture with conifers because conifers provide an ideal habitat for rabbits, which browse the tops and gnaw the bark of hardwood seedlings.

Spacing: Plant at 3 m (10 ft) between rows and 1.5 m (5 ft) within rows. This spacing requires the planting of 2,222 trees/ha (871 trees/ac). It allows the passage of a medium-sized tractor between rows of trees for chemical or mechanical weed control, promotes reasonably early canopy closure to shade out competing vegetation, and allows for possible mortality and trees of poor form.

Planting stock: 2+0 seedlings

Time of planting: 20 April to 15 May

Method of planting: machine planting or spade planting by the wedge method

Weed control after planting: Within days of planting, spray 5.5 kg/ha (5.0 lb/ac) of active simazine over the entire plantation

area or the site-prepared strips. In October of the first and second years or April of the second and third years after planting, spray 6.6 kg/ha (6.0 lb/ac) of active simazine over the same area. Where necessary, continue spraying after the third year until the trees have outgrown the weed competition.

Rodent control: On sites with dense rabbit populations it may be necessary to protect the young seedlings from browsing by intensive hunting, fencing of the total plantation area, or wire screening of individual seedlings. Where stem girdling by mice is a problem, eliminate weeds or place tree guards around the main stems.

Pruning: Starting in the second summer after planting, prune one side of forked leaders. Starting in the fifth summer, remove the lowest branches every 3 to 5 years. However, always leave a crown of two-thirds to one-half of the total height of the tree.

NORTHERN RED OAK

(*Quercus rubra* L.)

Where to plant: For optimum growth, plant in deep, fertile, moist but well drained fine sands, sandy loams, and loams. This species will also grow in soils ranging from poorly drained clay to well drained shallow or rocky soils. However, tree growth on these sites will be poor.

Where not to plant: in excessively dry or poorly drained soils

Site preparation: In weed-infested former fields and pastures, spray 4.7 L/ha (½ gal/ac) of Vision® or Roundup® in late August over the entire plantation area. One week after spraying, plow and disk or rototill the sprayed area. In fields currently under cultivation, plow and disk after harvest. On sites on which mechanical site preparation is not possible or desirable, spray 4.7 L/ha (½ gal/ac) of Vision® or Roundup® in August in strips at least 1.5 m (5 ft) wide.

Species mixtures: Plant either alone or in mixture with white ash, basswood, black cherry, sugar maple, or other hardwood

species suitable for the soil and drainage conditions of the planting site.

Red oak should not be grown in mixture with conifers because conifers provide an ideal habitat for rabbits, which browse the tops and gnaw the bark of red oak seedlings. In plantations with even relatively low rabbit populations, the browsing and bark gnawing will prevent most red oak seedlings from producing stems of acceptable size and quality.

Spacing: Plant at 3 m (10 ft) between rows and 1.5 m (5 ft) within rows. This spacing requires the planting of 2,222 trees/ha (871 trees/ac). It allows the passage of a medium-sized tractor between rows of trees for chemical or mechanical weed control, promotes reasonably early canopy closure to shade out competing vegetation, and allows for possible mortality and trees of poor form.

Planting stock: 2+0 seedlings

Time of planting: 20 April to 15 May

Method of planting: machine planting or spade planting by the wedge method

Weed control after planting: Shortly after planting, spray 6.0 kg/ha (5.5 lb/ac) of active simazine over the entire plantation area or the site-prepared strips. Repeat this treatment in October of the first and second years or April of the second and third years after planting. Where necessary, continue spraying after the third year until the trees have outgrown the weed competition.

Rodent control: On sites with dense rabbit populations it may be necessary to protect the young seedlings from browsing by intensive hunting, fencing of the total plantation area, or wire screening of individual seedlings. Where stem girdling by mice is a problem, eliminate weeds or place tree guards around the main stems.

Pruning: Starting in the third summer after planting, prune one side of forked leaders and remove the lowest branches every 2 or 3 years. However, always leave a crown of two-thirds to one-half of the total height of the tree.

RED ASH

(*Fraxinus pennsylvanica* Marsh.)

This species is very similar in appearance and wood quality to white ash but does not attain the height or the excellent stem form of white ash at maturity. However, it is an excellent plantation species and is recommended for planting on sites that are less than optimum for white ash.

Where to plant: For optimum growth, plant in deep, fertile, moist but well drained to imperfectly drained loams, clay loams, or clays. Red ash will also grow well in poorly drained soils that are flooded for short periods of time and in medium- to coarse-textured upland sands and loams with good moisture supplies.

Site preparation: In weed-infested former fields and pastures, spray 4.7 L/ha (½ gal/ac) of Vision® or Roundup® in late August over the entire plantation area. One week after spraying, plow and disk or rototill the sprayed area. In fields currently under cultivation, plow and disk after harvest. On sites on which mechanical site preparation is not possible or desirable, spray 4.7 L/ha (½ gal/ac) of Vision® or Roundup® in August in strips at least 1.5 m (5 ft) wide.

Species mixtures: Plant either alone or in mixture with other hardwood species suitable for the soil and drainage conditions of the planting site. Do not plant red ash in mixture with conifers because the conifers provide an ideal habitat for rabbits and deer, which will browse the tops or gnaw the bark of the red ash seedlings.

Spacing: Plant at 3 m (10 ft) between rows and 1.5 m (5 ft) within rows. This spacing requires the planting of 2,222 trees/ha (871 trees/ac). It allows the passage of a medium-sized tractor between rows of trees for chemical or mechanical weed control, promotes reasonably early canopy closure to shade out competing vegetation, and allows for possible mortality and trees of poor form.

Planting stock: 2+0 seedlings

Time of planting: 20 April to 15 May

Method of planting: machine planting or spade planting by the wedge method

Weed control after planting: Red ash has a very low tolerance for simazine and is easily damaged by dosages tolerated by most other tree species. Shortly after planting, spray 3.3 kg/ha (3.0 lb/ac) of active simazine on loam soils and 4.4 kg/ha (4.0 lb/ac) on clay loam and clay soils. In October of the first and second years or April of the second and third years after planting, spray 4.4 kg/ha (4.0 lb/ac) of active simazine on all soils. Spray the entire area or the site-prepared strips. Where necessary, continue spraying after the third year until the trees have outgrown the weed competition.

Rodent control: Where stem girdling by mice is a problem, eliminate weeds or place tree guards around trees.

Pruning: Starting in the second summer after planting, prune one side of forked leaders. Starting in the third summer remove the lowest branches every 2 or 3 years. However, always leave a crown of two-thirds to one-half of the total height of the tree.

SILVER MAPLE

(*Acer saccharinum* L.)

Where to plant: For optimum growth, plant in moist loams or clay loams. This species will also grow well in organic soils such as peat or muck, or in clay soils as long as soil moisture is high throughout the growing season.

Where not to plant: in infertile, eroded, shallow, dry soils and on exposed ridges or knolls

Site preparation: In weed-infested former fields and pastures, spray 4.7 L/ha (1/2 gal/ac) of Vision® or Roundup® in late August over the entire plantation area. One week after

spraying, plow and disk or rototill the sprayed area. In fields currently under cultivation, plow and disk after harvest. On sites on which mechanical site preparation is not possible or desirable, spray 4.7 L/ha (1/2 gal/ac) of Vision® or Roundup® in August in strips at least 1.5 m (5 ft) wide.

Species mixtures: On wet sites and on organic soils, plant silver maple alone. On better drained sites, plant silver maple in mixture with white ash, black walnut, sycamore, basswood, or other hardwood species suitable for the soil and drainage conditions of the planting site.

Spacing: Plant at 3 m (10 ft) between rows and 1.5 m (5 ft) within rows. This spacing requires the planting of 2,222 trees/ha (871 trees/ac). It allows the passage of a medium-sized tractor between rows of trees for chemical or mechanical weed control, promotes reasonably early canopy closure to shade out competing vegetation, and allows for possible mortality. On wet sites on which tractor operations are limited, plant at 1.8 x 1.8 m (6 x 6 ft) to promote early canopy closure and thereby reduce the number of chemical weed control treatments required. This spacing requires the planting of 3,086 trees/ha (1210 trees/ac).

Planting stock: 2+0 seedlings

Time of planting: 20 April to 15 May

Method of planting: machine planting or spade planting by the wedge method

Weed control after planting: Shortly after planting, spray 5.5 kg/ha (5.0 lb/ac) of active simazine over the entire plantation area or the site-prepared strips. In October of the first and second years or April of the second and third years after planting, spray 6.6 kg/ha (6.0 lb/ac) of active simazine over the same areas. Where necessary, continue spraying after the third year until the trees have outgrown the weed competition.

Rodent control: Where stem girdling by mice is a problem, eliminate weeds or place tree guards around trees.

Pruning: Prolific sprouting from the root collar and lower stem is characteristic of silver maple. To obtain maximum growth on the main stem and to improve tree form of individual, high-value trees, remove all sprouts from the lower stem each winter; this work is time consuming, but must be repeated annually. In other plantations, do not prune. After crown closure, natural selection will reduce the number of stems.

SUGAR MAPLE

(*Acer saccharum* Marsh.)

Where to plant: For optimum growth, plant in deep, fertile, moist, but well drained sandy loams and loams. Seedlings will also grow in soils ranging from sand to clay and stony tills. However, tree growth on these sites will be slower than on the loams.

Where not to plant: in excessively dry, poorly drained or shallow soils

Site preparation: Seedlings are very sensitive to competition from weeds and grasses. In weed-infested former fields and pastures, spray 4.7 L/ha (½ gal/ac) of Vision® or Roundup® in late August over the entire plantation area. One week after spraying, plow and disk or rototill the sprayed area. In fields currently under cultivation, plow and disk after harvest. On sites on which mechanical site preparation is not possible or desirable, spray 4.7 L/ha (½ gal/ac) of Vision® or Roundup® in August in strips at least 1.5 m (5 ft) wide.

Species mixtures: Plant only in mixture with other hardwood species suitable for the soil and drainage conditions of the planting site. Sugar maple is subject to feeding by the potato leafhopper (*Empoasca fabae* Harv.), which causes serious growth retardation and multiple branching. Although any sugar maple tree may be attacked, damage is generally more serious in pure than in mixed plantations.

Sugar maple should not be grown in mixture with conifers because conifers provide an ideal habitat for rabbits, which

browse the tops and gnaw the bark of young maple seedlings. In plantations with even relatively low rabbit populations, the browsing and bark gnawing will prevent most sugar maple seedlings from producing stems of acceptable size and quality.

Spacing: Plant at 3 m (10 ft) between rows and 1.5 m (5 ft) within rows. This spacing requires the planting of 2,222 trees/ha (871 trees/ac). It allows the passage of a medium-sized tractor between rows of trees for chemical or mechanical weed control, promotes reasonably early canopy closure to shade out competing vegetation, and allows for possible mortality and trees of poor form.

Planting stock: 2+0 seedlings

Time of planting: 20 April to 15 May

Method of planting: machine planting or spade planting by the wedge method

Weed control after planting: Shortly after planting, spray 4.4 kg/ha (4.0 lb/ac) of active simazine on loam soils and 5.5 kg/ha (5.0 lb/ac) on clay loams over the entire plantation area or on the site-prepared strips. In October of the first and second years or April of the second and third years after planting, spray 5.5 kg/ha (5.0 lb/ac) of active simazine over the same areas. Where necessary, continue spraying after the third year until the trees have outgrown the weed competition.

Rodent control: On sites with dense rabbit populations, it may be necessary to protect the young seedlings from browsing by intensive hunting, fencing of the total plantation area, or wire screening of individual seedlings. Where stem girdling by mice is a problem, eliminate weeds or place tree guards around trees.

Pruning: Never prune in late winter or early spring because heavy bleeding may occur. Starting in the second summer after planting, prune one side of forked leaders. Starting in the third summer, remove the lowest branches every 2 or 3 years. However, always leave a crown of two-thirds to one-half of the total height of the tree.

WHITE ASH

(*Fraxinus americana* L.)

Where to plant: For optimum growth, plant in deep, moist, but well drained to imperfectly drained loams, clay loams or clays, preferably with high nitrogen and moderately high calcium contents. White ash will also grow in sandy loams if there is sufficient moisture. The species requires a high degree of soil moisture and will tolerate temporary flooding.

Where not to plant: in infertile, eroded, shallow soils; on dry, sandy or gravelly exposed ridges; in any soil with a topsoil depth of less than 40 cm (16 in.); in swamps

Site preparation: In weed-infested former fields and pastures, spray 4.7 L/ha (½ gal/ac) of Vision® or Roundup® in late August over the entire plantation area. One week after spraying, plow and disk or rototill the sprayed area. In fields currently under cultivation, plow and disk after harvest. On sites on which mechanical site preparation is not possible or desirable, spray 4.7 L/ha (½ gal/ac) of Vision® or Roundup® in August in strips at least 1.5 m (5 ft) wide.

Species mixtures: On intensively managed, highly productive sites, plant white ash alone. Such plantations may best be compared with fruit orchards. On all other sites plant white ash in mixture with black walnut, silver maple, basswood, sycamore (*Platanus occidentalis* L.), bur oak, or other hardwood species suitable for the soil and drainage conditions of the planting site. Do not plant white ash in mixture with conifers because the conifers provide an ideal habitat for rabbits and deer, which will browse the tops or gnaw the bark of white ash seedlings.

Spacing: Plant at 3 m (10 ft) between rows and 1.5 m (5 ft) within rows. This spacing requires the planting of 2,222 trees/ha (871 trees/ac). It allows the passage of a medium-sized tractor between rows of trees for chemical or mechanical weed control, promotes reasonably early canopy closure to shade out competing vegetation, and allows for possible mortality and trees of poor form.

Planting stock: 2+0 seedlings

Time of planting: 20 April to 15 May

Method of planting: machine planting or spade planting by the wedge method

Weed control after planting: White ash has a very low tolerance for simazine and is easily damaged by dosages tolerated by most other tree species. Shortly after planting, spray 3.3 kg/ha (3.0 lb/ac) of active simazine on loam, clay loam and clay soils. In October of the first and second years or April of the second and third years after planting, spray 4.4 kg/ha (4.0 lb/ac) of active simazine on all soils. Spray the entire area or the site-prepared strips. Where necessary, continue spraying after the third year until the trees have outgrown the weed competition.

Rodent control: Where stem girdling by mice is a problem, eliminate weeds or place tree guards around the stems.

Pruning: Starting in the second summer after planting, prune one side of forked leaders. Starting in the third summer, remove the lowest branches every 2 or 3 years. However, always leave a crown of two-thirds to one-half of the total height of the tree.

MINOR PLANTATION SPECIES

AMERICAN SYCAMORE

(*Platanus occidentalis* L.)

This species has been planted sparingly in Ontario and little is known about its potential as a plantation tree. When 2+0 seedlings were planted in mixture with other hardwood species, mean survival was only 39%, but 10-year height and diameter growth exceeded those of white ash, basswood and black walnut in an old field with a soil of imperfectly drained silt loam 60 to 80 cm deep over silty sand. Until improved planting techniques have been developed, apply the techniques prescribed for white ash.

AMUR MAPLE

(*Acer ginnala* Maxim.)

This is a small, shrubby tree that has no timber value. It is planted occasionally for aesthetic reasons in mixture with other hardwood species because of its strikingly brilliant red foliage in autumn. It grows well in soils ranging from sandy loams to clay loams. For successful planting, apply the techniques prescribed for white ash.

AUTUMN OLIVE

(*Elaeagnus umbellata* Thunb.)

This is a shrub species with no timber value. However, its ability to fix nitrogen and to shade out herbaceous competition, and its tolerance of juglone poisoning, have made it a preferred nurse species for black walnut. It is relatively easy to grow in the nursery and survives well in open-field plantations, and its growth rate during the early years after planting equals that of black walnut. In later years, black walnut outgrows autumn olive. This eliminates the need to cut the olives to provide additional growing space for the walnuts. Autumn olive is also valued as a source of food for wildlife. Its greatest disadvantage is its tendency to spread into neighboring fields. In some parts of the United States, autumn olive is classified as a noxious weed. For successful planting, use the techniques prescribed for black locust.

BUTTERNUT

(*Juglans cinerea* L.)

This species has been planted successfully by the same techniques used for the planting of black walnut. Butternut should be planted only in mixture with other hardwoods. To prevent excessive branching, spacing should not exceed 3 x 1.5 m (10 x 5 ft). Butternut is subject to attacks by *Nectria* canker and canker dieback (*Melanconsis juglandis* E. & E.), which slow growth, impair stem quality and eventually kill the tree.

EUROPEAN ALDER

(*Alnus glutinosa* L. [Gaertn.])

This species has little timber value but has been planted successfully as a nurse species for black walnut. Its ability to fix nitrogen has increased the nitrogen content in the leaves of interplanted black walnut. Its rapid juvenile growth provides excellent protection from damage by wind and improves natural weed control by shading. Starting approximately 10 years after planting, most European alders interplanted with black walnut are killed by juglone, a toxin produced by black walnut. This provides a natural thinning of the plantation when the walnut trees require additional growing space. For successful planting apply the techniques prescribed for basswood.

EUROPEAN MOUNTAIN ASH

(*Sorbus aucuparia* L.)

This species has no timber value but has been planted widely as an ornamental and as a source of food for many species of overwintering birds. It grows well in the open and in mixture with other hardwoods. However, its relatively small size makes it subject to suppression when planted at close spacing with faster-growing species such as silver maple, white ash or black walnut. For successful planting, apply the techniques prescribed for basswood.

EUROPEAN OAK

(*Quercus robur* L.)

This species is a preferred tree for landscape planting but appears to have potential as well for afforestation and windbreak plantings on imperfectly drained clay loam and clay soils. When it was planted experimentally near Parkhill, Middlesex County, in a soil of imperfectly drained clay loam at a spacing of 3 x 1.5 m (10 x 5 ft), 10-year survival and height growth of 2+0 seedlings were 95% and 4.4 m (14.4 ft), respectively. All trees were very branchy. Although closer spacing will reduce the number and size of branches, the branchiness might be advantageous in windbreak plantings. For successful planting, apply the techniques prescribed for bur oak.

MANITOBA MAPLE

(*Acer negundo* L.)

This is a fast-growing, short-lived, small tree of generally poor form and little timber value. However, its ease of establishment, rapid growth, and tolerance of a wide range of soil and climatic conditions make it a useful tree for the afforestation of disturbed sites and planting around homesteads and in windrows. When planted experimentally as a nurse species for black walnut, white ash and basswood in a fertile clay loam soil, Manitoba maple quickly outgrew the more valuable species and had to be girdled to release the interplanted species. For successful planting, apply the techniques prescribed for black locust.

NORTHERN CATALPA

(*Catalpa speciosa* Warder)

Catalpa has little value as a timber species other than for fence posts. However, its rapid growth, its importance as a shade species and its large, showy flowers make it a preferred species for ornamental planting. When it is planted in mixture with other hardwood species, its height growth is equal to that of basswood and black walnut and its diameter growth is substantially higher. For successful planting, apply the techniques prescribed for basswood.

RED MAPLE

(*Acer rubrum* L.)

This is a relatively fast-growing, medium-sized tree with a timber value similar to that of silver maple. Red maple occurs on a broad range of sites from poorly drained lowlands to upper slopes and dry ridges. It has been recommended for planting, but few successful plantations have been established. The species is difficult to grow in the nursery and survival and growth of planted trees have generally been poor. Until improved nursery and planting techniques are developed, planting of red maple is not recommended.

SHAGBARK HICKORY

(*Carya ovata* [Mill.] K. Koch)

and

BITTERNUT HICKORY

(*Carya cordiformis* [Wang.] K. Koch)

Neither species is currently recommended for the afforestation of former farmland because survival and growth have generally been unsatisfactory.

TULIP TREE

(*Liriodendron tulipifera* L.)

This is a beautiful, stately tree, but its range is confined to south of a line extending from Goderich to Toronto. It generally grows in mixture with other hardwoods. When planted experimentally in mixture with other hardwoods near Parkhill, Middlesex County, 2+0 seedlings survived and grew as well as white ash and better than black walnut, sugar maple or red oak. Tulip trees appear to have potential in afforestation when planted in mixture with other hardwoods on deep, moist loams. For successful planting, apply the techniques prescribed for basswood.

WHITE BIRCH

(*Betula papyrifera* Marsh.)

This species is a preferred tree for landscape planting. However, few white birch plantations have been established on former farmland in southern Ontario and little information is available on the effects of different afforestation techniques on seedling survival or on growth. When white birch was planted experimentally in small blocks and in alternate rows with other hardwood species in soils of imperfectly drained clay loams, 5-year survival and height growth ranged from 80 to 95% and from 3.0 to 3.5 m (10-11.5 ft), respectively. For successful planting, apply the techniques prescribed for basswood.

WHITE OAK

(*Quercus alba* L.)

Most attempts to plant white oak on former farmland have resulted in failure. The main reasons appear to be slow juvenile growth and susceptibility to browsing by rabbits. Until improved techniques are developed, planting of white oak is not recommended.

APPENDIX II
District Offices of the Ontario Ministry of Natural Resources in Southern Ontario

From the nearest District Office of OMNR, a landowner can secure technical assistance and tree application forms. Seedlings may be purchased from OMNR for planting in Ontario. Application forms and information on costs and regulations are available on request.

OMNR District	Address	Phone No.
Algonquin Region		
Algonquin Park District	Box 219 Whitney, Ontario K0J 2M0	(613) 637-2780
Bancroft District	Box 500 Bancroft, Ontario K0L 1C0	(613) 332-3940
Bracebridge District	Box 1138 Bracebridge, Ontario P0B 1C0	(705) 645-8747
Minden District	Minden, Ontario K0M 2K0	(705) 286-1521
Parry Sound District	4 Miller Street Parry Sound, Ontario P2A 1S8	(705) 746-4201
Pembroke District	Riverside Drive Box 220 Pembroke, Ontario K8A 6X4	(613) 732-3661
Eastern Region		
Brockville District	Box 605, Oxford Avenue Brockville, Ontario K6V 5Y8	(613) 342-8524
Carleton Place District	10 Findlay Avenue Carleton Place, Ontario K7C 3Z6	(613) 257-5735
Cornwall District	113 Amelia Street Cornwall, Ontario K6H 5V7	(613) 933-1774

Napanee District	1 Richmond Blvd. Napanee, Ontario K7R 3S3	(613) 354-2173
Tweed District	Metcalfe Street Tweed, Ontario K0K 3J0	(613) 478-2330

Central Region

Cambridge District	Box 2186 Cambridge, Ontario N3C 2W1	(519) 658-9355
Huronia District	Midhurst, Ontario L0L 1X0	(705) 728-2900
Lindsay District	322 Kent Street West Lindsay, Ontario K9V 4T7	(705) 324-6121
Maple District	Maple, Ontario L0J 1E0	(416) 832-2761
Niagara District	2541 Highway 20 East Fonthill, Ontario L0S 1E0	(416) 892-2656

Southwestern Region

Aylmer District	353 Talbot Street West Aylmer, Ontario N5H 2S8	(519) 773-9241
Chatham District	1023 Richmond Street W. Chatham, Ontario N7M 5J5	(519) 354-7340
Owen Sound District	611 Ninth Avenue East Owen Sound, Ontario N4K 3E4	(519) 376-3860
Simcoe District	548 Queensway West Simcoe, Ontario N3Y 4T2	(519) 426-7650
Wingham District	R.R. No. 5 Wingham, Ontario N0G 2W0	(519) 357-3131

APPENDIX III
Estimated 1989 Costs per Hectare (2.5 ac) of Site Preparation, Planting, Weed Control and Plantation Tending During the First 3 Years After Planting

Treatment	Cost ($/ha)
Vision® or Roundup® 4.7 L/ha (1/2 gal/ac) for application in August	70.00
Broadcast application of Vision® or Roundup® over the total plantation area in August of the year before planting	70.00
Plowing the total area 1 week after spraying with Vision® or Roundup®	100.00
Disking in two directions shortly after plowing	50.00
Planting stock and shipping costs of 2,222 seedlings/ha (871/ac) for planting at a spacing of 3.0 x 1.5 m (10 x 5 ft)	175.00
Machine planting	100.00
Princep Nine-T®, 5.0 kg/ha (4.5 lb/ac) for application shortly after planting	60.00
Broadcast application of Princep Nine-T® over the total area shortly after planting	70.00
Princep Nine-T® 6.0 kg/ha (5.5 lb/ac) for application in years 2 and 3	144.00
Broadcast application of Princep Nine-T® over the total area in April of the second and third years	140.00
Rodent control, pruning, supervision	100.00
Total cost for 3 years	$1,079.00

Note: These costs vary widely depending on the percentages of areas treated, site conditions, availability of equipment, and the ability of the plantation owner to carry out the work himself. These costs do not include provincial sales tax.

APPENDIX IV
Fact Sheet for Glyphosate

Trade name of herbicide:	Roundup® licensed for agricultural use, Vision® licensed for forestry use
Common name of active ingredient:	Glyphosate
Manufacturer:	Monsanto
Formulation:	water-soluble liquid
Concentration:	356 g/L of active ingredient (35.6%)
Suppliers:	Roundup® in containers of 1 and 10 L at most Co-op stores and garden centers Vision® in containers of 10 L from Monsanto Canada Inc., 55 Murray Park Road, Winnipeg, Manitoba R3J 3W2
1989 price:	$14.50/L
Description:	This is a non-selective contact herbicide that kills or injures all plants, including tree seedlings, when sprayed on the foliage. Glyphosate is inactivated in the soil, and therefore does not provide residual weed control. Perennials or unemerged plants arising from underground rhizomes or rootstocks will not be affected by the spray and will continue to grow. Since many annual weeds germinate from seed throughout the growing season, repeated applications may be necessary to control weeds that have germinated since the previous spraying.
Mode of action:	Glyphosate enters plants through the leaves and moves into the root system. Visible effects on most annual weeds occur within 2 to 4 days, but on most perennial weeds they may not occur until 7 to 10 days after spraying. Cold or cloudy weather at treatment time may slow down herbicide activity. Prolonged drought at the time of spraying or rainfall within 6 hours after application may prevent uptake of the chemical and an additional treatment may be required.

Spray equipment: Do not mix, store or apply Vision®, Roundup® or spray solutions of these chemicals in galvanized steel or unlined steel (except stainless steel) containers or spray tanks. Use only plastic, fiber glass, aluminum or stainless steel tanks. Spray large areas with tractor-mounted boom sprayers and small areas or spots with backpack or hand sprayers.

How to apply: For site preparation and in non-crop areas in which it is desirable to eliminate all vegetation, broadcast the spray mixture over the total area or apply in strips or spots. In areas in which young trees, shrubs or other desirable plants have been planted, either direct the spray away from the desirable vegetation or shield the vegetation from the spray. Never spray on windy days and always avoid drift that might injure or kill desirable vegetation.

When to apply: Apply at any time during the growing season as long as the vegetation is tall enough to provide adequate leaf surface to receive the spray. For spring application, spraying should be delayed until the weeds are 10 to 15 cm (4 to 6 in.) tall. The best control of most perennial weeds is obtained when treatment is made in late growth stages, as weeds are approaching maturity (August and September).

How much to apply: For large areas, mix 4.7 L of Vision® or Roundup® with 200 to 300 L of water (depending on the size and density of vegetation) for each hectare to be sprayed (1/2 gal with 20 to 30 gal of water for each acre). For small areas or spot treatments, mix 30 ml (1 fl oz) of Vision® or Roundup® with each 4.5 L (1 gal) of water. The area covered with 4.5 L (1 gal) of mixture depends on the height and density of the vegetation. For best results, wet the foliage uniformly and completely but avoid runoff from the leaf surfaces.

Note: Before using any pesticide product, read the manufacturer's guidelines carefully to determine safe handling procedures, recommended safety equipment, and first aid procedures to use in the event of an accident.

APPENDIX V
Calculation of Herbicide Dosage Required for the Spraying of Strips

The following calculation is required to compute the dosage required for the actual area being sprayed.

Example 1. Sprayed strips of a certain width will alternate with unsprayed strips of equal width. Therefore, only half of the total area will be sprayed. The amount of herbicide required is therefore only half of that required for spraying the total area. Expressed differently, the dosage recommended for the spraying of 1 ha or ac will treat 2 ha or ac.

Example 2. Sprayed strips 1.8 m (6 ft) wide will alternate with unsprayed strips 3.6 m (12 ft) wide. The amount of herbicide required is therefore only one-third of that required for spraying the total area. Expressed differently, the dosage recommended for the spraying of 1 ha or ac will treat 3 ha or ac.

APPENDIX VI
Calculation for the Conversion of Active Ingredient of Herbicide to Quantities Found in Commercial Products

Recommended dosages for herbicide applications are often expressed in terms of the active ingredient (a.i.) of the herbicide. To convert active ingredient to the quantity found in commercial products, divide the recommended dosage expressed in active ingredient by the percentage of active ingredient specified for the commercial product. Multiply the result by 100.

Example 1. Recommended dosage in active ingredient = 4.5 kg/ha

Active ingredient in commercial product = 90%

$\frac{4.5}{90} \times 100 = 5.0$ kg/ha of commercial product

Example 2. Recommended dosage in active ingredient = 3.0 kg/ha

Active ingredient in commercial product = 80%

Area to be treated = 3 ha

$\frac{3.0}{80} \times 100 = 3.75$ kg/ha x 3 ha = 11.25 kg of commercial product required to treat 3 ha

APPENDIX VII
Fact Sheet for Simazine

Common name of active ingredient: Simazine

Trade name of commercial product:	Princep Nine-T®
Formulation and concentration:	wettable powder, 90% active ingredient
1989 price:	$12.00 per kg of product
Available at:	Ciba-Geigy Canada Limited Agricultural Division 68 Century Avenue Mississauga, Ontario L5N 2W5 or most Co-op stores
Trade name of commercial product:	Simadex® 80W
Formulation and concentration:	wettable powder, 80% active ingredient
1989 price:	$9.00 per kg of product
Trade name of commercial product:	Simadex® flowable
Formulation and concentration:	liquid, 50% of active ingredient
1989 price:	$9.00 per kg of product
Available at:	Niagara May and Baker 403 Consortium Court London, Ontario N6E 2S8 or most Co-op stores

Description: Simazine is a selective pregermination herbicide used to control many broadleaved weeds and grasses. Some hardwood species are highly resistant to simazine injury, whereas others are injured or killed by dosages necessary for the effective control of most weeds and grasses. Once simazine is in the soil, its lifespan is greatly influenced by soil temperature. It is very stable at low temperatures and can persist in the soil for many months. At 25°C, 50% of the active ingredient will disappear within 20 days.

Mode of action: Simazine enters the plants through the roots. Any uptake through the aboveground parts of the plants is minimal. After translocation, simazine disrupts photosynthesis. Death occurs within a few weeks after application, depending on the rate of uptake.

Spray equipment: Simazine may be sprayed with any equipment suitable for the job that is to be done. For large areas, it is most economical to use a tractor-mounted boom sprayer, whereas small areas, strips or spots may be sprayed with backpack or hand sprayers.

How to apply: Since simazine is taken up mainly through the roots, it can be sprayed safely over the tops of tree seedlings and shrubs without the necessity of shielding or directing the spray away from the desirable vegetation.

When to apply: Apply in spring, as early as possible after the ground has thawed. This allows utilization of the soil moisture and spring rains to activate the herbicide before weed growth starts. Where early spring application is not feasible or practicable, apply simazine in late autumn, but before the soil is frozen.

How much to apply: Each species has its own tolerance to simazine. A safe dosage for one species may be detrimental to another species. For the application to hardwood trees and shrubs, see Table 1 on page 7. Simazine should not be used on soils with a high organic-matter content since much of the active ingredient will be tied up by the organic matter.

Note: Before using any pesticide product, read the manufacturer's guidelines carefully to determine safe handling procedures, recommended safety equipment, and first aid procedures to use in the event of an accident.

APPENDIX VIII
Recommendations for the Chemical Control of Grasses in Hardwood Plantations

A. Before the hardwood seedlings are planted:

Apply 4.7 L/ha (1/2 gal/ac) of Vision® or Roundup® in 300 L/ha (27 gal/ac) of water to actively growing grasses and broadleaf weeds. Use a tractor-mounted boom sprayer for broadcast coverage of large areas. For small areas, strips or spot treatments, mix 30 ml (1 fl oz) of Vision® or Roundup® with 4.5 L (1 gal) of water, and spray with a backpack or hand sprayer. Four and one half litres (1 gal) of mixture will treat 60 m^2 (650 ft^2). The spray coverage should be uniform and complete without wetting the foliage to the point of runoff. Where possible, plow and disk after 1 week. Even without plowing, however, grasses and broadleaved weeds will be killed by the herbicide.

B. After the hardwood seedlings have been planted:

Apply a *directed* spray of 4.7 L/ha (1/2 gal/ac) of Vision® or Roundup® in 300 L/ha (27 gal/ac) of water to actively growing grasses and broadleaved weeds. For small areas, strips or spot treatments, mix 30 ml (1 fl oz) of Vision® or Roundup® with 4.5 L (1 gal) of water and spray with a backpack or hand sprayer. Four and one half litres (1 gal) of mixture will treat 60 m^2 (650 ft^2). The spray coverage should be uniform and complete without wetting the foliage to the point of runoff. Be sure to avoid spraying the foliage of desirable vegetation and avoid drifting of the spray solution during application because any spray particles touching the leaves of trees or other desirable plants will injure or kill the plants.